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The Features of Liver Perfusion in Various Hepatic Diseases and Portal Hypertension According to Data of Multidetector Computed Tomography

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Abstract Perfusion computed tomography has a great potential for determining hepatic and portal blood flow; it offers the advantages of quantitative determination of lesion hemodynamics, distinguishing malignant and benign processes. Many studies have reported the use of this method in the assessment of hepatic fibrosis and hepatic perfusion changes associated with chronic liver disease (liver cirrhosis, liver fibrosis, portal hypertension). The main goal of liver perfusion imaging is to improve the accuracy in the characterization of liver disorders. In this study, we tried to identify the features of liver perfusion in various hepatic diseases and portal hypertension according to data of multidetector computed tomography. The study included three groups: blocking the intrahepatic postsinusoidal circulation - 63 patients with cirrhosis; blocking the intrahepatic presinusoidal circulation - 10 patients with liver fibrosis; blocking the subhepatic circulation - 13 patients with extrahepatic portal hypertension. And 24 healthy people were included to analyze the nature of changes in perfusion indicators relative to normal values. The study included the determination of liver perfusion parameters such as arterial fraction, portal fraction and portal index.

Keywords Liver cirrhosis, Liver fibrosis, Portal hypertension, Perfusion CT-imaging of the liver

1. Introduction

Hemodynamics disorders in liver cirrhosis (LC) affect all the main criteria for the severity and prognosis of the pathological process. Timely identification of the development of functional and hemodynamic complications of LC affects the choice of optimal treatment tactics and, accordingly, the duration of its effectiveness. The degree of impaired intrahepatic circulation affects the functional status of hepatocytes, respectively; the state of perfusion of the liver will affect the effectiveness and long-term hepatoprotective therapy [1-3].

Decrease in liver perfusion and progression of impaired liver function leads to the development of decompensation of cirrhosis and the solution of the issue of radical treatment - liver transplantation [4,5]. The features of hemodynamic rearrangement affect the severity of portal hypertension (PH) and, accordingly, the frequency of complications such as variceal bleeding, splenomegaly and hypersplenism, the vascular component of ascites syndrome [6].

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Compensated indicators of hepatic perfusion expand the choice of surgical methods for the prevention of gastrointestinal bleeding.

The newest and most promising options for studying the features of intrahepatic hemodynamics is perfusion computed tomography (CT-perfusion). There are limited number of scientific studies in this direction, as well as the existence of controversial issues about the effectiveness of perfusion CT-imaging of the liver to verify specific criteria for assessing the LC severity and its complications [7,8].

The objective of this study was to determine the features of liver perfusion in various hepatic diseases and portal hypertension according to data of multidetector computed tomography.

2. Material and Methods

The research was conducted at the Republican Specialized Scientific-Practical Medical Center of Surgery named after academician V.Vakhidov (Tashkent, Uzbekistan). The study was conducted in 110 patients aged 18 to 67 years with various liver diseases and included three groups taking into account the level of the blocking the portal circulation:

- blocking the intrahepatic postsinusoidal circulation - 63 patients with LC,
- blocking the intrahepatic presinusoidal circulation - 10

patients with liver fibrosis (LF)
- blocking the subhepatic circulation - 13 patients with extrahepatic PH (EPH).

Also, 24 healthy people were included (fourth group) to analyze the nature of changes in perfusion indicators relative to normal values.

We used a multidetector CT "Aquilion One - 640" of the GENESIS version (Canon Medical Systems, Japan). The study included the determination of liver perfusion parameters:

- arterial fraction (AF),
- portal fraction (PF),
- portal index (PI).

These data were studied in all liver anatomical segments - at 8 points. That is, for 110 studied, 880 indicators of AF (ml/100 ml/min), PF (ml/100 ml/min) and PI (%) were obtained. The statistical data included for each indicator the determination of the average value (M), standard deviation (σ). Reliability calculation was carried out according to the definition of Student's t-test.

