

Changes in hepatic blood flow after splenectomy and pericardial devascularization

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Abstract

Objective To analyze hemodynamic changes in the portal vein and hepatic artery after splenectomy and pericardial devascularization.

Methods A total of 132 patients with portal hypertension who underwent splenectomy and pericardial devascularization in Beijing You'an Hospital from June 2014 to June 2017 were selected. Hemodynamic changes in the portal vein, hepatic artery, and hepatic elasticity were recorded before and at 1, 3, 6, 12, 24, and 36 months after the operation, and the characteristics of hepatic blood flow before and after surgery were analyzed.

Results Among the 132 patients, there were 89 men and 43 women aged 27–74 years, with a mean $\pm$ standard deviation) age of 48.6 ± 10.6 years. Liver stiffness at 1, 3, 6, 12, 24, and 36 months after surgery was significantly lower than that preoperatively (all $P < 0.05$). Additionally, portal vein flow and velocity at 1, 3, 6, 12, and 24 months after surgery were significantly lower than those preoperatively (all $P < 0.05$). Liver stiffness was positively correlated with portal vein flow and velocity. Hepatic artery flow at 1 month after surgery was significantly higher than that preoperatively ($P < 0.05$).

Conclusions After splenectomy and pericardial devascularization, short-term and long-term liver stiffness, portal vein flow, and mean velocity are lower than those preoperatively. Liver stiffness is positively correlated with portal vein flow and mean velocity. Splenectomy and pericardial devascularization may partially reverse liver cirrhosis and improve liver function.

Keywords: liver cirrhosis, splenectomy, pericardial devascularization, hemodynamics, portal vein flow

Introduction

Splenectomy with pericardial devascularization is an

effective and commonly used clinical treatment

for esophagogastric variceal rupture and bleeding

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caused by portal hypertension due to liver cirrhosis [1]. This approach can improve hematemesis and melena caused by rupture of the gastric fundus and esophageal varices, and reduce the probability of postoperative rebleeding [2–3]. In recent years, studies have reported the nutritional status [4] and changes in esophagogastric varices [5] of patients after splenectomy with pericardial devascularization.

This study aimed to determine the changes in liver elasticity and hepatic hemodynamics between before and at different time points after surgery with long-term follow-up.

Subjects and Methods

Patients

From June 2014 to June 2017, 132 patients with portal hypertension who underwent splenectomy with pericardial devascularization at Beijing You'an Hospital, Capital Medical University, were selected. The inclusion criteria were as follows: (1) patients with liver cirrhosis caused by various etiologies; (2) those who underwent splenectomy with pericardial devascularization; and (3) those with a history of upper gastrointestinal bleeding or endoscopic evidence of severe esophagogastric varices. The exclusion criteria were as follows: (1) combined cardiac, pulmonary, renal, or other vital organ dysfunction; (2) concomitant Budd–Chiari syndrome or cavernous transformation of the portal vein; (3) severe mental disorder; (4) combined with a malignant tumor; and (5) lost to follow-up or incomplete data.

Surgical procedure

Selective splenectomy combined with portal–systemic disconnection was performed. After ligation of the

splenic artery, the splenocolic, splenophrenic, and splenogastric ligaments were separated to expose the splenic hilum. The splenic vessels were separated from the pancreatic tail by finger dissection, and the upper and lower polar vessels were divided before removing the spleen. Along the lesser curvature, the gastric branches of the left gastric vein and the accompanying gastric branches of the left gastric artery were ligated and divided up to the cardia, preserving the main trunk of the left gastric vein. Using an ultrasonic scalpel, the esophageal branches, high-position branches, and ectopic high-risk branches of the left gastric vein were divided, and the communicating veins of the esophagus within 6–8 cm above the cardia were completely disconnected. This procedure completed the selective portal–systemic disconnection. Portal venous pressure was measured through the right gastroepiploic vein before splenectomy, after splenectomy, and after devascularization.

Postoperative anticoagulant therapy

A triple-drug regimen of warfarin, low-molecular-weight heparin, and aspirin was used. Low-molecular-weight heparin was initiated 24–48 h after surgery, with a volume of 0.3 mL every 12 h subcutaneously for 5–10 days. Warfarin was initiated 72 h after surgery, with a dose of 1.25–2.5 mg once daily orally. Aspirin was initiated 72 h after surgery, with a dose of 100 mg once daily orally. When the platelet count exceeded $300 \times 10^9/L$, ticlopidine 0.25 g once daily orally was added until platelets returned to normal levels.

