Available online at **www.ijmrhs.com**

ISSN No: 2319-5886

International Journal of Medical Research & Health Sciences, 2016, 5, 4:62-66

Determining the optimal portal blood volume in a shunt before surgery in extrahepatic portal hypertension

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ABSTRACT

The aim of the study: To determine the necessary shunt diameter and assess the optimal portal blood volume in a shunt in children with extrahepatic portal hypertension before the portosystemic shunt surgery. Changes in the liver hemodynamics were studied in 81 children aged from 4 to 7 years with extrahepatic portal hypertension. We established that it is necessary to calculate the shunt diameter and the blood volume in a shunt in patients with extrahepatic portal hypertension before the portosystemic shunt surgery. It allows us to preserve the hepatic portal blood flow and effectively decrease the pressure in the portal system. Portosystemic shunt surgery in patients with extrahepatic portal hypertension performed in accordance with the individualized shunt volume significantly decreases portal pressure, preserves stable hepatic hemodynamics and prevents gastro-esophageal hemorrhage.

Keywords: extrahepatic portal hypertension, hepatic blood flow volume, portosystemic shunt surgery, ultrasound examination.

INTRODUCTION

Extrahepatic portal hypertension (EPH)is the disease caused by the blockage of extrahepatic portal system vessels of various etiology. The treatment of the disease proved to have fair prospects thanks to the achievements in surgery and the development of new instrumental methods of diagnostics and treatment such as endoscopy, Doppler-echocardiography, contrast angiography and others.

Color flow Doppler imaging is highly informative and reliable in verifying the different types of venous lesions.[5,7,8]Currently it is accepted that portosystemic shunt is the most pathogenetically justified and effective method of treating patients with EPH. This method significantly lowers the threat of complications. [1-6]

However, there is still some room for investigating what the blood volume in a shunt should be to effectively lower portal pressure and maximally preserve intrahepatic portal blood flow necessary to maintain the metabolic processes and functional “competence” of the liver. The choice of surgical intervention in children with EPH has to be made individually in each case taking into account the liver hemodynamic disorders.

The aim of our work is to determine the necessary shunt diameter in children with EPH and identify the optimal blood volume in a shunt in patients with EPH during portosystemic shunt surgery.

MATERIALS AND METHODS

A total of 106 children aged 4 to 7 years were examined. 25 healthy children were in the control group, and the experimental group consisted of 81 children with extrahepatic hypertension. A complex ultrasound examination was conducted using ultrasound scanner *LOGIQ 700* (USA) with multifrequent transducers 2.5 - 7.5 MHz.

1. Ultrasonography was performed in real time in B - mode:
a)Assessing the contour measurements of liver and spleen tissue echostructure
b) general echography assessing the anatomical features of portohepatic vessels

2. Duplex scanning (DS) using color Doppler was performed. DS was conducted with the qualitative and quantitative assessment of Doppler frequency shift taking into account the maximal linear blood flow velocity (A, cm/sec), minimal linear blood flow velocity (B, cm/sec), and average linear blood flow velocity (TAMX, cm/sec) as well as indices of peripheral resistance – resistive (RI) and pulsatile (PI). Blood flow volume was calculated with the formula $Vvol = \pi R^2 \times TAMX \times 60$ (ml/min), where Vvol – blood flow volume, R – radius of the examined vessel. Hepatic portal system - the right and left branches of the portal vein (RPV and LPV), splenic vein (SV), hepatic artery proper (HAP), and splenic artery (SA) - was studied before and after the portosystemic shunt surgery and in the follow-up period.

