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ORIGINAL ARTICLE

Clamp-Crush Technique Versus Harmonic Scalpel for Hepatic Parenchymal Transection in Living Donor Hepatectomy: a Randomized Controlled Trial

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Abstract

Background Hepatic parenchymal transection is the most invasive step in donor operation. During this step, blood loss and unintended injuries to the intrahepatic structures and hepatic remnant may occur. There is no evidence to prove the ideal techniques for hepatic parenchymal transection. The aim of this study is to compare the safety, efficacy, and outcome of clamp-crush technique versus harmonic scalpel as a method of parenchymal transection in living-donor hepatectomy.

Methods Consecutive living liver donors, undergoing right hemi-hepatectomy, during the period between May 2015 and April 2016, were included in this prospective randomized study. Cases were randomized into two groups; group (A) harmonic scalpel group and group (B) Clamp-crush group.

Results During the study period, 72 cases underwent right hemi-hepatectomy for adult living donor liver transplantation and were randomized into two groups. There were no statistically significant differences between the two groups regarding preoperative demographic and radiological data. Longer operation time and hepatectomy duration were found in group B. There were no significant differences between the two groups regarding blood loss, blood loss during hepatectomy, and blood transfusion. More unexpected bleeding events occurred in group A. Higher necrosis at the cut margin of the liver parenchyma was noted in group A. There were no statistically significant differences between the two groups regarding postoperative ICU stay, hospital stay, postoperative morbidities, and readmission rates.

Conclusion Clamp-crush technique is advocated as a simple, easy, safe, and cheaper method for hepatic parenchymal transection in living donors.

Keywords Living donor liver transplantation · Parenchymal transection · Clamp-crush method · Harmonic scalpel method

Introduction

Safety of the donors is the main concern in living donor liver transplantation (LDLT). Living donors represent a special group of patients. They are healthy individuals, who are exposed to a major surgical procedure, in which the dominant proportion of their liver is extracted as a graft. So, all potential risk factors for the development of donor-related morbidities should be properly assessed and all efforts are made to be avoided.

Hepatic parenchymal transection is the most invasive step in donor operation. During this step, blood loss together with unintended injuries to the intrahepatic structures and hepatic remnant may occur. These are the main factors affecting the development of postoperative morbidities, as cut surface bleeding, biliary leakage, abdominal collections, and postoperative mortality.[1–3]

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Different techniques for hepatic parenchymal transection have been suggested to decrease intraoperative blood loss and avoid the development of postoperative morbidities. These include clamp-crush method (Kelly-klasia), ultrasonic dissection, hydro-dissection, microwave coagulators, radiofrequency coagulators, and stapling with vascular staplers.[2,4–6]

Several studies have evaluated different techniques of hepatic parenchymal transection.[2,4–6] Few of these were conducted in the field of LDLT.[7,8] However, there are no evidences to prove the ideal techniques for hepatic parenchymal transection in LDLT.

The aim of this study is to compare the safety, efficacy, and outcome of clamp-crush technique (Kelly-klasia) versus harmonic scalpel as a method of hepatic parenchymal transection in living-donor hepatectomy.

Materials and Methods

Study Design

Consecutive living liver donors, undergoing right hemihepatectomy for LDLT at Liver Transplantation Unit, Gastrointestinal Surgery Center, Mansoura University, Egypt, during the period from May 2015 to April 2016, were included in this prospective randomized study.

Informed consent was obtained from all cases included in the study, after a careful explanation of the nature of the intervention and possible management with its morbidity. This study was registered on "clinicaltrials.gov" under identifier number (NCT02853981) and approved by institutional review board and local ethical committee at Faculty of Medicine, Mansoura University.

Randomization

Cases were randomized into two groups using the closed envelope method. The envelopes were drawn and opened by a nurse not engaged in the study on the admission of the donor to the operating room.

Cases were divided into two groups; group (A) in which hepatic parenchymal transection was performed by harmonic scalpel and group (B) in which hepatic parenchymal transection was performed by spray clamp-crush (Kelly-klasia) technique.

Preoperative Donor Evaluation

A triple-phased multidisciplinary protocol for preoperative evaluation of potential donors was used in our unit and has been described elsewhere.[9]

Operative Technique

The surgical technique for donor hepatectomy has been described elsewhere.[9] Two experienced surgeons (Salah T, Sultan AM) in liver surgery performed the parenchymal transection of the study cases.

In brief, the patient is placed in supine position and inverted J-shaped incision was used. The right liver lobe is fully mobilized. The short hepatic veins are dissected and divided with preservation of significant right inferior hepatic vein for reconstruction. The right hepatic vein is identified and encircled. Then, intraoperative cholangiography is routinely done. Careful dissection of the right branches of the portal vein, hepatic artery is done. Then, intraoperative mapping of the middle hepatic vein and its significant tributaries (from segments V and VIII) by intraoperative ultrasound is done. The transection line is identified about 1 cm to the right side from the mapped middle hepatic vein. Hanging maneuver is used to maintain the transection plane during the parenchymal dissection.

Hepatic parenchymal transection is done by two different techniques (harmonic scalpel and Kelly-klasia).

