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Dynamic Networks of Human Homeostatic Control in Norm (Part 2)

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Abstract

We undertook this research to study the relationships between elements of the vascular system in individuals without clinical signs of pathology (in "norm"). Indicators of hemodynamics obtained by catheterization in various vascular areas (RA, RV, LV, PT, Ao, SS, RHV (FHVP and HVWP), CS) were the pressure levels (mmHg). During the correlation analysis, the significant ($P<0.05$) relation signs (+, 0, -) without regard to their power were considered.

The obtained results allow us to draw following conclusions:

- Capacitive venous vessels of the liver are a communication channel between the evolutionarily younger (lungs) and older (organs of the splanchnic pool) functional systems of the human body.
- Hepatic venous circulation is a field of interference of the information and biochemical relationships between the body and the external environment through the venous outflow from GIT (the zone preceding the liver) and arterial flow - CHA (an indicator of aortic hemodynamics and gas exchange in lungs).
- The result of marked interactions is an integrated bio-informatic flow of venous outflow from the liver (whose "thesaurus" includes the information volumes of organs preceding the liver), which has uniform hemodynamic and biochemical parameters and interacts with the blood flow of RA and all phases of CC and hemodynamics in IVC/SVC pools and CS.
- The intersystem relationship in the cardio-hepato-pulmonary complex of the human body is the highest biology hierarchical level of the homeostatic relationships in the human–external-environment system. **(Int J Biomed. 2016;6(3):179-183.)**.

Key Words: human homeostasis control matrix • hydrodynamic balance • hepatic venous outflow • coronary sinus

Abbreviations

Ao, aorta**; CC,** cardiac cycle**; CS,** coronary sinus**; CHA,** common hepatic artery *(a. hepatica communis)*; **CO,** cardiac output**; CT,** coeliac trunk *(truncus coeliacus)*; **DP, d**iastolic pressure; **EDP,** end-diastolic pressure; **FHVP,** free hepatic venous pressure; **GIT,** gastrointestinal tract; **HVWP,** hepatic venous wedge pressure; **HPV,** hepatic portal vein *(v. portae hepatis)*; **IJV,** internal jugular vein *(v. jugularis interna)*; **IVC**, inferior vena cava *(v. cava inferior)*; **LV,** left ventricle *(ventriculus sinister)*; **LA,** left atrium *(atrium sinistrum)*; **M,** maximum pressure; **MP,** medium pressure; **N,** Norm; **PP,** pulse pressure; **PT,** pulmonary trunk *(truncus pulmonalis)*; **RHV,** right hepatic vein *(v. hepatica dextra)*; **RA,** right atrium *(atrium dextrum)*; **RV,** right ventricle *(ventriculus dexter)*; **RHA/LHA,** right/left hepatic artery; **RLL/LLL,** right/left lobe of the liver; **SS,** sigmoid sinuses *(sinus sigmoideus)*; **SinP,** sigmoid sinus pressure; **SVC,** superior vena cava *(v. cava superior)*; **SP,** systolic pressure; **SVP,** hepatic sinusoidal pressure; **SA,** splenic artery; **SV,** stroke volume.

Materials and Methods

All of the research was conducted in the same laboratory and with the help of the same methods and equipments in the supine position (in the perpendicular position to the vector of gravity when its influence in all parts of the venous system is equal). The catheterization was performed by percutaneous puncture of the right femoral artery and the right femoral vein under local anesthesia, using the Seldinger technique. A vein dilator was used during the vein puncture. The catheter reached the aforesaid parts of the cardiovascular system. The arterial pressure values were recorded for the thoracic aorta.

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The studies were monitored by using radiography equipment. The detailed description of studied groups were presented in Part 1 of this publication. [1]

Discussion

Capacitive liver vessels, being negatively correlated (Table 1) with the hemodynamic processes described previously ("single units": RA-RV and RV-PT; vascular flow to RA; hemodynamics of CS except PP),[2-10], are pathways of outflow from organs of the splanchnic pool (SP) and participate in the generation of pulsating turbulent flow (the work of the right heart chambers). In "norm," they provide a laminar permanent outflow during CC in the zone of hydrostatic indifferent points and regulate inflow (CHA and HPV) according to outflow (RHV) due to their anatomical and functional features:

1. Coincidence of the axes of the mouths of RHV and CS; lack of influence of the venous damping of IVC in the study block: a fixed capacity (RHV) – a variable capacity (RA).