3. Results

The perfusion values for any variation of blocking the portal circulation were significantly different from those in healthy group, with the exception of only the AF in LF. In case of LC the PF decreased from 154.9±1.9 ml/100 ml/min (normal values) to 146.3±3.1 ml/100 ml/min ($p<0.05$). In case of EPH the PF decreased from 154.9±1.9 ml/100 ml/min (normal values) to 107,0±5.5 ml/100 ml/min ($p<0.001$). In case of LF the PF was significantly higher than the norm - 169.4±5.0 ml/100 ml/min ($p<0.01$).

Correspondingly, a decrease in portal blood flow showed a compensatory increasing in the AF - from 34.4±0.9 (the norm) to 41.4±0.7 ml/100 ml/min in patients with LC ($p<0.001$) and to 49.5±1.7 ml/100 ml/min ($p<0.001$) for EPH (table 1). The obtained values (fig. 1) of the liver perfusion fractions showed a high degree of linear relationship of the features of changes in the intrahepatic blood flow at various etiology of PH in relation to the norm.

It should be noted that with LF against the background of increased values of the PF, there was no significant increase in arterial supply (35.1±1.8 ml/100 ml/min; $p>0.05$). In turn, the average value of the PI in LF despite the increase in the PF was significantly higher than normal due to improved arterial blood flow (from 18.2±0.3 to 21.1±0.7%; $p<0.001$), which also indicates a violation of portal liver perfusion. High indices of this fraction are apparently associated with the formation of a presinusoidal block, which allows preserving the portal inflow in quantitative terms, but at the same time leads to a qualitative decrease in the properties of portal perfusion.

Depending on the block level in patients with LC an intermediate value of the PI was obtained with its increase due to an increase in arterial and decrease in the portal fraction - 23.8±0.4% ($p<0.001$). The maximum deviation of this indicator due to the most pronounced growth of the AF and the lowest portal perfusion value, was obtained in the group with EPH - 35.6±1.5% ($p<0.001$). This suggests that during the formation of the subhepatic block of portal blood flow, significant liver arterialization is the result of the early development of pathology.

There were 8 cases of EPH with an intrauterine malformation of the portal system (cavernous portal vein transformation) and 5 cases of EPH with portal vein thrombosis as the result of an early neonatal pathology (umbilical sepsis). In other words, the development and progression of PH in these cases occurred from birth. Respectively, a sharp restriction of the PF due to the partial or complete absence of portal blood flow caused a significant redistribution of liver arterial blood supply with the compensatory reserves of arterial circulation. That is why, in our study, the level of arterial perfusion in EPH reached 49.5±1.7 ml/100 ml/min, while in LC this fraction compensatory increased only to 41.4±0.7 ml/100 ml/min ($p < 0.001$ - between these groups) (fig. 2).

For illustrative examples, we showed liver perfusion indicators in patients with normal liver, LC, LF, and EPH (fig. 3-6). It should also be noted that the CT-perfusion allows to determine the features of the portal system angioarchitectonics, which is important for planning surgical treatment, including palliative surgery - portosystemic shunting or disconnecting interventions, as well as radical treatment - liver transplantation. This visualization of the liver circulation allows to clearly define the features of the portal and arterial architectonics.

4. Conclusions

The etiological factor in the development of PH affects the features of changes in liver perfusion, while blocking the presinusoidal circulation in LF leads to PF increasing with a slight change in AF and minimal increase in the PI.

In case of LC with blocking the postsinusoidal circulation, a decrease in the PF is observed, which leads to a compensatory increase in AF and a correspondingly higher increase in the PI.

In case of blocking the subhepatic circulation, the most pronounced deviations in liver perfusion are detected: the preservation of the minimum PF level; partial or complete absence of portal blood flow, the maximum compensatory stimulation of reserve capabilities of arterial supply with a significant increase in the PI (with the early development of PH).

