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Dynamic Indicators of Perfusion Computer Tomography at Cirrhosis of the Liver with Portal Hypertension in the Assessment Efficiency of Portosystem Bypass System

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Abstract--*The article presents an analysis of perfusion computed tomography indicators in patients with cirrhosis of the liver, who have performed various options for portosystemic shunting to prevent the development of bleeding from varicose veins of the esophagus and stomach. The main objective of the study was to evaluate the effectiveness of decompression during shunting and its effect on liver perfusion parameters. The analysis included 27 patients with cirrhosis of the liver (LC) who underwent portosystemic shunting. The mean age of the patients was 39.0 ± 2.9 years. All patients had a history of one to three episodes of esophageal-gastric hemorrhage. Studies have proved the high information content of perfusion computed tomography in the verification of two interrelated types of changes characteristic of this type of decompression operations: a decrease in the portal fraction (PF) of liver perfusion from 144.6 ± 2.1 to 128.4 ± 2.2 ml / 100 ml / min (p <0.001) with stimulation of compensatory reserves with an increase in arterial inflow (AF) from 40.2 ± 0.9 to 47.3 ± 0.9 ml / 100ml / min (p <0.001) and, accordingly, a significant increase in the value of the portal index (PI) from 22.2 ± 0.4 to 27.9 ± 0.6% (p <0.001), providing in the immediate postoperative period or improving the functional status of the stable state of hepatocytes by MELD scale.*

Keywords--*perfusion computed tomography, liver cirrhosis, portal hypertension, portosystemic shunting.*

I. INTRODUCTION

One of the options for surgical prophylaxis of bleeding from varicose veins of the esophagus and stomach (VVES) in patients with portal hypertension (PH) is portosystemic shunting (PSS) [1]. Unlike endoscopic techniques aimed at the direct elimination of varicose veins (ligation, sclerotherapy) or traditional uncoupling gastroesophageal collector operations, which are characterized by interruption of the venous outflow towards the cardia of the stomach, PSS refers to interventions with a decompressive effect - reduction of portal pressure due to the creation of anastomosis between the portal basin (with high portal pressure) and the inferior vena cava system (with normal venous pressure) [2]. Among the entire spectrum of interventions for the prevention of bleeding from VVES, it is PSS, by the use of certain recommendations, that gives the most reliable and long-term result [3]. This factor is especially important for surgical schools where a radical program for the treatment of cirrhosis of the liver (LC) is absent or is at the developmental stage — liver transplantation, which is caused by a high mortality rate due to esophageal-gastric bleeding.

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Considering the fact that MSCT is an effective method for assessing the features of the angioarchitectonics of the portal pool and the state of liver perfusion with verification of the indicators of fractions of the intrahepatic blood flow (arterial - AF and portal - PF), as well as their ratio (PI), it is interesting to analyze the dynamics of these parameters in patients with LC before and after PSS [4-8]. It should be noted that such an analysis has not yet been carried out in the world; accordingly, this study will not only further substantiate the effectiveness of one of the latest techniques in assessing the severity of the cirrhotic process - MSCT-perfusion of the liver, but also determine specific criteria for identifying the quality of decompression in PSS and its effect on intrahepatic hemodynamics.

The aim of the study: to determine the effect of decompression of the portal system in PSS in patients with LC on intrahepatic blood flow according to perfusion computed tomography.

II. MATERIALS AND RESEARCH METHODS

The study included 27 patients with LC who, for 2018-2019, performed various variants of PSS for the prevention of recurrence of bleeding from VVES. The average age of the patients was 39.0 ± 2.9 years, men were 15 (55.6%), women - 12 (44.4%). All patients had a history of one to three episodes of esophageal-gastric hemorrhage.

The etiological factor of LC was viral hepatitis "B" in 25 and "C" in 2 patients. According to standardized recommendations for PSS, all patients at the time of surgery according to the criteria of Child-Pugh (1973) were assigned to functional classes A (16 patients) and B (11 patients).

