

Original Research Article

Clinical outcome of hepatic resection for malignant liver tumors in elderly patients

Ashraf M. El-Badry, Ahmed Abdelkahaar Aldardeer*

Department of Surgery, Sohag University Hospital, Faculty of Medicine, Sohag University, Sohag, Egypt

Received: 09 July 2021

Revised: 30 July 2021

Accepted: 31 July 2021

*Correspondence:

Dr. Ahmed Abdelkahaar Aldardeer,
E-mail: ashour2003@gmail.com

Copyright: © the author(s), publisher and licensee Medip Academy. This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License, which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

ABSTRACT

Background: Aging hinders the liver capacity to reconstitute its volume and function after partial hepatectomy. Concomitant hepatic parenchyma disorders and major resections may increase the susceptibility of elderly patients to worse postoperative outcome.

Methods: Prospectively collected medical records of adult patients who underwent elective partial hepatectomy for malignant liver tumors at Sohag University Hospital (June 2014–May 2020) were analyzed. A group of elderly (≥ 65 years) were compared with a matched control group of non-elderly (< 65 years) patients as regards posthepatectomy liver failure (PHLF) and overall complications, including mortality. Markers associated with PHLF and postoperative death were investigated.

Results: Forty-eight patients were enrolled, 24 per group. 34 were males (71%). All patients had primary hepatic malignancy or metastatic tumors. Hepatocellular carcinoma (HCC) was the most common indication for liver resection in both groups (32 patients, 66.6%). Elderly patients exhibited significantly higher grades of overall postoperative complications ($p < 0.05$). PHLF was significantly increased in the elderly group, in evident connection with significant persistence of higher bilirubin levels and reduced prothrombin concentration ($p < 0.05$) until 5th postoperative day. Subgroup analysis showed that major resections and cirrhosis correlated with increased morbidity among elderly compared with younger patients. Postoperative mortality occurred in 3 elderly cirrhotic patients, who failed to recover normal platelet count postoperatively.

Conclusions: In elderly patients, major liver resection for malignant tumors is associated with worse outcome, particularly in those with coexisting cirrhosis. Predictors include early postoperative thrombocytopenia and persistent hyperbilirubinemia and coagulopathy.

Keywords: Elderly, Liver Resection, Cirrhosis

INTRODUCTION

Liver cancer ranks seventh among most common types of malignancy and the second among causes of cancer-related mortality.¹ Aging correlates with increased incidence of primary and metastatic liver cancers with subsequent rise of oncologic liver resection procedures.^{2,3} Advanced age may predispose the elderly patients, compared with their younger counterparts, to serious

postoperative complications after liver resections, particularly major hepatectomy.^{4,6}

Restoration of liver volume after partial hepatectomy depends on adequate regeneration of hepatic parenchymal cells.⁷ However, normalization of liver functions relies on both the volume and parenchymal quality of the postoperative liver remnant.⁸ Impaired quality of liver parenchyma is related to a number of factors, among which advanced age and cirrhosis are directly related to reduced

capacity of liver regeneration and delayed recovery of liver functions.⁹⁻¹¹

Due to the progressive increase in life expectancy, several cancer types are increasingly detected in aged patients. It is anticipated that the elderly population will harbor 60% of all malignant tumors.¹² In this context, the incidence of hepatocellular carcinoma (HCC) which represent the most common liver cancer, is rising among aged population.¹³

Most commonly, aged patients with HCC have additional burden due to preexisting liver cirrhosis in relation to chronic hepatitis C and B viral infections.^{14,15} Liver resection remains as valuable alternative curative strategy for elderly cirrhotic patients despite the known superiority of liver transplantation (LTx) regarding overall and recurrence-free survival due to the remarkable shortage of donors.¹⁶⁻¹⁹

A similar situation is reported in the setting of metastatic liver cancers which exhibit progressive increase elderly patients.²⁰

In this study, we aimed at investigating the influence of advanced age, with or without concurrent parenchymal liver disorders, on the clinical outcome after resection of primary and metastatic liver cancer.

METHODS

Prospectively collected medical database of adult patients (age >18-year-old) with who underwent elective liver resection for primary and secondary liver cancers at Sohag University Hospital (June 2014–May 2020) was analyzed. An elderly group (≥ 65 years) was compared with control group of younger (<65 years) patients with matching gender, preoperative liver functions, liver transection technique, duration of intermittent portal triad occlusion (Pringle's maneuver), and number of resected liver segments. Exclusion criteria entailed age <18 years, impaired liver functions (child B and C cirrhosis), emergency liver resection, reduced platelet count preoperatively to $<100 \times 10^9/l$, combined visceral resections and any modality of preoperative interventional procedures, including ablative interventions and/or chemo-embolization.