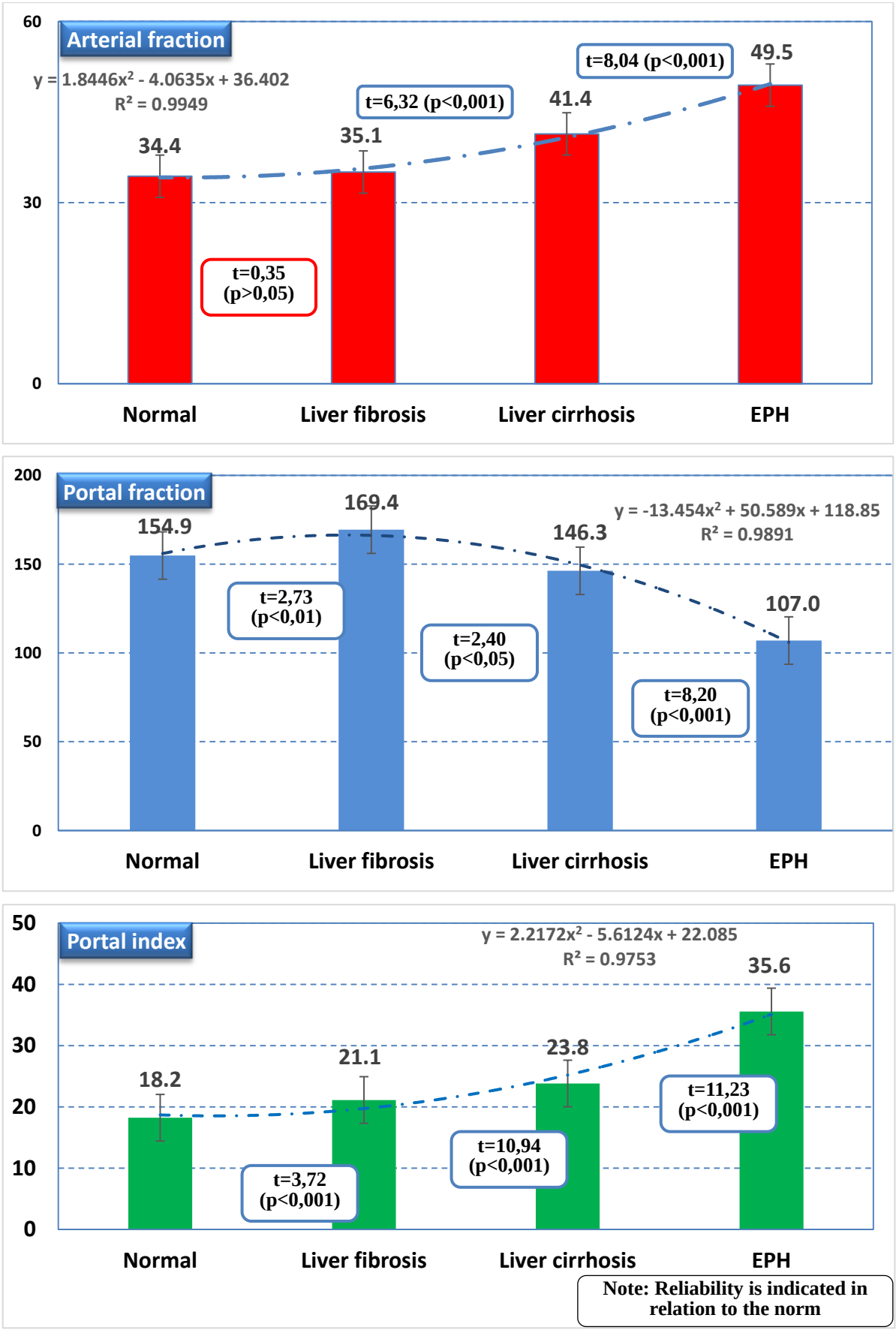


Figure 1. Indicators of perfusion CT imaging of the liver

Table 1. Indicators of perfusion CT imaging of the liver in various etiology of portal hypertension

Pathology	AF			PF			PI		
	Value	σ	m	Value	σ	m	Value	σ	m
In normal case	34,4	11,9	0,9	154,9	26,2	1,9	18,2	4,2	0,3
Liver cirrhosis	41,4	15,7	0,7	146,3	68,4	3,1	23,8	9,2	0,4
T-criterion	6,32 (p<0,001)			2,40 (p<0,05)			10,94 (p<0,001)		
Liver fibrosis	35,1	15,1	1,8	169,4	42,2	5,0	21,1	6,1	0,7
T-criterion normal	0,35 (p>0,05)			2,73 (p<0,01)			3,72 (p<0,001)		
T-criterion to LC	3,29 (p<0,01)			3,97 (p<0,001)			3,25 (p<0,01)		
Extrahepatic PH	49,5	17,0	1,7	107,0	56,3	5,5	35,6	15,5	1,5
T-criterion normal	8,04 (p<0,001)			8,20 (p<0,001)			11,23 (p<0,001)		
T-criterion to LC	4,46 (p<0,001)			6,22 (p<0,001)			7,49 (p<0,001)		
T-criterion to LF	5,89 (p<0,001)			8,40 (p<0,001)			8,62 (p<0,001)		