Among the PSS variants, distal splenorenal anastomosis was performed in 19 (70.4%) patients, splenosuprarenal anastomosis in 6 (22.2%) and lateral-lateral shunt in 2 (7.4%) patients.

Evaluation of perfusion parameters was carried out on a wide-detector computer tomograph "Aquilion One - 640" version GENESIS (Canon Medical Systems, Japan). The studies were carried out before surgery and after PSS at the time of discharge of patients from the hospital (on days 8-11). The analysis included the determination of liver perfusion parameters and the features of angioarchitectonics of the vessels of the portal basin. The features of perfusion in LC before and after PSS were studied taking into account the dynamic assessment of arterial fraction (AF), portal fraction (PF) and portal index (PI). Since this study is new, and according to limited literature there is a significant scatter even of normative indicators of intrahepatic blood flow fractions, to improve the quality of analysis in each patient, these parameters were studied in all anatomical segments of the liver - at 8 points. That is, for 21 patients, 216 indicators of AF (ml / 100ml / min), PF (ml / 100ml / min) and PI (%) were obtained. In turn, the study of angioarchitectonics of the vessels of the portal basin before and after PSS included determination of the diameters (mm) of v. Portae, v. lienalis, and A. Hepatica, estimation of the volume of the spleen (ml). After PSS, also according to MSCT splenoportography, the anastomosis zone of v. lienalis with v. Renalis sinistra, patency of the shunt, the presence of additional inclusions in the lumen of the veins were verified. Also, to analyze the nature of changes in perfusion indicators relative to standard values, the study included a group of healthy individuals - 24 people, with an average age of 37.8 ± 1.7 years, 12 men and women - 12 (44.4%). All statistically processed data included for each indicator the determination of the value (M), standard deviation (σ), and the average error of the

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arithmetic mean (m). The text material shows the mean and error (M ± m). Reliability calculation was carried out according to the determination of t-criteria by Styudent.

III. THE RESULTS OF THE STUDY.

First of all, we present the dynamics of indicators of MSCT perfusion of the liver. According to all the criteria studied, the perfusion values before and after PSS were significantly different from those in healthy individuals. In the background of a decrease in the portal fraction (PF) to 144.6 ± 2.1 ml / 100 ml / min with standard values of 154.9 ± 1.9 ml / 100 ml / min ($p < 0.01$), a compensatory increase in the arterial fraction was noted (AF) - from 34.4 ± 0.9 with a norm of up to 40.2 ± 0.9 ml / 100ml / min in patients with LC to PSS ($p < 0.001$). Accordingly, the value of the portal index (PI) also significantly changed with its growth due to an increase in arterial and a decrease in the portal fraction - from 18.2 ± 0.3 to 22.2 ± 0.4% ($p < 0.001$), respectively. Perfusion indexes after PSS differed with an even more pronounced significant difference from the normative values for all these criteria (Table 1).

Table 1 Liver's perfusion indexes before and after PSS

Pathology	AF			PF			PI		
	Perfusion Index	**σ**	**m**	**Perfusion Index**	**σ**	**m**	**Perfusion Index**	**σ**	**m**
Normal	34,4	11,9	0,9	154,9	26,2	1,9	18,2	4,2	0,3
Before surgery	40,2	13,6	0,9	144,6	30,4	2,1	22,2	6,4	0,4
Norm t-criteria	4,64 (p<0,001)			3,67 (p<0,01)			7,49 (p<0,001)		
After surgery	47,3	13,1	0,9	128,4	32,2	2,2	27,9	8,5	0,6
Norm t-criteria	10,44 (p<0,001)			9,17 (p<0,001)			14,73 (p<0,001)		
Pre-surgery t-Criteria	5,50 (p<0,001)			5,39 (p<0,001)			7,81 (p<0,001)		