The study was approved by the Sohag Faculty of Medicine Committee on medical ethics.

The data were analyzed by statistical package for the social sciences (SPSS) data base with application of Chi-square test and test of comparison of proportions, p value <0.01-0.05.

We enrolled all elderly patients who fulfilled the inclusion criteria within the time frame of the study these patients were compared to matching control group (1:1) of younger patients. The number of enrolled patients is the sum of both groups.

Preoperative assessment

Standard preoperative evaluation comprised thorough clinical examination and abdominal imaging. Laboratory tests included tumor markers alfa-fetoprotein (α -FP), carbohydrate antigen 19:9 (CA) and CEA (carcinoembryonic antigen). Cirrhotic patients were assigned child-Pugh score. Signs of portal hypertension were endoscopic evidence of esophageal varices, marked splenomegaly and platelet count $\leq 100 \times 10^3/\mu l$. Triphasic computed tomography (CT) abdominal scanning and contrast enhanced chest CT were carried out in all patients. Liver resection was undertaken in the setting of technically resectable tumor (s) provided that sufficient remnant liver volume is secured. Resected liver specimens were histopathologically assessed for the number of tumors, size, tumor differentiation, vascular invasion, and the status of resection margins. An informed consent was obtained from all patients prior to any intervention.

Anesthesia and surgical procedures

Surgical procedures were constantly carried out by the same team of surgeons. In cirrhotics, excessive liver mobilization and needless dissection of liver ligaments were avoided to decrease intraoperative blood loss and prevent postoperative exacerbation of portal hypertension. Liver transection was performed during intermittent inflow occlusion. To that end, a vessel loop or plastic tube was used as tourniquet around the hepatoduodenal ligament. Low central venous pressure (0–5 mm H₂O) was kept during transection to reduce backflow from the hepatic venous tributaries while sufficient urine output was preserved.

Postoperative assessment

Liver functions, particularly plasma levels of bilirubin and albumin in addition to the coagulation profile were regularly monitored. Postoperative complications comprised bleeding, bile leakage, intra-abdominal infection, PHLF and wound sepsis. Platelet count was regularly checked. Furthermore, severity of postoperative complications was assessed by Clavien-Dindo system.²¹ Moreover, as we have previously described, each patient was given a postoperative score of complications (from one to seven) through assigning one point the seven grades which have been described in this system (I, II, IIIa, IIIb, IVa, IVb and V) in ascending order.²¹ Mortality during the initial postoperative 30 days following liver resection, was considered as hepatectomy-related postoperative death, even if occurred after discharge from the hospital. Statistical analysis was done using by unpaired t-test using GraphPad Prism 6.0 software.

RESULTS

As per the study protocol, forty-eight patients were enrolled (twenty-four per group). Patients were significantly older in the elderly compared with the non-

elderly control group. Thirty-four patients were males, equally distributed between both groups. Indications of liver resection are listed in Table 1. A subgroup of 32 patients with HCC (16 per group) had compensated liver cirrhosis (child-Pugh class A) in relation to chronic hepatitis C viral infection. It is worth mentioning that among our patients there was neither cases of high steatosis grades nor cholestasis (as we do not perform liver resection in cholestatic patients except in those who had their bilirubin level normalized after successful internal or external biliary drainage). Systemic hypertension and diabetes mellitus were more common in the elderly (14 and 8 patients, respectively) compared with the non-elderly group (6 and 4, respectively), however both were adequately controlled before surgery. Preoperative data are outlined in Table 2.

Table 1: Indications of liver resection.

| Indications of liver resection | No. |
|--|-----|
| Primary liver cancer | |
| Hepatocellular carcinoma (cirrhotics) | 32 |
| Intrahepatic cholangiocarcinoma | 2 |
| Metastatic (metachronous) liver cancer from | |
| Colon | 8 |
| Rectum | 2 |
| Gall bladder | 2 |
| Adrenal gland | 2 |
| Total | 48 |

All cases were equally divided between the elderly and non-elderly groups

Operative data

Liver parenchyma transection was undertaken using clamp crushing technique in all patients. A vessel sealing device was utilized (in combination with the crushing clamp) in 26 patients (13 per group).