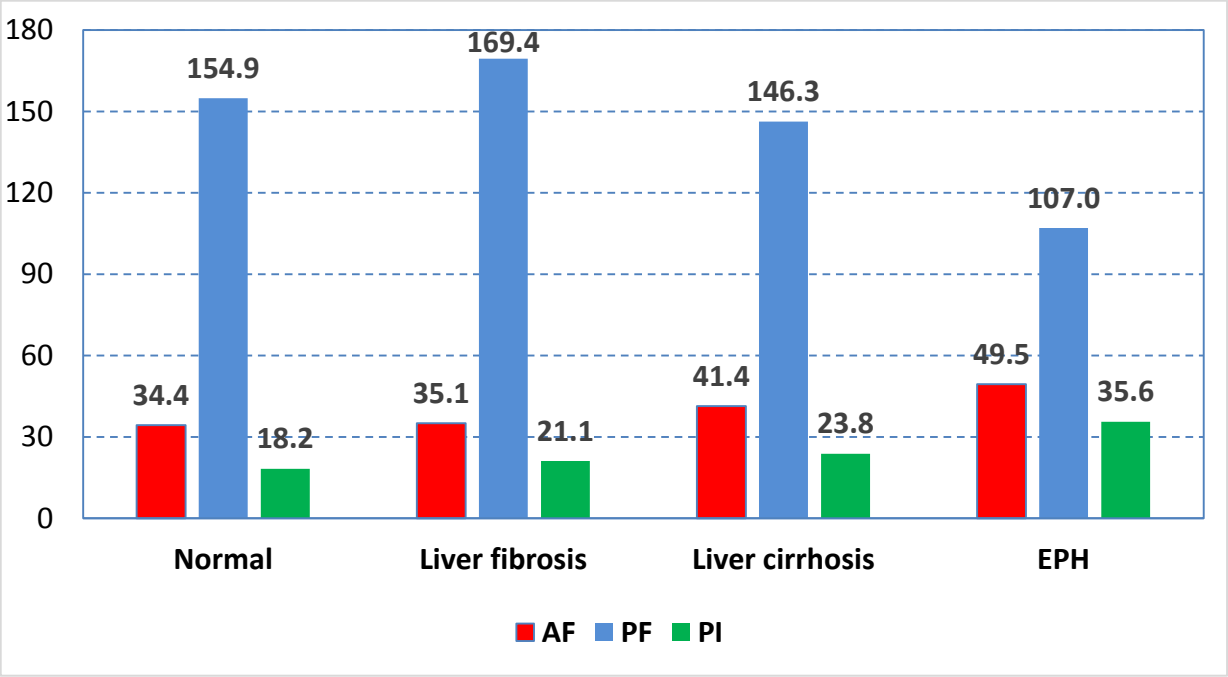