Thrombolytic therapy for portal vein thrombosis

Low-molecular-weight heparin (0.6 mL) was administered every 12 h subcutaneously for 10–14 days. Urokinase 200,000 U was also administered over 30

min by continuous intravenous infusion, followed by a maintenance dose of 30,000–50,000 U/h for 3–5 days.

Hepatic transient elastography and Doppler ultrasound

Liver elasticity and hepatic blood flow were measured before surgery and at 1, 3, 6, 12, 24, and 36 months after surgery. Hepatic hemodynamic parameters that were measured included the diameter, velocity, and flow volume of the portal vein and hepatic artery.

Observation indices

General data, including sex, age, and medical history, were collected. Additionally, we collected clinical data, including routine blood test results, the coagulation profile, hepatic and portal venous blood flow by ultrasound, and liver elasticity.

Follow-up

The patients were followed for 5–66 months, with a mean follow-up of 36 months. Follow-up ended in December 2022. Within 3 months after surgery, blood tests, the coagulation profile, hepatic and portal venous ultrasound, and liver elasticity were performed every 2–4 weeks. From 3 to 6 months postoperatively, these parameters were measured every 1–3 months, and after 6 months, they were measured every 6 months. If upper gastrointestinal bleeding recurred, endoscopy was performed to confirm variceal rupture, and sclerotherapy or band ligation was performed. Endoscopy was repeated every 6–12 months.

Statistical analysis

SPSS 20.0 software was used for statistical analysis. Measurement data that conformed to a normal distribution are expressed as the mean $\pm$ standard deviation (mean $\pm$

s), and comparisons between pre- and postoperative data were made using paired-sample *t*-tests. Measurement data that did not conform to a normal distribution are expressed as the median (P_{25} , P_{75}), and comparisons were made using the Wilcoxon signed-rank test. A *P* value < 0.05 was considered statistically significant.

Results

General characteristics

Among the 132 patients, 89 were men and 43 were women aged 27–74 years, with a mean age of 48.6 ± 10.6 years. There were 85 cases of hepatitis B cirrhosis, 8 cases of hepatitis C cirrhosis, 19 cases of alcoholic cirrhosis, 7 cases of primary biliary cholangitis, and 3 cases of autoimmune cirrhosis. According to the Child–Pugh classification, 84 cases were grade A, 43 cases were grade B, and 5 cases were grade C.

Comparison of liver elasticity before and after surgery

Liver elasticity was significantly lower at 1, 3, 6, 12, 24, and 36 months after surgery than before surgery (all $P < 0.05$) (Table 1).

Comparison of portal venous flow and velocity and hepatic arterial flow before and after surgery

Portal venous flow at 1, 3, 6, 12, 24, and 36 months after surgery was significantly lower than that before surgery (paired *t*-test, all $P < 0.05$) (Table 2). Mean portal venous flow velocity was significantly lower at 1, 3, 6, 12, and 24 months after surgery than before surgery (paired *t*-test, all $P < 0.05$) (Table 3). Hepatic arterial flow at 1 month after surgery was significantly higher than that before surgery (paired *t*-test, all $P < 0.05$) (Table 4).

Table 1. Comparison of liver elasticity before and after surgery.

Time point	Paired cases (n)	Preoperative (kPa)	Postoperative (kPa)	Z value	P value
1 month after surgery	68	17.6 (12.4–27.7)	16.1 (10.6–24.0)	−3.733	< 0.001
3 months after surgery	59	17.6 (12.2–26.3)	14.6 (10.2–19.1)	−4.044	< 0.001
6 months after surgery	43	18.4 (12.4–27.0)	13.0 (9.1–17.8)	−4.317	< 0.001
12 months after surgery	48	17.7 (12.3–25.9)	11.9 (9.3–18.6)	−5.000	< 0.001
24 months after surgery	19	20.5 (13.4–28.4)	11.5 (8.4–15.1)	−3.284	< 0.001
36 months after surgery	11	22.0 (13.4–35.8)	10.0 (8.7–17.3)	−2.134	0.033

Data are n or the median (P_{25} , P_{75}).

Table 2. Comparison of portal venous flow before and after surgery.