The analysis of data on the effect of PSS on liver perfusion indices showed the high efficiency of the MSCT technique in determining the features of intrahepatic hemodynamics in LC. The formation of an artificial outflow of portal blood in PSS is aimed specifically at reducing high portal pressure due to the redistribution of part of the portal blood flow to the system of the inferior vena cava (anastomosis between the splenic and left renal veins). According to the decompressive effect of these operations, the volume of hepatopoietic blood flow decreases, which was reflected in a significant decrease in the portal fraction (PF) from 144.6 ± 2.1 to 128.4 ± 2.2 ml / 100 ml / min ($p < 0.001$). A positive feature of such decompression is a reduction in the risk of bleeding from VVES, however, on the other hand, a factor in reducing the volume of intrahepatic perfusion should affect the functional status of hepatocytes, namely, worsen these indicators. With this in mind, another positive effect of PSS should be noted. Due to the significant portal decompression and a sharp decrease in this fraction of hepatic blood flow, the compensatory

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mechanism for maintaining hepatoperfusion is maximally activated - redistribution of arterial blood circulation towards the liver. The preservation of such reserve capabilities is justified by the fact that PSS, being a complex surgical intervention, is performed only for patients with LC in the background of absent signs of decompensation of the main pathological process. Accordingly, surgical decompression of the portal system stimulates the launch of a compensatory increase in arterial blood flow. Thus, according to MSCT perfusion of the liver, the arterial fraction (AF) after PSS (on average for 10 days) increased from 40.2 ± 0.9 to 47.3 ± 0.9 ml / 100ml / min ($p < 0.001$). These changes in the volume of portal and arterial blood were reflected in a significant increase in the value of the portal index (PI) from 22.2 ± 0.4 to 27.9 ± 0.6% ($p < 0.001$). If we talk about relative indicators, the arterial fraction grew on average by 17.6%, the portal fraction decreased by 11.2%, and the portal index increased by 25.6%

One more positive fact in terms of redistribution of arterial blood should be noted. In the previous chapter, it was proved that the gradual progression of the intrahepatic block leads to an increase in the arterial fraction, but the diameter of the hepatic artery did not play a significant role, since these indicators were practically the same with a vessel diameter of up to and more than 4.5 mm. In turn, PSS due to rapid portal decompression contributed to the growth of the arterial fraction of hepatic perfusion with a parallel significant expansion of A. Hepatica with the same level of growth as the AF value - 17.6% (from 4.8 ± 0.2 to 5, 7 ± 0.2 mm; $p < 0.05$) (Table 2). An effective decompressive effect of PSS is proved by data on the dynamics of the diameter of the vessels of the portal system and the volume of the spleen. So, before surgery, the average volume of the spleen was 1646.3 ± 111.4 ml, and after PSS by the time of the second MSCT study (on average for 10 days) it decreased to 1309.9 ± 100.9 ml ($p < 0.01$) The diameter of v.portae also significantly decreased (from 16.4 ± 0.6 to 13.8 ± 0.5; $p < 0.05$), as well as the width of v.lienalis (from 15.7 ± 0.6 to 13, 5 ± 0.6; $p < 0.05$).

Table 2 Average diameter of vessels and spleen volume before and after PSS

Perfusion Index		**Norm**	**Before surgery**	**After surgery**	**t (PSS)**	**p**
Volume of the spleen (ml)	value	216,0	1646,3	1309,9	2,24	<0,05
	σ	85,6	557,2	462,2		
	m	17,5	111,4	100,9		
Diameter of v.portae (mm)	value	12,3	16,4	13,8	3,23	<0,01
	σ	1,1	3,0	2,3		
	m	0,2	0,6	0,5		
Diameter of v.lienalis (mm)	value	7,1	15,7	13,5	2,50	<0,05
	σ	1,1	3,0	2,8		
	m	0,2	0,6	0,6		
Diameter of a.Hepatica (mm)	value	4,3	4,8	5,7	-2,69	<0,05
	σ	0,6	1,0	1,1		
	m	0,1	0,2	0,2		

On average, already in the early post-shunt period, due to the decompressive effect of PSS the volume of the spleen decreased by 20.4%, the diameter of the portal vein decreased by 15.6%, and the splenic vein by 14.1%, while, as mentioned above, the diameter a .Hepatica increased by 17.6%