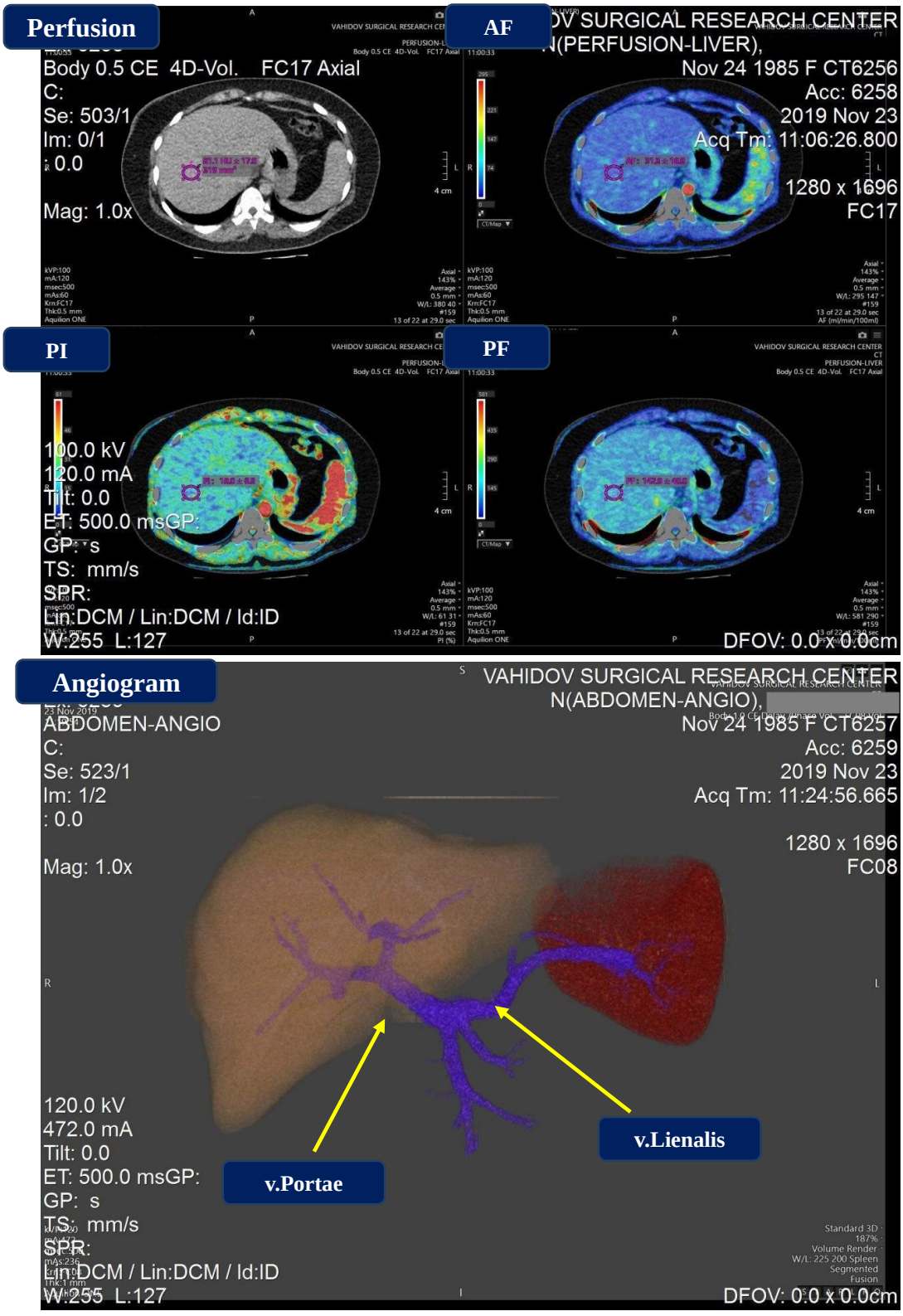