In group A, harmonic scalpel wave blade (HARMONIC WAVE® Open Shears – ETHICON) is used to achieve division and hemostasis of the hepatic parenchyma from the start till the end of hepatic parenchymal transection, unless significant vessels are encountered which require ligation and division.

In group B, a Kelly clamp is used to crush the hepatic parenchyma along the planned transection line. If insignificant vessels (less than 2 mm) are encountered, they are divided by monopolar diathermy (70-W coagulation spray mode – Covidien Force FX Electrosurgical Generator). When significant vessels (more than 2 mm) are encountered, they are clipped or ligated and divided. Identification and preservation of significant segments V and VIII vein are done for future reconstruction in both groups.

The right hepatic duct is usually transected under cholangiography guidance. After completion of the parenchymal dissection, heparin (100 IU/kg) is injected before right hepatic artery clamping. The right branches of the hepatic artery and portal vein are divided. Finally, division of the right hepatic vein and the right hemi-liver graft is extracted to the back table. A check-cholangiogram is performed to ensure the absence of bile leakage and stricture.

Postoperative Care and Follow-up

All cases are transferred to intensive care unit (ICU) for monitoring after the operation, then the case is transferred to the hospital ward.

Follow-up laboratory evaluation is done daily including complete blood picture, liver functions, kidney functions, and C-reactive protein (CRP). Abdominal ultrasonography is done daily. Oral fluids are started once intestinal sounds are restored. Abdominal drain is removed if the daily abdominal drainage is serous and less than 100 cc provided absence of any fluid collection.

After discharge, the cases are followed up regularly in outpatient visits including detailed laboratory evaluation and abdominal ultrasonography.

Study Outcomes

Primary outcomes of the study included blood loss (during parenchymal resection and total operative blood loss) and blood transfusion requirements. Secondary outcomes included parenchymal transection time, total operating time, necrosis at the cut margin of the remnant liver by pathological examination, perioperative morbidities (bleeding and bile leakage), postoperative biochemical markers (leucocytic count, platelets, bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), international normalized ration (INR), CRP), and hospital stay.

Clinical Definitions

Postoperative morbidity is defined as adverse events occurring during the first 60 postoperative days and is graded according to the Clavien-Dindo classification. Major complications are defined as class 3 or higher.[10] Postoperative biliary fistula and hepatic dysfunction are defined according to the international Study Group of Liver Surgery (ISGLS).[11,12]

Necrosis at the cut margin of the remnant liver was evaluated by pathological examination. A rectangular wedge was taken from the cut margin of the left hemi-liver (remnant liver) by surgical scalpel after finishing the parenchymal transection. The specimen is then sent for pathological examination.

Statistical Analysis

Categorical variables are expressed as number and percentage, while continuous variables are expressed as mean and standard deviation or median and range when appropriate. Comparison between groups is done by chi-square test for categorical variables and independent sample t test or Mann-Whitney test for continuous variables.

Statistical analysis is performed using IBM-SPSS software for windows, version 20. A p value < 0.05 is considered to be significant.

Results

During the study period, 72 cases underwent right hemi-hepatectomy for adult LDLT at Liver Transplantation Unit, Gastrointestinal Surgery Center, Mansoura University, Egypt and were included in our study.

Cases were randomized into two groups: group A (harmonic scalpel group) included 36 cases (50%) and group B (Kelly-klasia group) included 36 cases (50%).

Demographic Data

Preoperative data of the study cases is shown in Table 1. There were no statistically significant differences between the two groups regarding preoperative demographic and radiological data.

Operative Data

Operative data of the study cases is shown in Table 2. Larger graft to recipient weight ratio (GRWR) and right portal vein diameter were found in group A. More segment five veins were found in group A.

Longer operation time and hepatectomy duration were found in group B ($p = 0.001$). There were no significant differences between the two groups regarding blood loss ($p = 0.113$), blood loss during hepatectomy ($p = 0.587$), and blood transfusion requirement ($p = 0.317$). More unexpected bleeding events occurred in group A (8 cases (22.2%)) than group B (1 case (2.8%)), but this was statistically significant ($p = 0.013$).

A significantly higher necrosis at the cut margin of the liver parenchyma was noted in group A (0.5 mm (0.4–1.5)) than group B (0.3 (0.2–0.8)), ($p = 0.011$).

Postoperative Data

Postoperative data of the study cases is shown in Table 3. There were no statistically significant differences between the two groups regarding postoperative ICU stay, overall hospital stays, postoperative morbidities, and readmission rates.

Postoperative laboratory results of the study cases are shown in Table 4 and Figs. 1 and 2. A significant increase in postoperative serum ALT in 1st and 3rd postoperative days (POD) was found in group A. A significant increase in postoperative serum total bilirubin and INR in 5th and 7th PODs was found in group A. Finally, a significant increase in postoperative serum CRP in 5th and 7th PODs was found in group A.