We calculated the volumetric portal blood flow which is equal to the PV volumetric blood flow in the control group V_{volPV}. In patients with extrahepatic block it equals the sum of the volumetric blood flows in the right and left intrahepatic branches of the portal vein $Vvol_{\sum 1} = Vvol_{RPV} + Vvol_{LPV.}$

The total volumetric afferent hepatic blood flow is $Vvol_{\sum 2=}$ $Vvol_{\sum 1} + Vvol_{HAP}$, где $Vvol_{HAP}$ – hepatic artery proper blood flow. Ratio of arterial to portal blood flow (Doppler perfusion index (DPI)) was determined and equaled $Vvol_{HAP}/Vvol_{\sum 1.}$ The percentage of the volumetric blood flow in HPA in the total volumetric liver blood flow - Doppler perfusion ratio (DPR) – was calculated using the formula $(Vvol_{HAP}/Vvol_{\sum 2})*100$.

The results were statistically processed using STATISTICA V 5.0 for Windows software. To evaluate the statistical significance of the differences we used the non-parametric Mann-Whitney criterion. Correlation analysis was used to study dependence between the variables. The critical level of significance during hypothesis testing was $p = 0.05$.

Analysis of the earlier SRA (splenic-renal anastomosis) surgeries in 30 children where no shunt diameter calculations were conducted revealed that 5 patients (16.6%) had gastro-esophageal hemorrhages in post-operative period, and in 3 patients (10%) II and II degree esophageal varices remained. Bleeding as a rule was moderate.

In order to estimate the necessary shunt volume, hepatic hemodynamics was studied in 51 patients with EPH. The diameter, velocity parameters and volumetric blood flow were measured in the portal system vessels, hepatic and splenic arteries before the operation. Ultrasound examination (color flow Doppler) of the 51 children revealed portal vein thrombosis in 18 patients (35.3%), and 33 children (64.7%) had cavernous transformation of the portal vein. 14 children (25%) had II degree esophageal varices, 17 (30.3%) – III degree and 11 patients (19.6%) had IV degree esophageal varices.

RESULTS AND DISCUSSION

Tables 1 and 2 show the results of studying the vascular changes and hepatic hemodynamics in the control group before and after the operation.

Examination of portohepatic blood flow in 25 children from the control group aged between 4 and 7 years revealed that the diameter of the extrahepatic part of the portal vein was 0.68±0.03 cm, the right branch of the portal vein was 0.59±0.02 cm and the left branch 0.53±0.03 cm in diameter. The mean linear velocity in the portal vein was 19.67±3 cm/sec, then it decreased in the right branch of the PV to 15.5±2 cm/sec, and in the left branch it was 13.71±2 cm/sec. Volumetric blood flow in the PV was 428.39±109.87 ml/min, 254.13±52.57 ml/min in the right branch and 181.39±50.66 ml/min in the left one.

Diameter of the splenic vein was 0.49±0.02 cm, the mean linear velocity was slightly higher than that in the portal vein and equaled 21.53±2.92 cm/sec, and the volumetric blood flow was 243.48±56.05 ml/min. Measurements of the splenic artery diameter, mean linear velocity and volumetric blood flow were higher than those in the hepatic artery proper. The splenic artery diameter was 0.4±0.02 cm, while that of the hepatic artery proper was 0.27±0.03; the mean linear velocity in the splenic artery was 44.91±3.9 cm/sec, compared to 32.16±3.03 cm/sec in the hepatic artery proper; the volumetric blood flow in the splenic artery was 338.44±67.09 ml/min, versus 110.42±51.47ml/min. VvolΣ1 was 435.57±10.31 ml/min, VvolΣ2 545.99±15.45, Doppler perfusion index measured 0.25±0.002, and Doppler perfusion ratio equaled 20.18%.