Time point	Paired cases (n)	Preoperative (mL/min)	Postoperative (mL/min)	Z value	P value
1 month after surgery	59	1,458.0 (993.0–1,999.0)	883.5 (727.0–1,166.8)	−5.914	< 0.001
3 months after surgery	45	1,539.0 (990.5–1,895.0)	958.0 (745.0–1,281.0)	−4.509	< 0.001
6 months after surgery	47	1,467.0 (993.0–1,890.0)	898.0 (652.0–1,320.0)	−4.714	< 0.001
12 months after surgery	38	1,516.0 (1,005.7–1,882.5)	821.0 (618.5–1,148.5)	−5.127	< 0.001
24 months after surgery	19	1,458.0 (976.0–1,810.0)	1,094.7 (955.3–1,237.4)	−3.040	0.002
36 months after surgery	11	1,055.0 (950.0–1,566.0)	813.0 (674.0–1,109.0)	−2.067	0.042

Data are n or the median (P_{25} , P_{75}).

Table 3. Comparison of mean portal venous flow velocity before and after surgery.

Time point	Paired cases (n)	Preoperative (cm/s)	Postoperative (cm/s)	t value	P value
1 month after surgery	61	19.28 ± 3.55	13.32 ± 3.50	6.187	< 0.001
3 months after surgery	47	17.95 ± 4.59	14.45 ± 4.92	3.778	< 0.001
6 months after surgery	47	18.20 ± 4.47	14.85 ± 4.53	3.225	0.002
12 months after surgery	43	18.67 ± 4.88	14.57 ± 4.15	4.198	< 0.001
24 months after surgery	19	19.13 ± 4.06	14.15 ± 3.23	2.728	0.014
36 months after surgery	11	20.13 ± 6.03	14.75 ± 4.59	1.874	0.090

Data are n or the mean ± standard deviation.

Table 4. Comparison of hepatic arterial flow before and after surgery.

Time point	Paired cases (n)	Preoperative (mL/min)	Postoperative (mL/min)	t value	P value
1 month after surgery	62	101.56 ± 12.89	164.54 ± 20.89	−2.550	0.013
3 months after surgery	47	225.44 ± 24.08	201.77 ± 22.50	1.326	0.191
6 months after surgery	49	216.46 ± 27.12	242.09 ± 17.83	−1.150	0.253
12 months after surgery	38	203.63 ± 46.69	202.08 ± 36.08	0.085	0.933
24 months after surgery	19	197.78 ± 26.05	236.58 ± 36.31	−1.062	0.302
36 months after surgery	10	246.80 ± 17.04	229.00 ± 17.12	0.432	0.676

Data are n or the mean ± standard deviation.

Discussion

According to relevant domestic and international guidelines, the preferred treatment for gastrointestinal bleeding caused by portal hypertension is endoscopic hemostasis or a transjugular intrahepatic portosystemic shunt [6]. Endoscopic treatment

is ineffective for acute bleeding, and refractory re-bleeding often requires multiple repeated endoscopic interventions. A transjugular intrahepatic portosystemic shunt is suitable for acute bleeding cases but is prone to causing hepatic encephalopathy and may create difficulties for subsequent liver transplantation. Splenectomy with pericardial devascu-

larization can effectively control acute bleeding and achieve good survival outcomes [7]. Therefore, splenectomy with pericardial devascularization remains one of the main treatment methods for esophago-gastric variceal bleeding due to portal hypertension in China [8].

Splenectomy with pericardial devascularization can greatly improve the degree of esophageal and gastric varices [9], and it has also been found to improve the nutritional status [4]. In this study, long-term follow-up was conducted to observe the short- and long-term changes in liver elasticity and hemodynamic characteristics of the liver after surgery.

The improvement of hepatic fibrosis after splenectomy with pericardial devascularization has been the focus of some studies. Studies have shown that serum fibrosis markers decrease within a short period after splenic devascularization, and liver stiffness also decreases. One study of 39 patients with cirrhosis who underwent splenectomy with pericardial devascularization evaluated serum fibrosis markers [10]. This previous study showed that postoperative laminin, type IV collagen, hyaluronic acid, and type III procollagen N-terminal peptide levels were significantly lower after surgery than before surgery. Additionally, liver stiffness at 1 month after surgery was lower than that before surgery. These findings suggest that these four hepatic fibrosis markers and liver stiffness show characteristic short-term decreases after surgery, which may be related to the transient activation of fibrosis degradation. These results are consistent with those in the present study. Moreover, this change persisted beyond 6 months in our study because follow-up for up to 36 months after surgery showed that liver stiffness remained lower than that preoperatively. This finding indicated that the change in liver stiffness was not temporary but continuous.