Discussion

The success of pediatric LDLT leads to the expansion of the procedure to adult patients utilizing right hemi-liver grafts.[13] Despite being a life-saving procedure for the recipient, the least harm to the donor is not accepted. This difficult state created controversies and concerns about the

Table 1 Preoperative data of the study cases (*RHV* right hepatic vein, *IRHV* inferior right hepatic vein, *V5* segment 5 vein, *V8* segment 8 vein, *GRWR* graft to recipient weight ratio, *RLP* residual liver percentage)

Variables	All cases (*N* = 72)	Group A (*N* = 36)	Group B (*N* = 36)	*p* value
Age (years)	24 (18–63)	23.5 (19–63)	26 (18–42)	0.568
Sex				0.337
Male	43 (59.7%)	19 (52.8%)	24 (66.7%)	
Female	29 (40.3%)	17 (47.2%)	12 (33.3%)	
Body mass index (kg/m^2)	26.2 (18–36.8)	26.3 (18–32.4)	26.2 (19.7–36.8)	0.969
Degree of relationship				0.214
Son	21 (29.2%)	9 (25%)	12 (33.3%)	
Daughter	19 (26.4%)	12 (33.3%)	7 (19.4%)	
Wife	7 (9.7%)	1 (2.8%)	6 (16.7%)	
Brother	7 (9.7%)	4 (11.1%)	3 (8.3%)	
Sister	2 (2.8%)	2 (5.6%)	0	
Cousin	2 (2.8%)	0	2 (5.6%)	
Nephew	10 (13.9%)	5 (13.9%)	5 (13.9%)	
In laws	3 (4.2%)	2 (5.6%)	1 (2.8%)	
Mother	1 (1.4%)	1 (2.8%)	0	
Blood groups				0.706
A −	1 (1.4%)	0	1 (2.8%)	
A +	25 (34.7%)	14 (38.9%)	11 (30.6%)	
AB +	1 (1.4%)	1 (2.8%)	0	
B −	1 (1.4%)	1 (2.8%)	0	
B +	15 (20.8%)	7 (19.4%)	8 (22.2%)	
O −	4 (5.6%)	2 (5.6%)	2 (5.6%)	
O +	25 (34.7%)	11 (30.6%)	14 (38.9%)	
ABO matching				0.091
Identical	59 (81.9%)	28 (77.8%)	31 (86.1%)	
Compatible	13 (18.1%)	8 (22.2%)	5 (13.9%)	
Rh matching				0.706
Identical	65 (89.2%)	32 (88.9%)	33 (91.7%)	
Compatible	7 (9.7%)	4 (11.1%)	3 (8.3%)	
Degree of steatosis in preoperative biopsy				0.125
No	55 (76.4%)	24 (66.7%)	31 (86.1%)	
Less than 10%	15 (20.8%)	11 (30.6%)	4 (11.1%)	
11–20%	2 (2.8%)	1 (2.8%)	1 (2.8%)	
Preoperative radiology and volumetry				
Hepatic artery number				1
Single	72 (100%)	36 (100%)	36 (100%)	
Origin of hepatic artery				0.429
Celiac trunk	65 (90.3%)	31 (86.1%)	34 (94.4%)	
Superior mesenteric artery	7 (9.7%)	5 (13.9%)	2 (5.6%)	
Portal vein number				0.314
Single	71 (98.6%)	36 (100%)	35 (97.2%)	
Double	1 (1.4%)	0	1 (2.8%)	
RHV dominance	57 (79.2%)	25 (69.4%)	32 (88.9%)	0.079
IRHV number				0.271
Single	12 (16.7%)	7 (19.4%)	5 (13.9%)	
Double	2 (2.8%)	2 (5.6%)	0	
V5	10 (13.9%)	6 (16.7%)	4 (11.1%)	0.223
V8	3 (4.2%)	1 (2.8%)	2 (5.6%)	0.212
Hepatic ducts number				0.341
Single	31 (43.1%)	18 (50%)	13 (36.1%)	
Double	41 (56.9%)	18 (50%)	23 (63.9%)	
Total liver volume (cc)	1440 (1060–2140)	1445 (1060–2140)	1410 (1150–2100)	0.942
Estimated graft volume (cc)	880 (520–1300)	875 (520–1300)	980 (600–1280)	0.822
Recipient weight (kg)	85 (36–109)	83 (36–106)	86.5 (62–109)	0.252
Estimated GRWR	1.05 (0.8–1.74)	1.14 (0.83–1.68)	1.02 (0.8–1.74)	0.23
Estimated RLP (%)	38.5 (28.09–62.04)	38.18 (29.76–62.04)	238.86 (28.09–49.15)	0.35

safety of living donation.[14] In spite of these controversies and concerns, LDLT remains an important therapeutic option for patients with end-stage liver disease.