Table: 1. Hepatic hemodynamics parameters in patients with extrahepatic portal hypertension before and after porto-systemic shunt surgery in the control group. (I- control group, II - before surgery, III - after surgery)

Cavernous transformation of the portal vein №33									
Vessels	**D (см)**			**TAMX (cm/sec)**			**Vvol (ml/min)**		
	I	II	III	I	II	III	I	II	III
RPV	0.59±0.002	0.57±0.003*	0.57±0.003*	15.5±0.2	19.3±0.2*	8.82±0.15*	254.13±5.25	295.34±6.5*	134.97±4.01*
LPV	0.53±0.003	0.47±0.003*	0.47±0.003*	13.71±0.2	16.5±0.2*	10.58±0.1*	181.39±5.06	171.67±4.61*	110.08±2.62*
HAP	0.27±0.003	0.3±0.003*	0.3±0.003*	32.16±0.6	34.4±0.3*	35.3±0.32*	110.42±5.14	145.82±4,6*	149.64±4.78*
SA	0.4±0.002	0.4±0.002	-	44.9±0.3	62.7±0.3*	-	338.44±6.7	472.51±7.33*	-
SV**	0.49±0.002	0.87*	0.87*	44.91±0.3	11.9±0.1	13.1±0.12	248.48±0.15	358.71±6.02	394.89±6.78*
Portal vein thrombosis № 18									
Vessels	**D (см)**			**TAMX (cm/sec)**			**Vvol (ml/min)**		
	I	II	III	I	II	III	I	II	III
RPV	0.59±0.002	0.52±0.003*	0.51±0.003*	15.5±2.0	12.5±0.2*	5.77±0.14*	254.18±5.25	159.2±4.73*	70.69±2.79*
LPV	0.53±0.003	0.49±0.003*	0.5±0.003*	13.71±0.2	10.71±0.2*	8.25±0.15*	181.39±5.06	121.12±3.45*	97.14±3.18*
HAP	0.27±0.003	0.33±0.002*	0.33±0.002*	32.16±0.6	47.4±0.4	37.4±0.3*	110.42±5.14	243.12±5.34*	191.83±4.12*
SA	0.4±0.002	0.39±0.002	-	44.91±0.3	61.8±0.3*	-	338.44±6.7	442.73±7.03*	-
SV**	0.49±0.002	0.87±0.002*	0.79±0.002*	44.91±0.3	10.1±0.1	13.3±0.13*	338.44±6.7	360.06±5.4	390.96±6.02*

statistically reliable differences compared to control group (p< 0.005);
*SV **- in control group (I)- hepatopetal blood flow in the group of children with EPH (II, III) – hepatofugal blood flow.*

Table: 2. Volumetric blood flow indicators of hepatic vessels in control group (I): EPH with PV cavernous transformation thrombosis before (II) and after (III) portosystemic shunt surgery.

Vessels	**normal levels**	**PV thrombosis**	**PV thrombosis**	**Cavernous transformation**	
	I	II	III	II	III
VvolΣ_1	435.57±10.31	280.32±8.15*	167.83±6.97*	467.10±11.19*	244.95±6.62*
Vvol HAP	110.42±5.14	243.12±5.34*	191.83±4.12*	145.82±4.6*	149.64±4.78*
Vvol Σ_2	545.99±15.45	523.14±13.52*	359.66±11.06*	612.92±25.79*	394.52±11.40*
DPI	0.25±0.002	0.86±0.003*	1.1*	0.31*	0.61*
DPR %	20.18	46.48*	40.6*	23.69*	37.81*
Vvol SV **	-	360.006±5.4	390.96±6.62	358.71±6.02	399.89±6.78
Vvol SA	338.44±6.7	442.73±7.03*	-	472.51±7.35*	-

** statistically reliable differences compared to control group (p< 0.005);*

The conducted research revealed certain regularities in the afferent blood flow, which create optimal conditions for organ hemodynamics and the hepatic cell functions. Previous studies of EPH patients before and after spleen-renal anastomosis (SRA) brought us to the conclusion that after the operation portal blood pressure and risk of complications should lower optimally while portal hepatic perfusion (portal blood flow) is maximally preserved. To achieve this, it is necessary to create the anastomosis diameter able to provide portal blood shunt with the volume equal to that of hepatofugal blood flow in the splenic vein established before the surgery.