By observing hepatic hemodynamics after splenectomy with pericardial devascularization, this study showed that hepatic arterial flow significantly increased only within 1 month after surgery, and returned to the preoperative level after 3 months. This change was inconsistent with the change in liver stiffness, which suggested that hepatic arterial flow had little effect on postoperative liver stiffness. However, portal venous flow and mean velocity were significantly lower in the short and long term after surgery than preoperatively. These changes were consistent with the trend in liver stiffness, which indicated that portal venous flow and mean velocity were associated with liver stiffness. Previous studies using Doppler ultrasonography and transient elastography to observe the relationship between portal venous hemodynamics and liver stiffness in patients with cirrhosis and portal hypertension showed that portal venous flow, mean velocity, and liver stiffness were higher than those in healthy individuals [11]. Additionally, liver stiffness was positively correlated with portal venous flow and mean velocity. These results are consistent with those in the present study, which also showed significant differences between preoperative and postoperative portal venous flow, mean velocity, and liver stiffness at 2–3 years after surgery.

Conclusion

In conclusion, short- and long-term liver stiffness, portal venous flow, and mean velocity after splenectomy with pericardial devascularization are lower than those before surgery, which may partially reverse liver cirrhosis and improve liver function.

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Author contributions

Xiaofei Zhao and Zizhao Zhu contributed to the conceptualization, data collection, and manuscript drafting. Pu He and Liang Di performed data analysis and prepared the figures. Guangming Li participated in methodology design and data interpretation. Daobing Zeng supervised the project, contributed to manuscript revision, and is the corresponding author. All authors read and approved the final manuscript.

Conflicts of Interest

All authors declare no conflicts of interest.

References

- [1] Qi WL, Wen J, Wen TF, Peng W, Zhang XY, Shen JY, et al. Prognosis after splenectomy plus pericardial devascularization vs transjugular intrahepatic portosystemic shunt for esophagogastric variceal bleeding. *World J Gastrointest Surg.* 2023 (15):1641–1651.
- [2] Wang D, Chen X, Lv L, Yang T, Huang B, Cao Y, et al. The learning curve of laparoscopic splenectomy and esophagogastric devascularization for portal hypertension with 10-year follow-up. *Surg Endosc.* 2024 (38):5228–5238.
- [3] Wang Z, Zhang Z, Guo X, Xu W, Wei N, Zhang Q, et al. Efficacy, feasibility and safety of TIPS in the treatment of recurrent portal hypertension with variceal bleeding after open splenectomy and esophagogastric devascularization. *Abdom Radiol (NY).* 2025 (50):393–399.
- [4] Zeng DB, Di L, Zhang RC, Guo QL, Duan BW, Jia CY, et al. The effect of splenectomy on the reversal of cirrhosis: a prospective study. *Gastroenterol Res Pract.* 2019 (2019):5459427.
- [5] Ding YH, Zhang HY, Guo H, Shen H. Application effect of nursing based on Rockall score-guided detailed planning in patients with decompensated cirrhosis and acute upper gastrointestinal bleeding. *Beijing Med J.* 2023 (45):458–460. In Chinese.
- [6] Zhang QK, Zhang Z, Ma C, Zhang HT, Li GM, Wang ML. Clinical efficacy and surgical approach study of laparoscopic splenectomy and devascularization for portal hypertension with gastrointestinal bleeding. *Beijing Med J.* 2022 (44):499–504. In Chinese.
- [7] Chen B, Wang J, Sheng W, Ma B, Xu P, Cheng X, et al. Prognosis of laparoscopic splenectomy and pericardial devascularization versus TIPS for the treatment of esophagogastric variceal bleeding in cirrhosis. *Surg Endosc.* 2024 (38):2106–2115.
- [8] Cao R, Lu X, Wu Y, Li S, Gong J. Laparoscopic splenectomy and esophagogastric devascularization versus endoscopic variceal ligation plus laparoscopic splenectomy in the treatment of portal hypertension. *J Laparoendosc Adv Surg Tech A.* 2023 (33):1052–1057.
- [9] Zeng DB, Di L, Ding J, Duan BW, Guo QL, Lin DD, et al. Efficacy of devascularization for esophagogastric varices caused by portal hypertension due to liver cirrhosis. *Chin J Hepatobiliary Surg (Electronic Edition).* 2019 (8):306–310. In Chinese.
- [10] Kong D, Chen X, Lu S, Guo Q, Lai W, Wu J, et al. Short-term effects of splenectomy on serum fibrosis indexes in liver cirrhosis patients. *Int J Clin Exp Pathol.* 2015 (8):15260–15264.
- [11] Cheng XF, Liang XB, Xiong XQ, Tang YL, Chen P. Correlation analysis between portal venous pressure and FibroScan measurements in patients with cirrhosis and portal hypertension. *J Clin Hepatobiliary Dis.* 2015 (31):381–383. In Chinese.