The safety of the donor is of paramount importance for the success of LDLT in any transplant center.[15,16] Hepatic parenchymal transection is the most invasive step in

Table 2 Operative data of the study cases (*GRWR* graft to recipient weight ratio, *RLP* residual liver percentage, *RHV* right hepatic vein, *IRHV* inferior right hepatic vein, *V5* segment 5 vein, *V8* segment 8 vein, *MHV* middle hepatic vein)

Variables	All cases (*N* = 72)	Group A (*N* = 36)	Group B (*N* = 36)	*p* value
Donor operation				0.358
Right hepatectomy	71 (98.6%)	35 (97.2%)	36 (100%)	
Left hepatectomy	1 (1.4%)	1 (2.8%)	0	
Actual graft volume (cc)	860 (480–1483)	885 (536–1277)	825 (480–1483)	0.341
Recipient weight (kg)	83 (36–116)	80.5 (36–100)	86 (60–116)	0.082
Actual GRWR	1.05 (0.68–1.67)	1.09 (0.71–1.51)	0.97 (0.68–1.67)	0.049
Actual RLP (%)	40.06 (23.14–60.88)	38.51 (26.38–60.88)	42.39 (23.14–58.58)	0.069
Number of hepatic veins				0.093
1	38 (52.8%)	15 (41.7%)	23 (63.9%)	
2	25 (34.7%)	17 (47.2%)	8 (22.2%)	
3	8 (11.1%)	3 (8.3%)	5 (13.9%)	
4	1 (1.4%)	1 (2.8%)	0	
RHV size (mm)	25 (12–30)	25 (12–30)	25 (12–30)	0.335
IRHV	15 (20.8%)	8 (22.2%)	7 (19.4%)	0.774
IRHV size (mm)	12 (6–15)	12 (6–15)	10 (8–12)	0.509
V5	16 (22.2%)	10 (27.8%)	6 (16.7%)	0.042
V5 size (mm)	8 (7–15)	8 (7–15)	8 (7–12)	0.244
V8	6 (8.3%)	2 (5.6%)	4 (11.1%)	0.314
V8 size (mm)	8 (5–12)	7.5 (7–8)	9 (5–12)	0.481
Number of portal veins				0.614
1	68 (94.4%)	35 (97.2%)	33 (91.7%)	
2	4 (5.6%)	1 (2.8%)	3 (8.3%)	
Portal vein size (mm)	10 (7–25)	10 (7–25)	8 (7–20)	0.039
Number of hepatic arteries				0.943
1	70 (97.2%)	36 (100%)	34 (94.4%)	
2	2 (2.8%)	0	2 (5.6%)	
Cholangiogram Hwang classification				0.238
A	31 (43%)	16 (44.4%)	15 (41.7%)	
B	8 (11.1%)	6 (16.7%)	2 (5.6%)	
C1	10 (13.9%)	2 (5.6%)	8 (22.2%)	
C2	15 (20.8%)	9 (25%)	6 (16.7%)	
D	5 (6.9%)	2 (5.6%)	3 (8.3%)	
3 ducts	3 (4.2%)	1 (2.8%)	2 (5.6%)	
Cholangiogram graft hepatic ducts				0.813
Single	26 (36.1%)	14 (38.9%)	12 (33.3%)	
Multiple	46 (63.9%)	22 (61.1%)	24 (66.7%)	
Cholangiogram hepatic ducts number				0.588
1	26 (36.1%)	14 (38.9%)	12 (33.3%)	
2	39 (54.2%)	20 (55.6%)	19 (52.8%)	
3	7 (9.7%)	2 (5.6%)	5 (13.9%)	
Actual number of hepatic ducts				0.604
1	29 (40.3%)	17 (47.2%)	12 (33.3%)	
2	38 (52.8%)	19 (52.8%)	19 (52.8%)	
3	5 (6.9%)	0	5 (13.9%)	
MHV included in graft	2 (2.8%)	1 (2.8%)	1 (2.8%)	1
Post-hepatectomy cholangiogram				0.314
Free	71 (98.7%)	36 (100%)	35 (97.2%)	
Mild narrowing	1 (1.4%)		1 (2.8%)	
Intraoperative bile duct injury	0	0	0	–
Operation time (min)	390 (290–600)	360 (290–475)	440 (315–600)	0.001
Hepatectomy duration (min)	62.5 (35–126)	60 (35–100)	80 (50–126)	0.001
Blood loss (ml)	400 (50–1750)	300 (50–1750)	500 (150–1020)	0.113
Blood loss during hepatectomy (ml)	300 (30–1450)	275 (30–1450)	300 (50–600)	0.587
Accidental Bleeding events	9 (12.5%)	8 (22.2%)	1 (2.8%)	0.013
Blood transfusion	1 (1.4%)	0	1 (2.8%)	0.317
Resection surface area (cm^2)	140 (75–300)	140 (84–300)	136 (75–192)	0.942
Necrosis at the cut margin (mm)	0.5 (0.2–1.5)	0.5 (0.4–1.5)	0.3 (0.2–0.8)	0.011

donor operation. During this step, blood loss together with unintended injuries to the intrahepatic structures and hepatic remnant may occur. These are the main factors affecting the development of postoperative morbidities, as cut surface bleeding, biliary leakage, abdominal collections, and postoperative mortality.[1–3]

Table 3 Postoperative data of the study cases (*ICU* intensive care unit)