To mitigate intraoperative bleeding, liver transection was performed during cycles of intermittent (in cirrhotic patients) or continuous (in non cirrhotics) inflow occlusion of the portal triad (Pringle’s maneuver).

Due to high prevalence of liver cirrhosis among the elderly group and their matched non-elderly control, we attempted at maximum preservation of adequate liver remnant. Thus, only one third of the study population (sixteen patients, 8

in each group) had major hepatectomy, defined as resection of ≥ 3 segments. The remaining 32 patients (66.6%) who were equally divided between both groups underwent resection of 1-2 liver segments. No significant difference between both group with regard to the operative time and total period of liver ischemia. Nonetheless, blood loss and transfusions were significantly higher among elderly patients, mostly in the cirrhotic sub-group. Operative data were summarized in Table 3.

Incidence of POD-1 thrombocytopenia

All non-cirrhotic patients in both groups had normal platelet count ($>140 \times 10^9/l$) on POD-1 and later on with no PHLF until discharge. Contrarily, among the 16 patients of the elderly cirrhotic subgroup, 6 patients (37.5%) had POD-1 thrombocytopenia $<100 \times 10^9/l$ compared with none in the non-elderly cirrhotic subgroup. Of note, POD-1 thrombocytopenia $<100 \times 10^9/l$ developed exclusively after major resections.

Predictors of posthepatectomy liver failure (PHLF)

Manifestations of PHLF included persistent jaundice, bleeding tendency, ascites and hepatic encephalopathy. Plasma levels of bilirubin and albumin in addition to prothrombin concentration on POD-5 were considered as markers of functional recovery of the remnant liver. These values were significantly reduced with significantly higher levels of total bilirubin on POD-5 in elderly compared with the non-elderly control group (Table 4). This difference was more pronounced among the elderly cirrhotic subgroup compared with their non-elderly cirrhotic controls (Table 5). Persistent increase of bilirubin level >3 mg/dl with concomitant decline of prothrombin concentration $<50\%$ was observed in the same 6 elderly cirrhotic patients who developed POD-1 thrombocytopenia $<100 \times 10^9/l$ after major resection.

Postoperative complications and length of hospital stay

Postoperative complication score was significantly higher among elderly patients compared with the non-elderly group. Likewise, the length of hospital stay was significantly prolonged among elderly cirrhotics (Table 6). These differences were particularly evident in the elderly cirrhotic subgroup compared with the control non-elderly cirrhotic patients (Table 7).

Table 2: Preoperative data.

| Data | Elderly (≥ 65 years) | Non-elderly (<65 years) | P value |
|--------------------------------------|----------------------------|----------------------------|-----------|
| Clinical data | | | |
| Age, median (range) | 71 (65-77) | 51 (42-64) | $<0.05^*$ |
| Portal vein diameter (mm, US) | 12 (11-16) | 11 (9-15) | ns |
| Spleen (longest dimension in cm, US) | 13.5 (12-15) | 12 (12-16) | ns |
| Tumor size (cm) | 6 (4-13) | 5 (3-13) | ns |
| Laboratory data | | | |
| Bilirubin (mg/dl) | 0.7 (0.4-1.1) | 0.75 (0.4-1) | ns |

Continued.

| Data | Elderly (≥ 65 years) | Non-elderly (<65 years) | P value |
|--------------------------------|----------------------------|----------------------------|---------|
| Albumin (g/dl) | 3.9 (3.5-5.0) | 4.1 (3.8-5.1) | ns |
| Prothrombin concentration (%) | 75 (88-106) | 82 (80-110) | ns |
| Platelet count $\times 10^9/l$ | 188 (160-340) | 214 (172-405) | ns |

*significant difference; ns: non-significant difference; cm: centimeter; L: liter, mm: millimeter; US: ultrasonography