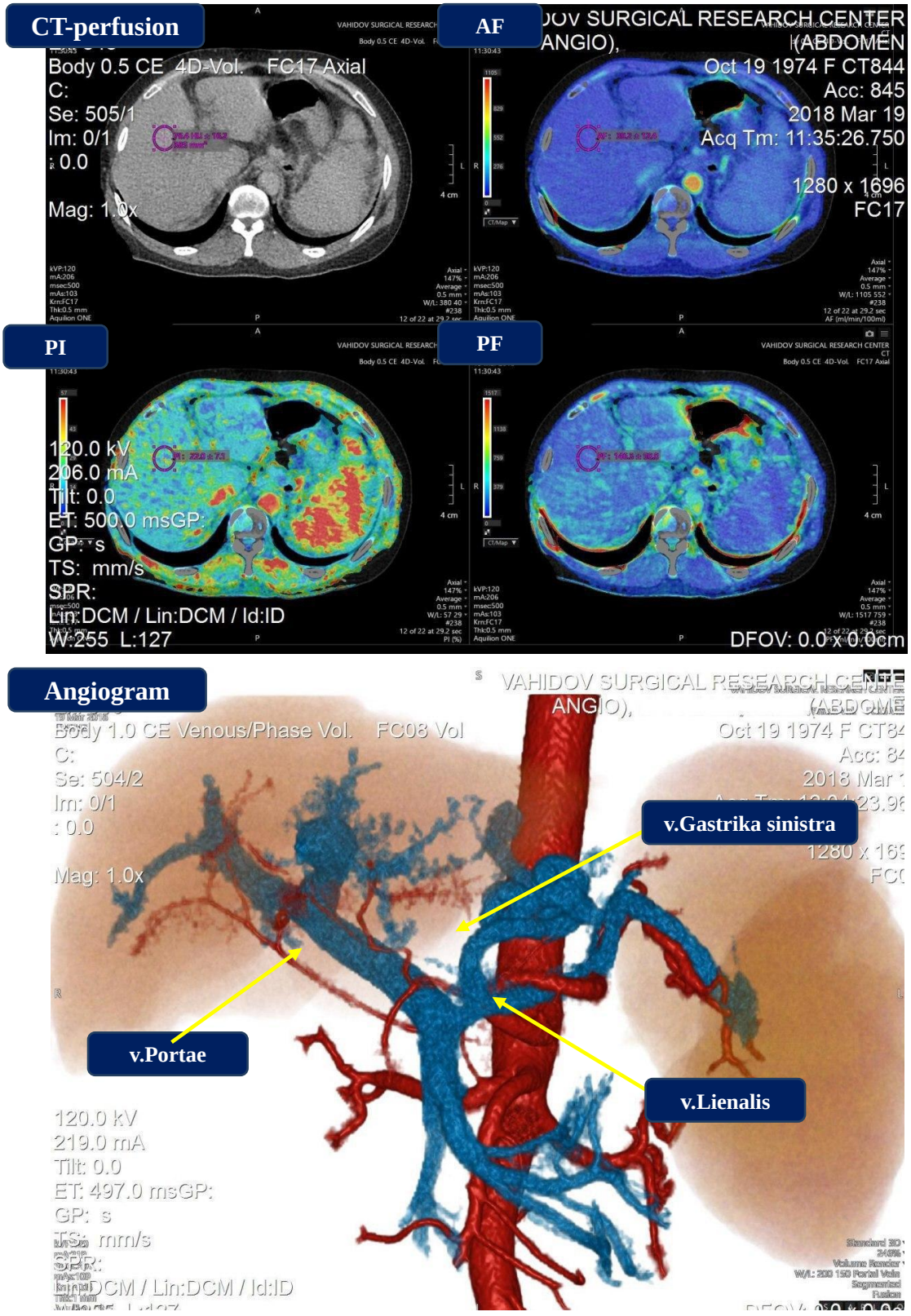