Variables	All cases (*N* = 72)	Group A (*N* = 36)	Group B (*N* = 36)	*p* value
ICU stay (days)	2 (2–7)	2 (2–7)	2 (2–4)	0.627
Hospital stay (days)	7 (5–21)	6 (5–21)	7 (5–14)	0.332
Complications	18 (25%)	8 (22.2%)	10 (27.8%)	0.952
Clavien-Dindo grades				0.761
I	2 (2.8%)	1 (2.8%)	1 (2.8%)	
II	6 (8.4%)	3 (8.3%)	3 (8.3%)	
IIIa	7 (9.7%)	3 (8.3%)	4 (11.1%)	
IIIb	3 (4.2%)	1 (2.8%)	2 (5.6%)	
IV	0	0	0	
V	0	0	0	
Early mortality	0	0	0	–
Bile leakage	5 (6.9%)	3 (8.3%)	2 (5.6%)	0.643
Bile leakage management				0.171
Conservative	5 (6.9%)	3 (8.3%)	2 (5.6%)	
Biloma	4 (5.6%)	2 (5.6%)	2 (5.6%)	1
Biloma management				0.261
Aspiration	2 (2.8%)	1 (2.8%)	1 (2.8%)	
Tube drainage	1 (1.4%)	0	1 (2.8%)	
Surgery	1 (1.4%)	1 (2.8%)	0	
Biliary strictures	0	0	0	–
Collections	13 (18.1%)	8 (22.2%)	5 (13.9%)	0.374
Collection management				0.524
Conservative	9 (12.6%)	6 (16.6%)	3 (8.3%)	
Aspiration	3 (4.2%)	1 (2.8%)	2 (5.6%)	
Tube drainage	1 (1.4%)	1 (2.8%)	0	
Internal hemorrhage	2 (2.8%)	0	2 (5.6%)	0.314
Wound gaping	1 (1.4%)	0	1 (2.8%)	0.382
Postoperative ascites	2 (2.8%)	0	2 (5.6%)	0.314
Neurological				0.382
Bilateral neuropraxia	1 (1.4%)	0	1 (2.8%)	
Re-exploration	3 (4.2%)	1 (2.8%)	2 (5.6%)	0.709
Re-exploration cause				0.389
Internal hemorrhage	2 (2.8%)	0	2 (5.6%)	
Biloma drainage	1 (1.4%)	1 (2.8%)	0	
Readmission	3 (4.2%)	2 (5.6%)	1 (2.8%)	0.582

Over the last years, several technological advances have focused on different techniques for hepatic parenchymal transection. These include ultrasonic dissection, hydro-dissection, microwave coagulators, radiofrequency coagulators, and stapling with vascular staplers.[2,4–6,17–19] On the other hand, the classic clamp-crush technique (Kelly-klasia technique) is a simple method avoiding the need for special equipment.[20]

Each of those hepatic transection techniques has its own advantages and disadvantages, but they share the same objectives including decreasing the blood loss during parenchymal transection, shortening the duration of parenchymal transection, avoidance of unintended injury of intrahepatic and adjacent structures, and adequate sealing of small bile ducts to prevent postoperative biliary leaks.

Several studies have evaluated different techniques of hepatic parenchymal transection.[2,4–6] Few of these were conducted in the field of LDLT.[7,8] However, there are no evidences to prove the ideal techniques for hepatic parenchymal transection in the field of LDLT.

In our unit, we adopted the use of the harmonic scalpel (HARMONIC WAVE® Open Shears – ETHICON) since 2004 for hepatic parenchymatous division in LDLT. Harmonic scalpel allows sealing of small blood vessels and bile ducts between the vibrating blades during hepatic parenchymal transection resulting in reduction of blood loss and transection duration.[21,22] On the other hand, it is associated with unintended bleeding events during parenchymal transection because of accidental injury of larger intrahepatic blood vessels. It cannot be used close to the hilar area because of the risk of thermal injury to adjacent vital structures. The necrotic area at the resection surface may result in postoperative biliary leakage or abdominal collections. Also, the added financial cost of harmonic scalpel blades.

In this study, we evaluated the safety, efficacy, and outcome of clamp-crush technique (Kelly-klasia) as an alternative method for the standard harmonic scalpel as a method of hepatic parenchymal transection in living-donor hepatectomy.

Blood loss during liver resection and subsequent blood transfusion have been identified as the main predictors affecting the development of surgical morbidities and mortality.[2,5,23] Some studies found a significant reduction in blood loss and transfusion requirements during parenchymal

Table 4 Postoperative laboratory results of the study cases (*WBCs* white blood cells, *POD* postoperative day, *ALT* alanine aminotransferase, *AST* aspartate aminotransferase, *INR* international normalized ratio, *CRP* C-reactive protein)