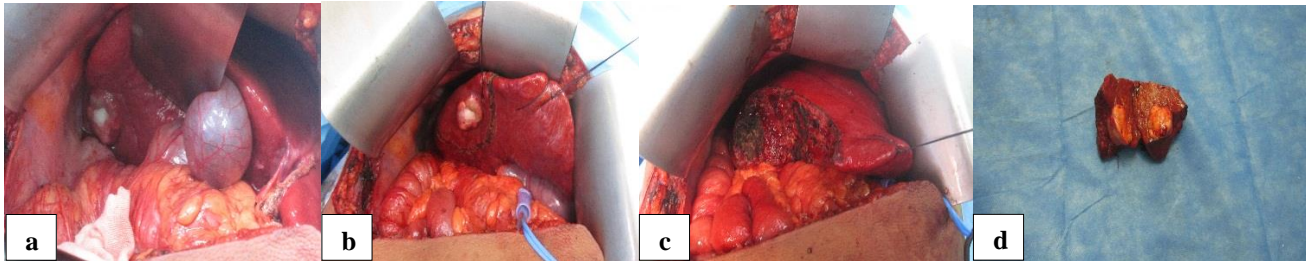


Figure 1: Non-anatomic liver resection (segments VI), for HCC in cirrhotic liver (a) tumor in segment IV during initial exploration, (b) Pringle's maneuver using vessel loop as tourniquet around the portal triad for non-selective inflow occlusion), the liver capsule was cauterized along the line of transection, (c) right lobe after completion of tumor removal within resected segment VI, and (D) resected specimen (segment IV) within macroscopically adequate safety margin.

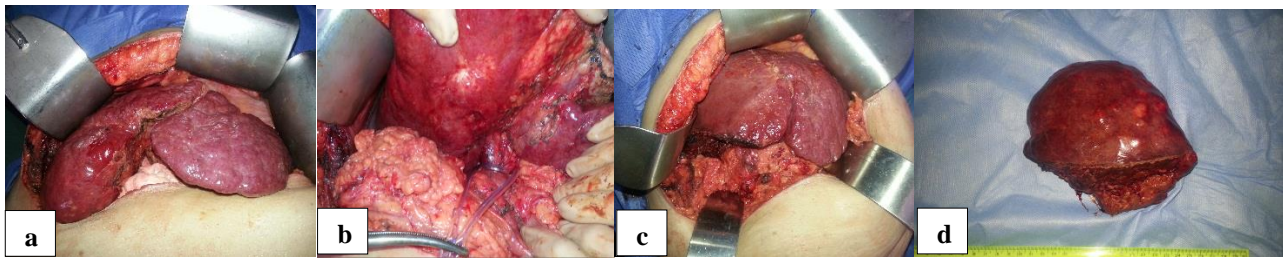


Figure 2: Non-anatomic liver resection (segments V and VI), for exophytic HCC in cirrhotic liver of elderly patient (a) tumor hanging from the right lobe, (b) Pringle's maneuver using plastic drainage tube as tourniquet around the portal triad for non-selective inflow occlusion, (c) right lobe after completion of tumor resection, and (d) resected specimen within macroscopically adequate safety margin.

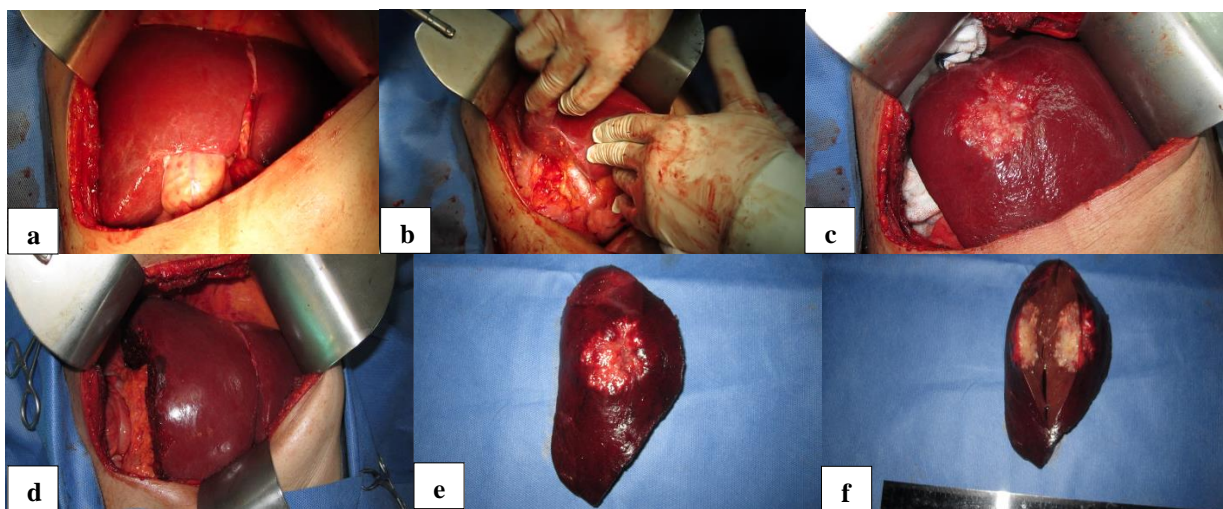


Figure 3: Anatomic liver resection (right posterior sectionectomy, segments VI and VII were resected), for metastatic colon cancer to the liver of non-elderly patient (a) initial exploration, tumor not seen as it is located in the posterior segments of the right lobe, (b) right lobe mobilized for adequate tumor exposure, (c) tumor fully accessible for resection after clockwise rotation of the right lobe, (d) right posterior sectionectomy completed, (e) resected tumor within adequate safety margin, and (f) resected specimen bisected.