All this convincingly testifies to the good decompressive effect of the PSS and the high methodological effectiveness of MSCT for assessing dynamic data on hemodynamic reconstruction and the features of

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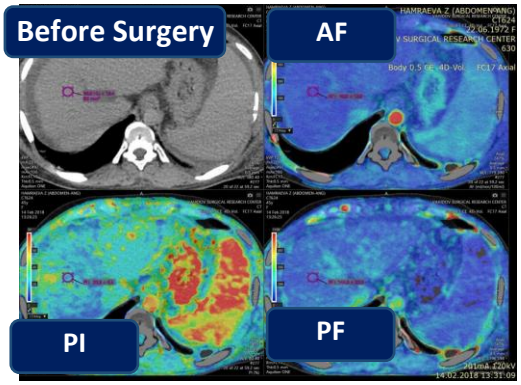
angioarchitectonics of the portal basin. In order to fully assess the significance of hemodynamic restructuring in the presence of PSS, we additionally evaluated the functional status of the liver before and after surgery on the MELD scale (Model for End-Stage Liver Disease - model of the final stage of liver disease).

On the 1-2 days after PSS, due to the factor of complicated surgical intervention, the MELD indicator increased slightly from 12.3 ± 0.5 to 12.5 ± 0.6 points ($p > 0.05$), but by 7-8 days in the background of standard postoperative therapy, the MELD value significantly decreased to 11.0 ± 0.3 points ($p < 0.05$). Accordingly, the hemodynamic restructuring of the portal blood flow during the PSS not only does not adversely affect the functional status of the liver, but also due to a significant increase in the arterial fraction contributes to its improvement. Of course, for patients with LC, this positive aspect of PSS cannot have a long-term prognosis, in contrast to the effect of prophylaxis of bleeding from VVES. This is due to the main pathological process - the progression of LC, and in the future for patients with persistent hepatitis, depending on its degree of activity, the development of decompensation will be inherent, with the need to consider the only option for radical treatment - liver transplantation.

Thus, the MSCT study with the determination of liver perfusion parameters and the features of the angioarchitectonics of the portal system in LC is a high-quality method for assessing the effectiveness of PSS. Unlike other methods of radiation imaging, this technique makes it possible to verify in dynamics two main interrelated types of changes characteristic of LC in patients with PSS. Evaluation of liver perfusion after surgery allows you to determine the degree of decrease in the portal fraction and the value of compensatory arterialization. At the same time, a decrease in portal perfusion in the background of an increase in the arterial fraction and, accordingly, the portal index (Fig. 1) will testify to the decompressive effect of PSS.

In turn, the analysis of MSCT angiograms before and after shunting also allows you to establish direct facts that indicate the adequate function of the superimposed shunt. In particular, this is evidenced by a decrease in the volume of the spleen, the diameter of the portal and splenic veins already in the early postoperative period. In turn, no less valuable information is a statement of the fact of thrombosis of the anastomosis.



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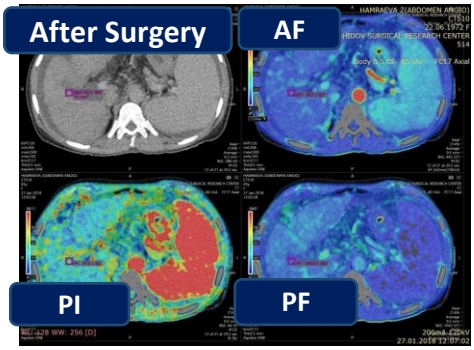
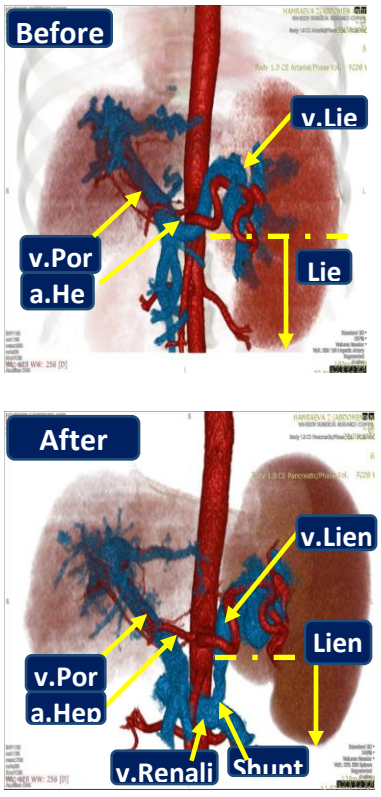