Variables	All cases ($N = 72$)	Group A ($N = 36$)	Group B ($N = 36$)	p value
WBCs 1st POD (× $10^3/\mu l$)	16.2 (5.7–38)	16.6 (5.7–25.7)	15.5 (8.3–38)	0.697
WBCs 3rd POD (× $10^3/\mu l$)	10.1 (4–19.9)	10.4 (4–19.9)	10.1 (4.4–19)	0.628
WBCs 5th POD (× $10^3/\mu l$)	7 (3.1–12.2)	7.1 (3.9–10.6)	6.9 (3.1–12.2)	0.51
WBCs 7th POD (× $10^3/\mu l$)	7.7 (4.1–17.7)	7.65 (5–11.2)	7.9 (4.1–17.7)	0.136
Platelets 1st POD (× $10^3/\mu l$)	190 (24–354)	190 (116–310)	193.5 (24–354)	0.677
Platelets 3rd POD (× $10^3/\mu l$)	156.5 (74–250)	169 (74–214)	146.5 (79–250)	0.102
Platelets 5th POD (× $10^3/\mu l$)	162.5 (26–266)	178.5 (26–245)	158.5 (79–266)	0.72
Platelets 7th POD (× $10^3/\mu l$)	200 (69–276)	200 (111–276)	195 (69–275)	0.986
Total bilirubin 1st POD (mg/dl)	1.7 (0.7–6.1)	1.7 (0.7–6.1)	1.8 (0.9–4)	0.937
Total bilirubin 3rd POD (mg/dl)	1.7 (0.5–7.1)	1.75 (0.5–7.1)	1.7 (1–5.4)	0.928
Total bilirubin 5th POD (mg/dl)	1.1 (0.5–6.1)	1.2 (0.5–6.1)	1.1 (0.5–4.2)	0.029
Total bilirubin 7th POD (mg/dl)	0.7 (0.4–7)	0.8 (0.4–7)	0.55 (0.5–2.5)	0.012
Direct bilirubin 1st POD (mg/dl)	0.7 (0.3–2.5)	0.7 (0.5–2.3)	0.65 (0.3–2.5)	0.863
Direct bilirubin 3rd POD (mg/dl)	0.75 (0.3–4.2)	0.8 (0.5–4.2)	0.7 (0.3–3.3)	0.867
Direct bilirubin 5th POD (mg/dl)	0.8 (0.3–5.3)	0.8 (0.5–4.9)	0.8 (0.3–3.3)	0.534
Direct bilirubin 7th POD (mg/dl)	0.6 (0.3–5.3)	0.8 (0.5–5.3)	0.5 (0.3–1.5)	0.068
ALT 1st POD (IU/L)	179.5 (67–514)	217 (67–514)	163.5 (109–452)	0.005
ALT 3rd POD (IU/L)	110 (37–303)	141 (37–303)	103 (59–223)	0.01
ALT 5th POD (IU/L)	75 (25–218)	79.5 (25–138)	70.5 (40–218)	0.414
ALT 7th POD (IU/L)	56 (20–578)	57 (20–109)	50 (21–578)	0.817
AST 1st POD (IU/L)	151 (70–353)	152 (109–330)	148.5 (70–353)	0.411
AST 3rd POD (IU/L)	76.5 (40–152)	76.5 (44–152)	78 (40–151)	0.45
AST 5th POD (IU/L)	46 (24–157)	45.5 (28–94)	47 (24–157)	0.621
AST 7th POD (IU/L)	37 (21–413)	33 (21–109)	43 (27–413)	0.085
INR 1st POD	1.4 (1–2.9)	1.35 (1.2–1.8)	1.6 (1–2.9)	0.749
INR 3rd POD	1.4 (1–2)	1.4 (1–1.8)	1.35 (1–2)	0.82
INR 5th POD	1.3 (1–2)	1.45 (1–2)	1.3 (1–1.6)	0.024
INR 7th POD	1.1 (1–1.6)	1.2 (1–1.6)	1.1 (1–1.3)	0.046
CRP 1st POD (mg/dL)	38 (13–113)	37.5 (13–91)	38 (0–113)	0.588
CRP 3rd POD (mg/dL)	40.5 (4–99)	45.5 (4–99)	30 (0–93)	0.282
CRP 5th POD (mg/dL)	15.5 (5.6–95)	17.5 (6–95)	12 (0–45)	0.029
CRP 7th POD (mg/dL)	13 (6–64)	15.5 (0–64)	11 (0–47)	0.036

transection with clamp-crush technique compared to other transection methods.[20,24] This is related to the ability to identify intrahepatic structures that could be managed by clipping, ligation, or coagulation or can be reserved for future reconstruction in the recipient. On the other hand, Alexiou et al. in a systematic review and meta-analysis addressed that vessel sealing devices are superior to clamp-crush technique regarding intraoperative blood loss.[25] In our study, there were no significant differences between harmonic scalpel and clamp-crush techniques regarding intraoperative blood loss in the whole operation and during hepatic parenchymal transection. Also, there was no significant difference regarding the transfusion requirements. Similar findings were reported by Takayama et al. in a randomized trial comparing both techniques for hepatectomy in hepatic tumors. They concluded that hepatectomy quality is improved with clamp crush-technique; therefore, they advocated it as the option of choice for parenchymal transection.[26]

Of note, that unintended bleeding events occurring during parenchymal transection because of accidental injury of larger intrahepatic blood vessels is commonly seen with harmonic scalpel technique. Castaldo et al. found no differences between vessel sealing devices and clamp-crush technique in terms of blood loss or transfusion requirements, but hepatectomies performed with vessel sealing devices were associated with an increased risk of blood loss more than 1000 ml compared to clamp-crush technique. This may be explained by accidental injury of larger intrahepatic blood vessels.[27] In our study, more bleeding events occurred in harmonic scalpel technique than clamp-crush technique and this was statistically significant.