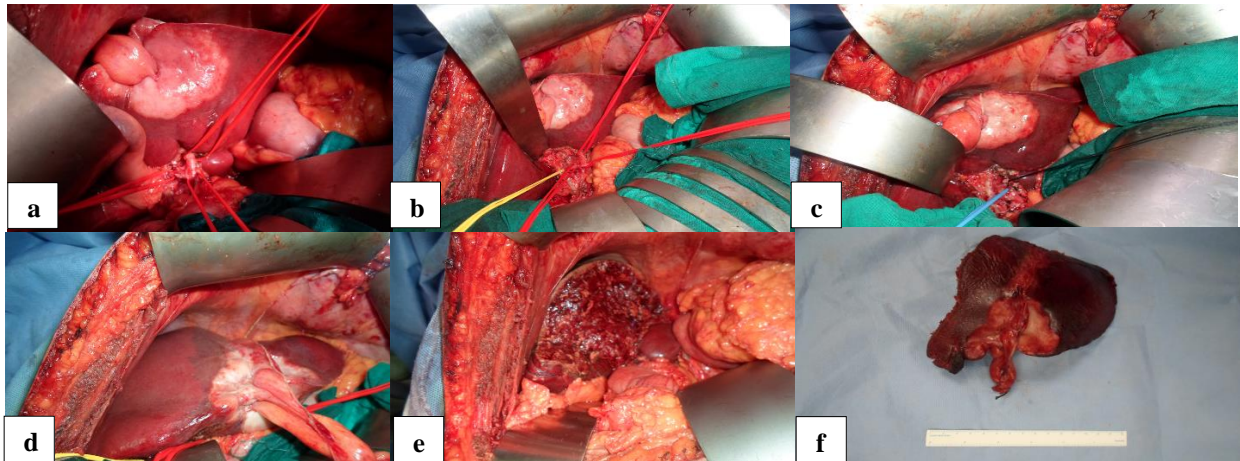


Figure 4: Major anatomic liver resection (left hepatectomy), for intrahepatic cholangiocarcinoma in elderly non-cirrhotic patient (a) initial exploration, tumor clearly exposed, (b) proper hepatic artery, right and left branches isolated, common bile duct protected, (c) portal vein isolated, left hepatic artery ligated, (d) ischemic left lobe after selective inflow occlusion of the left branch of hepatic artery and portal vein prior to liver transection, (e) left hepatectomy completed, and (f) resected tumor with adequate safety margin within the resected left liver lobe.

Table 3: Operative data.

| Operative data | Elderly (≥ 65 years) | Non-elderly (<65 years) | P value |
|---|----------------------|-------------------------|---------|
| Duration of surgery (minute)* | 210 (150-320) | 190 (130-290) | ns |
| Number of resected segments* | 3 (1-4) § | 3 (1-4) | ns |
| Central venous pressure cm/H₂O* | 4 (2-5) | 4 (1-5) | ns |
| Blood loss (ml)* | 1000 (200-1900) | 600 (150-1500) | <0.05** |
| Red blood cell transfusion (unit)* | 4 (0-7) | 2 (0-3) | <0.05** |
| Plasma transfusion (units)* | 5 (0-8) | 1 (0-4) | <0.05** |

*Median (range), **significant difference

Table 4: Postoperative markers of hepatic dysfunction on POD-5.

| Parameter | Elderly (≥65 years) | Non-elderly (<65 years) | P value |
|---|---------------------|-------------------------|---------|
| Indicators of liver dysfunction at POD-5 | | | |
| Bilirubin (mg/dl)§ | 2 (0.8-7.5) | 1 (0.7-2.8) | <0.05* |
| PC (%)§ | 75 (48-90) | 92 (65-98) | <0.05* |
| Albumin (g/dl)§ | 2.8 (2.4-4.0) | 3.7 (2.8-4.4) | <0.05* |

PC: prothrombin concentration, POD: postoperative day, *significant difference, §median (range)