Figure 2. Summary of liver perfusion CT scores depending on the cause of portal hypertension



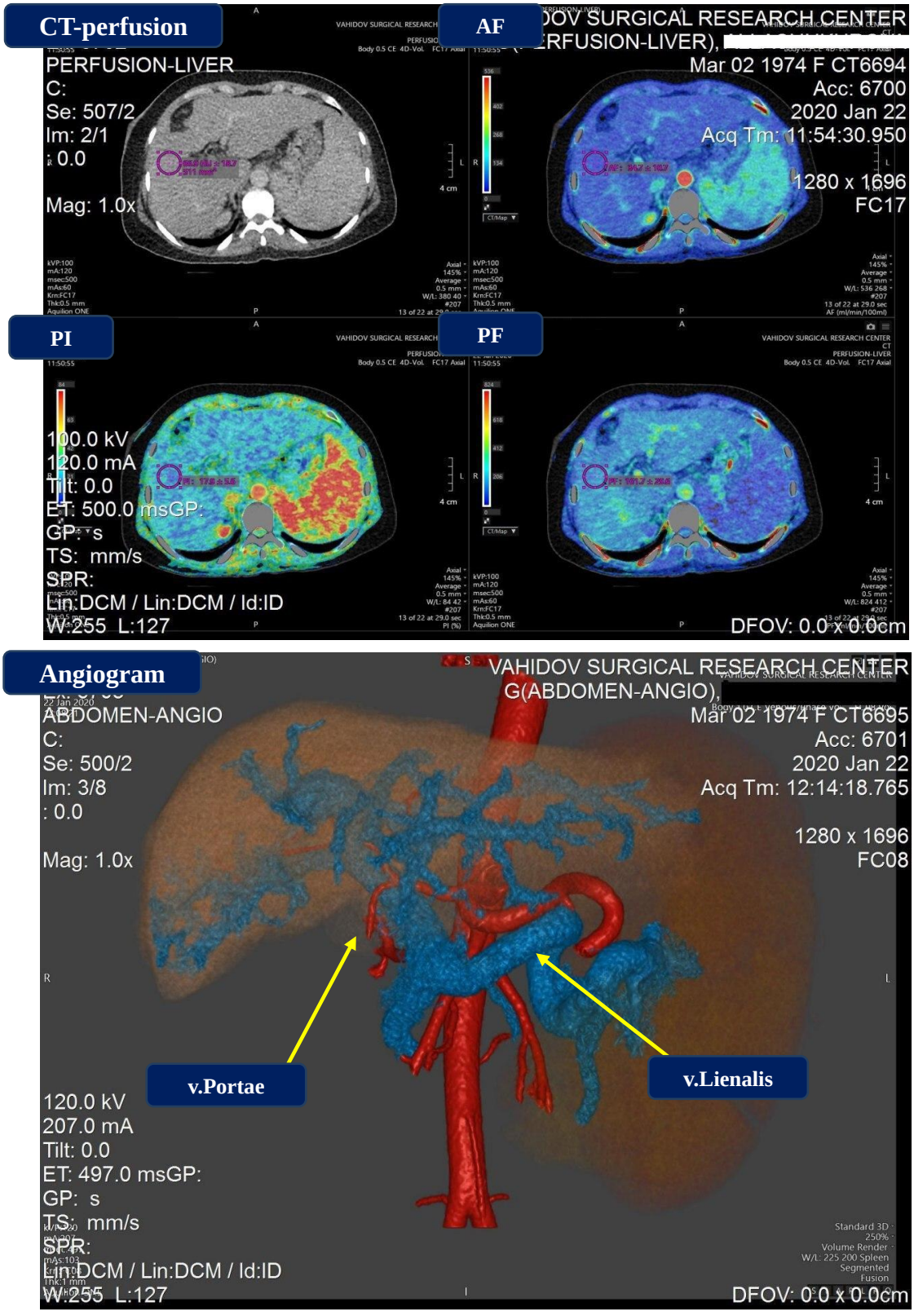
Hepatic CT-perfusion		CT-angiography	
AF (ml/100 ml/min)	31,3±16,0	v.Portae (mm)	10,0
PF (ml/100 ml/min)	152,9±40,0	v.lienalis (mm)	7,0
PI (%)	18,0±6,8	Spleen volume (ml)	276