2. The asymmetrically located intrahepatic part of branches of RHV depends on the surrounding tissues with fixing throughout to the encapsulated stroma of the liver, whose liquid medium is incompressible. Changing the configuration of the lumen and volume of RHV can only take place due to opposite changes in the surrounding vessels and tissues, which is analogous to the Monro–Kellie doctrine for the skull.

3. The structure of RHV is such that does not prevent

a) the retrograde pressure transmission (This effect is enhanced by the absence of the influence of the previous damper IVC.), or

b)the retrograde transmission of wave impulses and other central effects (cardiac activity).

4. An interaction of intrahepatic vessels of inflow (CHA and HPV) and outflow (RHV) occurring in mode of serried fingers (positive correlations with the Ao pulse pressure, see Table), leads to the fact that changes in pressure in RVH regulates the blood inflow to the liver parenchyma. Thus, an increase in the pressure in RHV leads to compression of intraorganic blood vessels of HPV and CHA, restricting blood flow to the liver. A decrease in the pressure in RHV is associated with the opposite effect. This pattern is more characteristic of RLL, where branches of RHA and HPV run parallel; the architectonics of intraorganic branches of LHA and HPV in LLL do not match. Thus, the regulation of inflow in the liver is dependent on the conditions of outflow. At the same time, there is an extrahepatic portion of magistral veins, which carries all the properties of the veins (changes in configuration and volume under changes in transmural pressure) in which the serried fingers mechanism does not work.

5. The lack of the effect of orthostasis on the intrahepatic part of IVC with fixing by fibrous rings at the entrance to and exit from the liver determines the hemodynamic stability of the outflow pathways by RHV.

6. Branches of RHV fall into the ampoule-shaped extension of the intrahepatic segment of IVC near its mouth, passing through a hole in the tendinous part of the diaphragm at an acute angle (35-40º), creating favorable conditions for blood circulation and drainage from RLL.

7. The mouth of IVC is provided with the closing apparatus, the myocardial sphincter, which performs the function of the fifth heart valve and the Eustachian valve of IVC; this sphincter is a structural and functional element of the heart. It takes part in preventing excessive blood regurgitation in IVC, protecting the liver, as the biochemical laboratory, against the stress effect of the regurgitation from RA, regulating the blood inflow to RV and preventing the chronic volume overload of RA. [11-13]

8. Heart chambers RA, RV, "united systole", CS) influence the hemodynamics in RHV; hemodynamic changes in these chambers affect the hepatic venous circulation and as a consequence, indirectly, the portal circulation (Table 1).

In norm, the anatomical structure of inflow and outflow pathways of the liver is built on the principle of minimizing the pressure fluctuations inside the liver parenchyma and constancy of liver functions. This structure aims to prevent the impact of the stress effect of the regurgitation from RA. This is achieved by hemodynamic and biochemical damping of arterial blood flow by SP organs, which precede the liver and form the blood flow in HPV.

Evolutionary deterministic branching of magistral vessels arising from the aorta and moving to each organ and functional element (FE), promotes the hemodynamic damping of arterial flow. Therefore, CT arises from the abdominal aorta at a right angle; RHA and SA arise from CT at an acute angle. The result is splitting of the spherical pulsating aortal flow, which is formed by LV, into a number of streams, which have different pressure and impulse and are specific to each organ of SP.

The difference in branching of the magistral blood vessels from Ao and the intensity of the determined response may be different for each organ and FE, as well as the degree of withdrawing information from the pulsating spheroid of the Ao pulse pressure. Laminar flow velocity in the cross section varies from zero at the wall of vessel to a maximum speed along the vessel's axis, having parabolic shape. With increasing the difference in pressure and the Reynolds number, parabola becomes increasingly elongate. Those, the stricture of the laminar flow has an elongated telescopic design, in which elements move with different speeds, where the structured layers are the independent variables, between which, there is an energy dissipation due to friction.[14] Thus, the angular differences in the ramifications of the vessels lead to a difference in the pressure levels (information) withdrawn from the spheroid of Ao, which causes the difference in information obtained by various SP organs. In norm, the spherical dissipative wave structure of the pulsating flow generated by LV in Ao reaches all points of the microcirculatory bed in the human body before aortic valve closure. The impulse of the pulse wave adapted for each organ with the participation of its own arterial system, outpacing the formation of the bio-informatic flow (BIF) formed by CC, prepares the exchange structures of the organ to receive this BIF. Vessels of inflow are in a single fascial bed with vessels of outflow; thus, the impulse of the pulse wave also affects the information flow of

the outflow pathway, sharing the information and performing the feedback functions. Along with the fact that each organ of SP obtains identical biochemical composition of the blood, the nature of branching of magistral vessels from Ao (which is specific to each organ) provides the targeted obtaining of the fixed front portion of the spheroid of the stroke pulse wave and forms the information flow individually for each organ. Thus, the biochemical composition of arterial blood is the same for all SP organs, but the impulse of the pulse wave is different and specific for each organ of SP. The arterial "knee" is a damping chamber, which creates a laminar flow providing the stable functioning of the liver in the norm.