Table 5: Subgroup analysis of postoperative markers of hepatic dysfunction on POD-5.

| Parameter | Elderly cirrhotics (≥65 years) | Non-elderly cirrhotics (<65 years) | P value |
|---------------------------|--------------------------------|------------------------------------|---------|
| Bilirubin (mg/dl)§ | 2.6 (1.7-7.5) | 1.4 (1.2-2.8) | <0.05* |
| PC (%)§ | 66 (48-76) | 84 (65-83) | <0.05* |
| Albumin (g/dl)§ | 2.5 (2.4-3.5) | 3.7 (2.8-3.9) | <0.05* |

PC: prothrombin concentration, POD: postoperative day, *significant difference, §median (range)

Table 6: Postoperative complications and hospital stay.

| Parameter | Elderly (≥65 years) | Non-elderly (<65 years) | P value |
|------------------------------------|---------------------|-------------------------|---------|
| Highest complication score§ | 7 (1-7) | 3 (0-3) | <0.05* |
| Length of hospital stay§ | 17 (8-38) | 11 (3-19) | <0.05* |
| Length of ICU stay§ | 4 (1-15) | 1 (0-6) | <0.05* |

POD: postoperative day, ICU: intensive care unit, *significant difference, §median (range)

Table 7: Subgroup analysis of postoperative complications and hospital stay.

| Parameter | Elderly cirrhotics (≥ 65 years) | Non-elderly cirrhotics (< 65 years) | P value |
|---|---------------------------------------|--|------------|
| Highest complication score[§] | 7 (2-7) | 3 (1-3) | $< 0.05^*$ |
| Length of hospital stay[§] | 21 (13-38) | 14 (8-19) | $< 0.05^*$ |
| Length of ICU stay[§] | 6 (3-15) | 2 (1-6) | $< 0.05^*$ |

POD: postoperative day, ICU: intensive care unit, *significant difference, [§]median (range)

Postoperative mortality

No mortality was recorded among non-elderly patients. However, 3 patients from the elderly group who underwent major resection died during the first postoperative month. Notably, those patients had POD-1 thrombocytopenia $< 100 \times 10^9/l$ with concomitant rise of bilirubin levels (> 3 mg/dl) and diminution of prothrombin concentration ($< 50\%$) on POD-5 and thereafter.

DISCUSSION

This study highlights the vulnerability of elderly patients to worse clinical outcome after partial hepatectomy. In particular, elderly patients with concomitant liver cirrhotics who are more susceptible to PHLF, increased morbidity and mortality after. Predictors of poor outcome include POD-1 thrombocytopenia and persistent derangement of bilirubin levels and prothrombin activity until POD-5.

Aging is associated with suboptimal tolerance to major liver insults, therefore, major hepatectomy in this category should be considered with much caution.^{20,22,23} Furthermore, associated parenchyma disorders, especially cirrhosis are known to impose high risk of PHLF after major resections.²⁴

POD-1 thrombocytopenia was reported as reliable prognostic sign for PHLF and increased mortality after partial hepatectomy.²⁵ We have regularly checked our patients postoperatively since POD-1 for thrombocytopenia $< 100 \times 10^9/l$, which was anticipated to impose high risk for development of PHLF.^{26,27} In line with current literature, PHLF occurred in 3 among 6 elderly cirrhotic patients who had POD-1 $< 100 \times 10^9/l$ after major resections.

Continuous elevation of serum bilirubin levels and reduction of prothrombin concentration until POD-5 is a valuable predictor of failure of recovery of hepatic functions and increased mortality after partial liver resection.^{28,29} We observed slower normalization of bilirubin and prothrombin levels among elderly patients. This finding was more evident among elderly cirrhotics in contrast to their non-elderly controls. Consistent with previous reports, postoperative death occurred in 3 out of 6 elderly cirrhotics patients who had high bilirubin level > 3 mg/dl and reduced prothrombin concentration down to $< 50\%$ until POD-5.^{26,30}

The severity of postoperative complications was objectively assessed by Clavien-Dindo system and our proposed scoring of grades of surgical complications.²¹ In contrast to the non-elderly group, elderly patients, particularly cirrhotics, exhibited significantly higher complication score. This might be reasonably attributed to the poorer quality of liver parenchyma due to aging.^{20,23} Likewise, increased occurrence of PHLF and surgical complications were noted in elderly cirrhotic patients who required significantly longer hospital stays compared with their non-elderly controls.²⁴