Figure 3. Normal perfusion CT-imaging and CT-angiogram of the liver



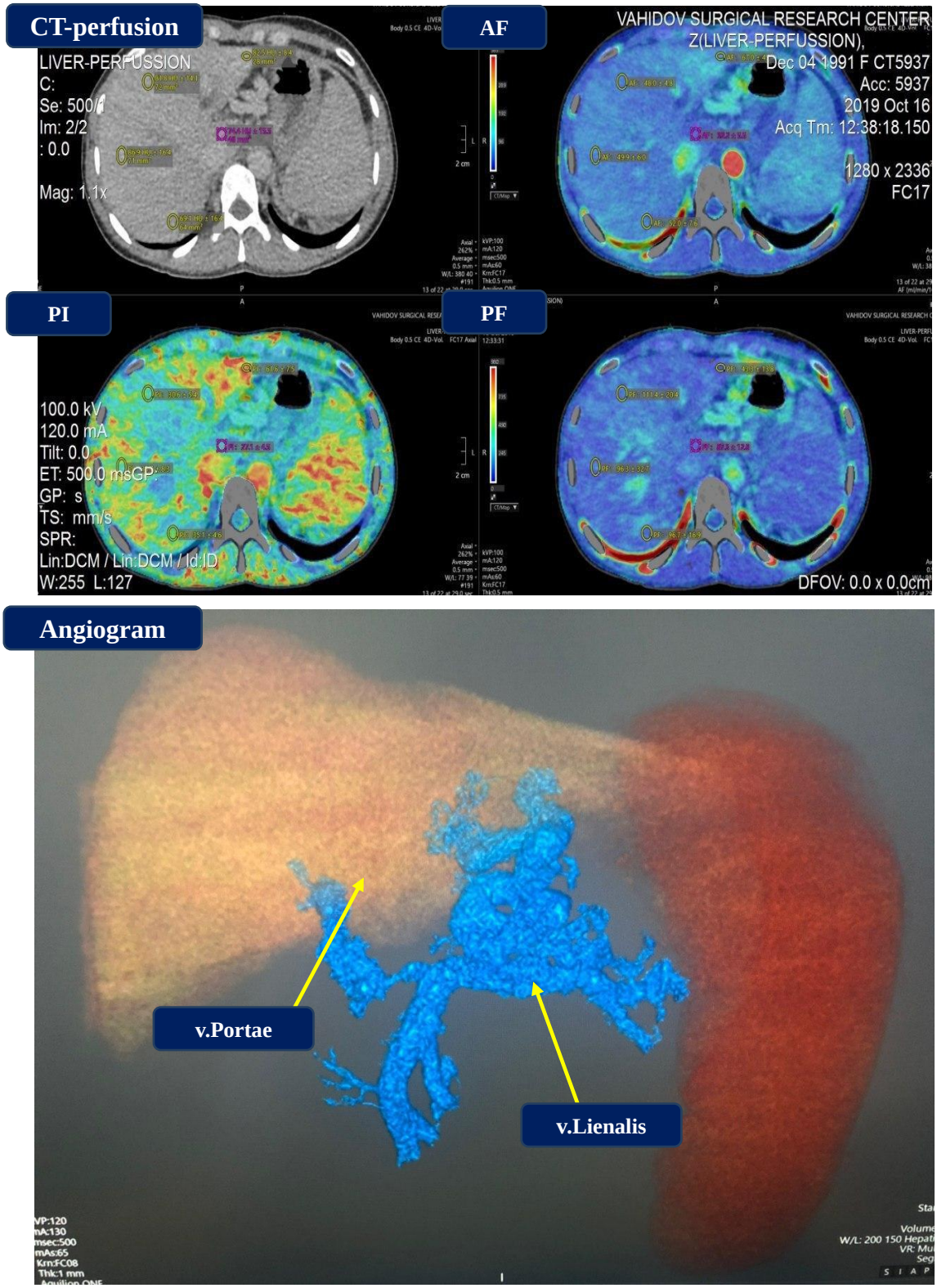
Hepatic CT-perfusion		CT-angiography	
AF (ml/100 ml/min)	39,2 ±12,4	v.Portae (mm)	18,0
PF (ml/100 ml/min)	146,3 ±50,0	v.lienalis (mm)	11,5
PI (%)	22,0 ±7,1	Spleen volume (ml)	2030

Figure 4. Perfusion CT-imaging and CT-angiogram in case of liver cirrhosis



Hepatic CT-perfusion		CT-angiography	
AF (ml/100 ml/min)	34,7 ±10,7	v.Portae (mm)	16,0
PF (ml/100 ml/min)	161,7 ±26,6	v.lienalis (mm)	13,5
PI (%)	17,9 ±5,6	Spleen volume (ml)	1546

Figure 5. Perfusion CT-imaging and CT-angiogram in case of liver fibrosis



Hepatic CT-perfusion		CT-angiography	
AF (ml/100 ml/min)	48,0 ±4,8	v.Portae (mm)	-
PF (ml/100 ml/min)	96,3 ±32,7	v.lienalis (mm)	11,0
PI (%)	30,6 ±5,4	Spleen volume (ml)	1850

Figure 6. Perfusion CT-imaging and CT-angiogram in case of extrahepatic portal hypertension

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