Pic.1. MSCT-perfusion of liver before and after distal the spleen-rhenal anastomosis.

Functioning bypass.

Table:3

Perfusion Index	**Before Surgery**	**After Surgery**
AF (ml/100ml/min)	40,9±12,9	45,7±9,2
PF (ml/100ml/min)	144,3±32,3	120,5±28,1
PI (%)	22,3±6,5	27,6±8,0



Pic.2. MSCT-splenoportogram before and after the spleen-rhenal anastomosis.

Functioning shunt.

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Table:4

Perfusion Index	Before Surgery	After Surgery
v.Portae (mm)	16,0	14,0
v.lienalis (mm)	14,0	13,0
a.Hepatica (mm)	4,0	5,0
Spleen Volume(ml)	1350,0	1195,0
Chamber of anastomosis (mm)	-	10,0

This type of complication of PSS is evidenced not only by the lack of visualization of the anastomotic zone with a statement of the presence of a blood clot in the lumen of the splenic vein, but also by slight changes in perfusion parameters with practically equivalent data on the volume of the portal and arterial fractions of the hepatic blood flow.

IV. THE DISCUSSION OF THE RESULTS.

Conducted studies on MSCT assessment of the effectiveness of PSS in patients with LC have proved the method to be highly informative due to the possibility of verifying in dynamics two main interrelated types of changes characteristic of this type of decompression operations. On the one hand, this is additional confirmation of the high quality of the analysis of perfusion parameters of the liver in patients with PH in the presence of intrahepatic block. Taking them into account will allow not only to assess the degree of compensation of portal and arterial blood flow, the indicators of which correlate with data on the functional status of hepatocytes, but also to determine the effect of PSS on the change in blood supply to the liver.

The following criteria testify to the decompressive effect of PSS and, accordingly, to the functional activity of the created anastomosis:

1. According to MSCT perfusion:

• a decrease in portal perfusion (PF) by an average of 11% compared to the source data;
• increase in arterial fraction (AF) by an average of 18%;
• a change in the portal index (PI) due to a decrease in the portal fraction and an increase in arterial blood flow with an average increase of 25%.

2. According to MSCT angiography:

• reduction in the size of the spleen in the early postoperative period by 10-20%;
• reduction of the diameter of the portal vein and splenic vein by 10-15%.

In turn, the following facts indicate thrombosis of the anastomosis:

1. According to MSCT perfusion:

• Absence or slight changes in portal perfusion (PF), arterial fraction (AF) and portal index (PI).

2. According to MSCT angiography:

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• lack of visualization of the anastomosis zone of the splenic and left renal veins;

• verification of the presence of a blood clot in the lumen of the splenic vein;

• lack of dynamics in changes in the volume of the spleen;

• lack of dynamics to reduce the diameter of the portal and splenic veins.

V. CONCLUSION

To conclude, PSS helps to decrease the portal fraction (PF) of liver perfusion from 144.6 ± 2.1 to 128.4 ± 2.2 ml / 100ml / min ($p < 0.001$), while the positive factor in response to venous decompression is stimulation of compensatory reserves with an increase in arterial inflow (AF) from 40.2 ± 0.9 to 47.3 ± 0.9 ml / 100ml / min ($p < 0.001$) and, accordingly, a significant increase in the value of the portal index (PI) from 22.2 ± 0.4 to 27.9 ± 0.6% ($p < 0.001$), providing in the immediate postoperative period an improvement or a stable state of the functional status of hepatocytes according to the MELD scale.

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