There was a significantly longer operating time and hepatectomy duration in clamp-crush technique in comparison to harmonic scalpel. This can be attributed to the time needed in ligation or suturing of intrahepatic vasculature after clamp crushing of the hepatic parenchyma, which can be sealed and divided by harmonic scalpel. Previous studies did not find statistically significant difference in the operating time between clamp-crush and other parenchymal transection techniques.[20]

Postoperative complications, especially biliary complications, adversely affect the outcomes after donor hepatectomy.[28,29] There is a great disparity in reported

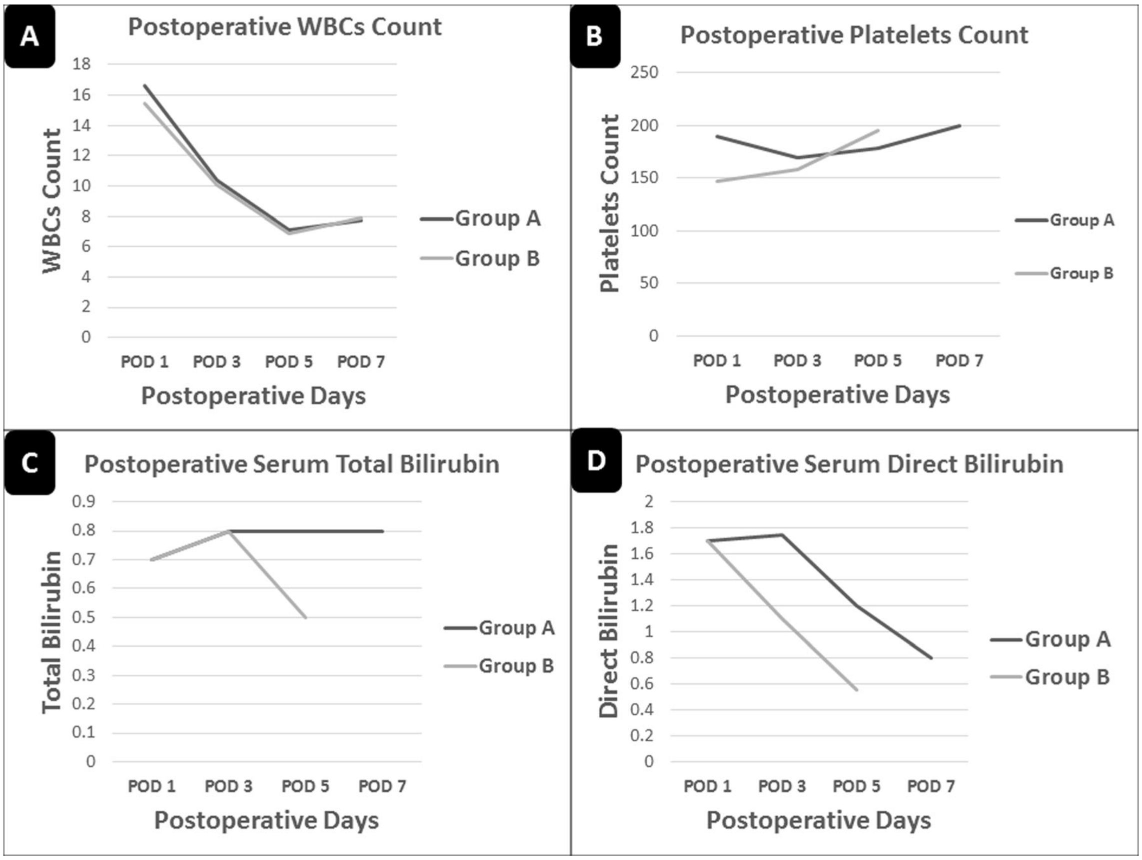

Fig. 1 Postoperative laboratory results of serum white blood cells (**a**), platelets (**b**), total bilirubin (**c**), and direct bilirubin (**d**)

complications rates after donor hepatectomy ranging from 21–67%.[30–33] In our study, the overall incidence of postoperative morbidities was 25%. There were no significant differences between the two techniques regarding postoperative morbidities and their classification according to Clavien-Dindo grading system. Also, there were no significant differences between the two techniques regarding postoperative ICU and overall hospital stay. Takayama et al reported similar results in their randomized trial.[26]

Biliary complications, especially bile leak, are serious postoperative morbidities after hepatic surgery influencing the postoperative surgical outcomes.[34] The use of harmonic scalpel has been found to have a significantly higher rate of postoperative bile leak.[22,35] This is related to mass coagulation of the deeper hepatic parenchyma including intrahepatic biliary ducts by harmonic scalpel leading to incomplete sealing of the Glisson's sheath.[36,37] On the contrary, Alexiou et al. in a systematic review and meta-analysis addressed that vessel sealing devices are associated with lower incidence of postoperative bile leak compared to clamp crush technique. This may explain shorter hospital stay noted with the use of the vessel sealing devices.[25] In our study, there were no significant differences between the two groups regarding postoperative bile leakage and bilomas.