The blood of CHA, which passes through a metabolic filter of lungs, has contact with the external environment through gas exchange in the lungs and reflects the functioning of small and large circulatory circles. The biochemical composition of the blood flowing from each organ of SP into HPV depends on the biochemical composition of arterial blood, the functioning of this organ and the functioning of other SP organs.

We identify the following groups of organs:

1. Organs of GIT (stomach, intestines). The biochemical composition of the blood flowing from these organs will depend on the biochemical composition of arterial blood, food, pancreatic juice and bile (ie, the influence of other organs of SP), microbial flora, the composition of intestinal gas, etc. Thus, a) these organs are associated with the external environment through the lungs and food; b) biochemical composition of the blood flowing from them depends on many factors and therefore is variable.

2. The spleen is an exclusive organ of SP, which is associated with environmental factors only through arterial blood, is not subjected to the influence of other SP organs, and affects only the liver.

3. The pancreas is an organ that occupies a special position among other SP organs. The shortest way communication with the external environment is realized through arterial blood. At the same time, the pancreas affects the functioning of other SP organs through pancreatic juice secreted in the intestinal lumen and active substances (hormones, enzymes, etc.) released into the blood flowing to HPV.

Biochemical damping of the blood flowing to the liver is provided by five BIFs:

- arterial blood of CHA, which passes through the metabolic filter of lungs and has contact with the external environment through gas exchange, reflecting the functioning of small and large circulatory circles;
- venous blood, which flows from the spleen;
- venous blood, which flows from the pancreas;
- venous blood, which flows from GIT; and
- lymph, which flows through the lymphatic pathways of SP organs.

Among these, CHA is the shortest way to deliver information about the activities of organs of the human body and their interaction with the environment through the most fast-acting factors - gases. Other SP organs also obtain the same information.

A feature of the biochemical composition of the blood coming from GIT is an independent relationship with the external environment through food. This relationship is not constant; it is less fast-acting and can be offset for many substances.

Communication between the spleen and the external and internal environments depends on the arterial blood. Thus, biochemical composition of the blood of HPV depends on the biochemical composition of arterial blood, food consumption, pancreatic juice and bile secreted in GIT lumen (the influence of other organs of SP), microbial flora, the intestinal gas composition, etc.

Of particular importance is the distribution of immiscible blood streams in HPV, which are formed by different SP organs. HPV has no valves, so there is a possible laminar flow in opposite directions.[11,15] Because of the hydrodynamic damping that provides the laminar flow, in norm, two blood streams can be distinguished in the HPV system:

a) an upper stream extending away from the spleen (SV) is directed to LLL without mixing with other streams;

b) a lower stream (from other SP organs) goes to RLL.

The hydrodynamic damping of blood pressure by the spleen as blood enters it selectively promotes the flow of information about the biochemical composition of the formed blood elements and plasma. To LLL, which regulates the most subtle abnormalities in the biochemical processes, the blood flows from the spleen, pancreas, stomach, and the left half of the colon. To RLL, which is the "working" portion of the liver and depends on the information coming from LLL, the blood flows from the small intestine, where basic digestion and absorption of nutrients are carried out, and from the right half of the colon.

Perhaps, the spleen is not only a hydrodynamic damper in the human body, but also an organ which duplicates the management of biochemical processes in the human body through its impact on the metabolic processes in LLL. The independence of the information flow coming from SV and CHA is one of the conditions for the functioning of SP organs as a biochemical damper that, in particular, is manifested in liver cirrhosis, hypertension, and peritonitis.

Thus, the liver has three BIFs, which integrate the communication between the right and left liver lobes:

1. By RHA/LHA (in LLL and RLL) through arterial blood carrying the information regarding the interaction between the liquid environment of the human body and the external gas environment in the lungs.

2. By HPV (in LLL) from the spleen (by SV).

3. By HPV (in RLL) from SP organs carrying the information regarding the interaction between the liquid environment of the human body and the external environment through factors coming from GIT.