It is possible when the shunt diameter equals to the splenic vein diameter determined before the operation. However, taking into account the fact that during CPA anastomosed vessels goffer and the anastomosis lumen decreases, the shunt vessel diameter should be 30 % larger than that of the splenic vein determined before the operation. In our study of the EPH patients the splenic vein diameter was 0.87 cm. 30% of 0.87 equals 0.26 cm. The diameter of the shunt vessels should be 0.87+0.26=1.13 cm. During SRA the extension of anastomosed end of the splenic vein was achieved by dissecting it lengthwise or at 35° angle. “End-to-side” and “end to side-to-side” SRA was performed.

Considering the abovementioned, SRA was conducted in 51 children. Out of them 18 (35.3%) had incomplete thrombosis of the portal vein and 33 had the PV cavernous transformation. Esophagogastroduodenoscopy revealed esophageal varices of the II degree in 17 children (33.3%), III degree in 21 children (41.2%), and 13 children (25.5%) had IV degree esophageal varices.

Having compared the hemodynamic parameters of the control group with those in the patients with PV thrombosis before and after the SRA surgery, we established that the volumetric blood flow VvolΣ1 (right and left branch of the PV) reduced by 35.7% before and 61.7% after the operation due to the reduction of the PV right and left branches’ diameters: 11.8% and 7.5% respectively. TAMX in the right and left branch of the portal vein also reduced 19.3% and 21.8% respectively.

The volumetric blood flow in the hepatic artery proper V_{volHAP} before the operation was increased by 121.1% and it decreased after the SRA, remaining, however, 73.7% higher. This increase before and after the operation is caused by the increase in the hepatic artery proper diameter and TAMX in in. The total afferent hepatic blood flow $Vvol\Sigma 2=Vvol\Sigma 1+Vvol_{HAP}$ before the operation was 4.2% lower, and after the SRA it reduced by 34.28%.

DPI in the control group was 0.25±0.002, before the operation it elevated to 0.86±0.002, and after the operation to 1.1±0.003. DPR percent concentration of the arterial blood in the efferent hepatic blood flow (with the norm of 20.18%) before the operation increased to 46.48%, and after the operation it slightly decreased to 40.6%.

Elevation of the Doppler perfusion index before and after the SRA is caused by the increase in the blood flow in the hepatic artery proper ($Vvol_{HAP)}$ and reduced blood flow in the right and left branches of the portal vein (VvolΣ1). Determining the DPR also indicates the elevated percent concentration of arterial blood in the efferent hepatic blood flow both before and after the SRA surgery. Two times increase of the splenic vein diameter was registered; hepatofugal blood flow which before the operation was 360±5.4 ul/min, after the SRA became 390.6±6.62 ul/min, that is, 8.5% more than it was before the surgery. This confirms the fact that the shunt diameter was selected correctly.

It was established that the decrease in the total portal hepatic blood flow (VvolΣ1) in patients with PV thrombosis has the following causes: reduced diameter and average linear velocity (TAMX) in the left and right intrahepatic branches of the PV; increased diameter of and hepatofugal blood flow in the splenic vein; pass of the portal blood through natural portocaval pathways and after the SRA operation through the artificial shunt into the inferior vena cava area. Here it should be underlined that determination of the optimal shunt blood volume in SRA maximally preserves the portal blood flow.

The increase in the blood flow in the hepatic artery proper and its elevated concentration (DPI and DPR) in the efferent hepatic blood flow may be considered as a compensatory response aimed at supplying the liver with sufficient blood flow. It allows preserving the liver cell function while maintaining the possibility of "hydraulic lock" development: in other words, arterial blood flow increase creates an additional obstacle to portal blood flow. We should point out that HAP $Vvol_{HAP}$ reduces to 191.83 ± 4.12 after the operation, that is 47.4% compared with the preoperative indicator due to reduced TAMX in the HAP. It has a positive effect on the hepatic hemodynamics, preventing the "hydraulic lock" development.