Regarding postoperative biochemical markers, a significant higher level of postoperative serum ALT at 1st and 3rd PODs was seen in harmonic scalpel group. Also, significant higher levels of postoperative serum total bilirubin and INR at 5th and 7th PODs were found in harmonic scalpel group. On the other hand, significant higher level of CRP at 5th and 7th PODs were seen in harmonic scalpel group. There were no significant differences between the two techniques regarding leucocytic and platelets count in the postoperative laboratory results.

One of the important aspects in comparing the two techniques is the overall cost added with the use of harmonic scalpel blades, especially in low income countries like Egypt. The added cost of using harmonic scalpel blade is almost US$700 per case. On the other hand, clamp-crush technique does not require any complex instruments and no excess added cost. Gurusamy et al. found that clamp-crush technique is two to six times cheaper than the other methods used for hepatic parenchymal transection depending on the number of surgeries performed every year.[20]

Although this study is a prospective randomized study, it is limited by small number of cases from a single center. This is related to the unique nature of the study cases. Also, the performance of prospective randomized study in surgical field is difficult because of the difficulty of patient recruitment.

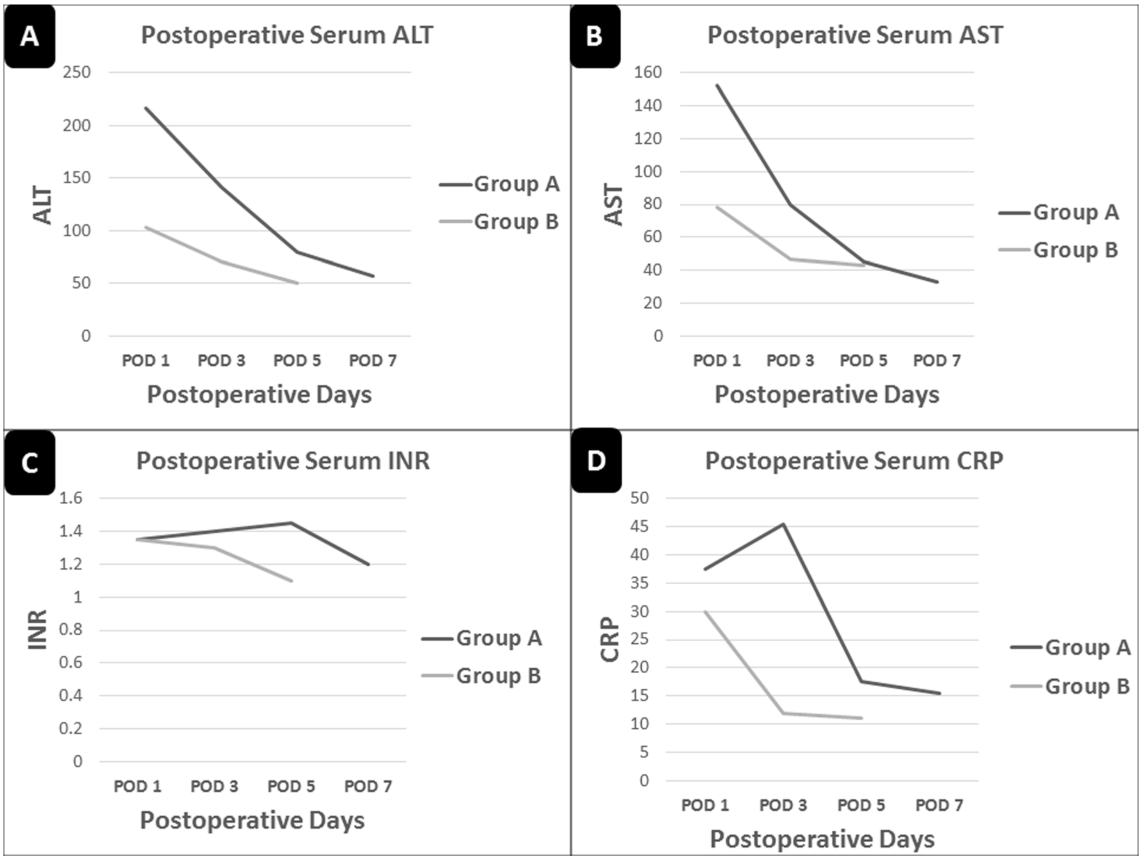

Fig. 2 Postoperative laboratory results of serum alanine aminotransferase (**a**), aspartate aminotransferase (**b**), international normalized ratio (**c**), and C reactive protein (**d**)

Another limitation of this study is the surgeon's familiarity with those parenchymal transection techniques.

Conclusion

Clamp-crush technique is advocated as a simple, easy, safe, and cheap method for hepatic parenchymal transection in living donors. It avoids the need for special complex equipment and subsequent added costs. It is not associated with significant increase in operation time, blood loss, transfusion requirements, and perioperative morbidities or mortality. It is associated with earlier recovery of liver functions.

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Drafting the manuscript or revising it critically for important intellectual content: all authors.

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