Thus, HPV is an exclusive vessel through which the integrated information flow (IIF) combining the two types of BIFs moves to the liver:

1. BIFs that mainly carry the information (regarding the interaction with external gas environment) in LLL, which is damped by the spleen (the organ of "stress situations") regulating the most subtle deviations in biochemistry.

2. BIFs that carry the information (regarding the interaction between the liquid environment of the human body

Table 1.

The extended summary matrix table of synergistic relationships for parameters of metabolism and hemodynamics

Variable		Ao				RA					RV		LV				SinP				PT				RHV				HVWP			
		SP	DP	PP	MP	A	X	V	Y	MP	EDP	MP	SP	PP	CO	SV	SP	DP	PP	MP	SP	DP	PP	MP	SP	DP	PP	MP	SP	DP	PP	MP
SinP	SP				+	-	+			+		+	-	-	-		x	x	x	x					-	-	+	-				
	DP		+		+		+			+		+	-	-	-		x	x	x	x												
	PP		-				-				+						x	x	x	x					-	-		-				
	MP				+		+		+	+	-	+	-	-	-	-	x	x	x	x					-	-	+	-				
HVWP	SP		-	+	-	-	-	-	-	-	-	+	x	x	x	x	-	-	-	-				-	+	+	+	+	x	x	x	x
	DP		-	+	-	-	-	-	-	-	-	+	x	x	x	x	-	-	-	-				-	+	+		+	x	x	x	x
	PP							-	-		+	+	x	x	x	x	-	-	-	-				+		-			x	x	x	x
	MP		-	+	-	-	-	-	-	-	-	+	x	x	x	x	-	-	-	-				-	+	+		+	x	x	x	x
PT	SP	+	+		+	+	+	+	+	+	+		x	x	x	x	+	+		+	x	x	x	x								
	DP		+		+						+		x	x	x	x			-		x	x	x	x								
	PP	+			+	+				+			x	x	x	x	+	+	+	+	x	x	x	x	+	+		+				
	MP	+	+		+	+	+	+	+	+	+	+	x	x	x	x		+	-		x	x	x	x								
CS	SP	+	+	-	+	+	+	+	+	+	+	-	x	x	x	x	+	+	-	+	+	+	+	+	-	-	+	-	-	-		-
	DP		+	-	+	+	+	+	+	+	+	-	x	x	x	x	-	-	+	-		+	-				+				+	
	PP		+	-					+			-	x	x	x	x	+	+	-	+	+		+	+	-	-		-	-	-	-	-
	MP	+	+	-	+	+	+	+	+	+	+	-	x	x	x	x	-	-	+	-	+	+			-	-	+	-	-	-	+	-

and the external environment through factors coming from GIT) from GIT in RLL.

Normally, each IIF entering the channels for the information collection from this system is not dominant (individually) in regulating the function of organs and the whole organism. We believe that the total humoral information delivered by HPV in the liver (in norm, 75% of blood volume) and dependent on the factors of the internal and external environments is subjected to significant correction and damping by other SP organs. The dependence of the liver on the overall characteristics of HPV weakens the influence of any single BIF, including the BIF moving by CHA. That is, biochemical regulation of the liver function is associative, which increases the stability of homeostasis and homeokinesis of the human body. Small and large circulatory circles are the interconnected systems with a partial cross-duplication of functions. In lungs (the pulmonary circulation), the metabolic and non-gas-exchange functions that belong to the systemic circulation (large circulatory circle) are partially represented.

Conclusion

The obtained results allow us to draw following conclusions:

- Capacitive venous vessels of the liver are a communication channel between the evolutionarily younger (lungs) and older (SP organs) functional systems of the human body.

- Hepatic venous circulation is a field of interference of the information and biochemical relationships between the body and the external environment through the venous outflow from GIT (the zone preceding the liver) and arterial flow - CHA (an indicator of aortic hemodynamics and gas exchange in lungs).

- The result of marked interactions is an integrated BIF of venous outflow from the liver (whose "thesaurus" includes the information volumes of organs preceding the liver), which has uniform hemodynamic and biochemical parameters and interacts with the blood flow of RA and all phases of CC and hemodynamics in IVC/SVC pools and CS.

- The intersystem relationship in the cardio-hepato-pulmonary complex of the human body is the highest biology hierarchical level of the homeostatic relationships in the human–external-environment system.

Competing interests

The authors declare that they have no competing interests.

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