Postoperative death occurred in 3 elderly cirrhotics in association with POD-1 thrombocytopenia $< 100 \times 10^9/l$ and continuously disturbed bilirubin levels and coagulation until POD-5. These findings conform with previous studies in which increased mortality was noted among HCC cirrhotic patients who developed immediate postoperative thrombocytopenia $< 100 \times 10^9/l$ after liver resection.^{31,32}

We chose the case-matched control design because it has the advantage study execution with low cost even small number of patients of while obtaining considerably reliable results and justifiable conclusions.^{33,34} 2016 yet, the inherent shortcomings of this methodology, such as the difficult case-control matching, the potential selection bias and confounding factors should be clearly emphasized.³⁵

CONCLUSION

Based on increased postoperative complications and mortality in elderly patients, particularly cirrhotics, strict selection criteria should be applied to accomplish satisfactory clinical outcome.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

- Shimada S, Kamiyama T, Orimo T, Nagatsu A, Asahi Y, Sakamoto Y, et al. Prognoses, outcomes, and clinicopathological characteristics of very elderly patients with hepatocellular carcinoma who underwent hepatectomy. *World J Surg Oncol.* 2020;18(1):122.
- Liu Z, Suo C, Mao X, Jiang Y, Jin L, Zhang T, Chen X. Global incidence trends in primary liver cancer by