Comparing the hemodynamic indices in the control group with those in patients with the PV cavernous transformation before and after the SRA surgery, it was established that these changes are less expressed than in the PV thrombosis. In case of the PV cavernous transformation the total volumetric portal blood flow VvolΣ1before the SRA surgery was 7.2% higher than the normal limit and after the surgery it decreased by 43.8% compared to norm. In case of the PV thrombosis VvolΣ1 decreased by 35.7% and 61.7% compared to norm before and after the surgery respectively.

Meanwhile, VvolΣ1 (in the PV branch) after the SRA remains in a larger amount and is 244.95 ± 6.62 l/min. The volumetric blood flow in the HAP before and after the SRA increased less than in thrombosis by 32.1% and 35.5% respectively due to the increase in the HAP diameter and the TAMX in it.

The total volumetric blood flow VvolΣ2 was 12.2% higher before the surgery than this figure in the control group (it was 4.2% lower in thrombosis), and it decreased by 27.2% (34.2% in thrombosis) after the operation. The DPI before and after the surgery increases and is 0.31 and 0.61 respectively, which is lower than in PV thrombosis. DPR before and after the surgery elevated by 23.69% and 37.81%. This is lower than the indicators in PV thrombosis.

Hepatofugal blood flow was registered in the splenic vein before and after the surgery. Its value was close to that in the PV thrombosis and was 358.71±6.02 ml/min and 399.89±6.78 respectively. It is 11.1% higher than before the operation, which means that the shunt diameter defined before the operation was selected correctly.

The study has shown that the hemodynamic changes of the blood flow in the afferent link in PV cavernous transformation before and after the SRA surgery were unidirectional with the thrombosis changes, though less expressed. The portal blood flow was preserved to a greater extent, and the arterial blood concentration increased to a lesser extent. These differences are presumably due to portal pressure and TAMX increase on the one hand, and on the other hand they might be caused by the fact that in the PV cavernous transformation there is a larger volume of portal blood going to the right and left branches of the PV than it occurs in thrombosis. After the SRA surgery the portal blood flow is preserved both in the situations of thrombosis and PV cavernous transformation.

The studies have shown that the SRA operation with the calculation of the required anastomosis diameter and the optimal amount of portal blood shunt allows relieving the portal system and reducing portal pressure due to the total blood shunting through natural shunts and created SRA. The portal blood flow is maximally preserved in this situation.

Everything mentioned above creates the condition for achieving an adequate volume of blood shunt. Blood volume increase through the SV after the surgery may be explained by a sufficient shunt diameter and decrease of blood flow resistance in the SV since the spleen capillary network has been cut off (splenectomy).

The obtained data reveal that adequate blood shunt volume through SV is possible with a shunt diameter equal to SV diameter before the surgery. However, taking into account the fact that during anastomosis goffering of anastomosed vessels occurs and their lumen reduces. The diameter of the shunt vessels should be 30% larger than the SV diameter. For example, in our study in children aged between 4 and 7 years old with 0.87 cm diameter of the SV the required diameter of the anastomosis is 1.13 cm (0.87+30%=1.13).

We assessed the SRA effectiveness according to the following criteria: absence of postoperative complications (bleeding, ascites); lowered degree of esophageal varices but not their complete reduction from the preoperative state; preserved intrahepatic portal blood flow and normal liver function.

CONCLUSION

We came to the conclusion that ultrasound examination with color flow Doppler is an informative noninvasive method providing proper assessment of the porto-hepatic blood flow in patients with EPH before and after the surgery. This allows planning vascular anastomosis and controlling the shunt function. The increase in hepatic arterial perfusion is a compensatory mechanism aimed at maintaining adequate liver hemodynamics and functioning.

Our study has shown that porto-systemic shunt surgery in EPH performed considering the preoperative hemodynamic shifts, bypassed vessels diameter, and portal blood bypass volume required in each case, allows maximal preservation of portal hepatic blood flow. Combined with the natural porto-caval anastomoses, this surgery can also reduce portal pressure, which prevents gastro esophageal bleedings and creates optimal conditions for the liver cell functioning.

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