- age at diagnosis, sex, region, and etiology, 1990-2017. *Cancer.* 2020;126(10):2267-78.
3. Hu SJ, Jiang SS, Zhang J, Luo D, Yu B, Yang LY, et al. Effects of apoptosis on liver aging. *World J Clin Cases.* 2019;7:691-704.
 4. Galun D, Bogdanovic A, Zivanovic M, Zuvela M. Short- and Long-Term Outcomes After Hepatectomy in Elderly Patients with Hepatocellular Carcinoma: An Analysis of 229 Cases from a Developing Country. *J Hepatocell Carcinoma.* 2021;8:155-65.
 5. Sioutas GS, Ziogas IA, Tsoulfas G. Frailty and Liver resection: where do we stand? *Hepatoma Res.* 2020;6.
 6. Dedinská I, Laca L, Miklušica J, Palkoci B, Skálová P, Lauková S, Osinová D, Strmeňová S, Janík J, Mokáň M. Complications of liver resection in geriatric patients. *Ann Hepatol.* 2017;16(1):149-56.
 7. Tao Y, Wang M, Chen E, Tang H. Liver Regeneration: Analysis of the Main Relevant Signaling Molecules. *Mediators Inflamm.* 2017;4256352.
 8. Lodewick TM, Alizai PH, van Dam RM, Roeth AAJ, Schmeding M, Heidenhain C, et al. Effect of Age on Liver Function in Patients Undergoing Partial Hepatectomy. *Dig Surg.* 2017;34(3):233-40.
 9. Yagi S, Hirata M, Miyachi Y, Uemoto S. Liver Regeneration after Hepatectomy and Partial Liver Transplantation. *Int J Mol Sci.* 2020;21:8414.
 10. Li M, Chu Z, Tan Z, Jin Y, Xu M, Ji Q. Impact of donor age on liver regeneration and function following adult living donor liver transplantation. *Exp Ther Med.* 2019;17(5):3965-70.
 11. Gong WF, Zhong JH, Lu Z, Zhang QM, Zhang ZY, Chen CZ, et al. Evaluation of liver regeneration and post-hepatectomy liver failure after hemihepatectomy in patients with hepatocellular carcinoma. *Biosci Rep.* 2019;39:BSR20190088.
 12. Guo H, Wu T, Lu Q, Dong J, Ren YF, Nan KJ, Lv Y, Zhang XF. Hepatocellular carcinoma in elderly: Clinical characteristics, treatments and outcomes compared with younger adults. *PLoS One.* 2017;12(9):e0184160.
 13. Brunot A, Le Sourd S, Pracht M, Edeline J. Hepatocellular carcinoma in elderly patients: challenges and solutions. *J Hepatocell Carcinoma.* 2016;3:9-18.
 14. Kulik L, El-Serag HB. Epidemiology and Management of Hepatocellular Carcinoma. *Gastroenterology.* 2019;156:477-91.
 15. Tu T, Bühler S, Bartenschlager R. Chronic viral hepatitis and its association with liver cancer. *Biol Chem.* 2017;398:817-37.
 16. Mikulic D, Mrzljak A. Liver transplantation and aging. *World J. Transplant.* 2020;10:256-66.
 17. Gómez Gavara C, Esposito F, Gurusamy K, Salloum C, Lahat E, Feray C, Lim C, Azoulay D. Liver transplantation in elderly patients: a systematic review and first meta-analysis. *HPB (Oxford).* 2019;21(1):14-25.
 18. Panayotova G, Lunsford KE, Latt NL, Paterno F, Guarrera JV, Pyrsopoulos N. Expanding indications for liver transplantation in the era of liver transplant oncology. *World J Gastrointest Surg.* 2021;13(5):392-405.
 19. Kow AWC. Transplantation versus liver resection in patients with hepatocellular carcinoma. *Transl Gastroenterol Hepatol.* 2019;4:33.
 20. van Tuil T, Dhaif AA, te Riele WW, van Ramshorst B, van Santvoort HC. Systematic Review and Meta-Analysis of Liver Resection for Colorectal Metastases in Elderly Patients. *Dig Surg.* 2019;36:111-23.
 21. Ali MM, El-Badry AM. Influence of combined mechanical-chemical versus mechanical bowel preparation on anastomotic leak and surgical site infections after elective resection of left colon cancer. *Int Surg J.* 2020;7:3192-7.
 22. Nachmany I, Pencovich N, Zohar N, Goykhman Y, Lubezky N, Nakache R, Klausner JM. Resection of colorectal liver metastases in the elderly-Is it justified? *J Surg Oncol.* 2016;113(5):485-8.
 23. Jin KM, Wang K, Bao Q, Wang HW, Xing BC. Liver resection for colorectal liver-limited metastases in elderly patients: a propensity score matching analysis. *World J Surg Oncol.* 2020;18:275.
 24. Feng JW, Qu Z, Wu BQ, Sun DL, Jiang Y. The preoperative fibrosis score 4 predicts posthepatectomy liver failure in patients with hepatocellular carcinoma. *Ann Hepatol.* 2019;18:701-7.
 25. Meyer J, Balaphas A, Combescure C, Morel P, Gonelle-Gispert C, Bühler L. Systematic review and meta-analysis of thrombocytopenia as a predictor of post-hepatectomy liver failure. *HPB (Oxford).* 2019;21(11):1419-26.
 26. Riediger C, Bachmann J, Hapfelmeier A, Friess H, Kleeff J, Mueller MW. Low postoperative platelet count is associated with negative outcome after liver resection for hepatocellular carcinoma. *Hepatogastroenterology.* 2014;61(133):1313-20.
 27. Takahashi K, Kurokawa T, Oshiro Y, Fukunaga K, Sakashita S, Ohkohchi N. Postoperative Decrease in Platelet Counts Is Associated with Delayed Liver Function Recovery and Complications after Partial Hepatectomy. *Tohoku J Exp Med.* 2016;239(1):47-55.
 28. Ocak I, Topaloğlu S, Acarli K. Posthepatectomy liver failure. *Turk J Med Sci.* 2020;50:1491-503.
 29. Rahnama-Azar AA, Cloyd JM, Weber SM, Dillhoff M, Schmidt C, Winslow ER, Pawlik TM. Update on Liver Failure Following Hepatic Resection: Strategies for Prediction and Avoidance of Post-operative Liver Insufficiency. *J Clin Transl Hepatol.* 2018;6(1):97-104.
 30. Balzan S, Belghiti J, Farges O, Ogata S, Sauvanet A, Delefosse D, Durand F. The "50-50 criteria" on postoperative day 5: an accurate predictor of liver failure and death after hepatectomy. *Ann Surg.* 2005;242(6):824-8.

31. Wang HQ, Yang J, Yang JY, Wang WT, Yan LN. Low immediate postoperative platelet count is associated with hepatic insufficiency after hepatectomy. *World J Gastroenterol.* 2014;20:11871-7.
32. Sigal SH, Sherman Z, Jesudian A. Clinical Implications of Thrombocytopenia for the Cirrhotic Patient. *Hepatic Med Evid Res.* 2020;12:49-60.
33. Pearce N. Analysis of matched case-control studies. *BMJ.* 2016;352:969.
34. Setia MS. Methodology Series Module 2: Case-control Studies. *Indian J Dermatol.* 2016;61:146-51.
35. Tenny S, Kerndt CC, Hoffman MR. Case Control Studies. StatPearls Publishing, 2021.

Cite this article as: El-Badry AM, Aldardeer AA. Clinical outcome of hepatic resection for malignant liver tumors in elderly patients. *Int Surg J* 2021;8:2525-32.