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BIOMECHANICS OF THE LEFT-HANDER

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Abstract. The purpose of this paper is to clarify the biomechanical features of symmetric organs functioning – the right and left hands. The main cause of symmetry deviation is explored: different arterial blood pressure in the arteries, providing blood to hand. The biomechanical possibilities of the appearance of left-handed features development are considered, when a human left arm is stronger and agiler than right, as opposed to other people. This variant is possible if the blood stream through the left subclavian artery with a lower arterial pressure at its input in comparison with arterial pressure at the input to the right hand, will be more than at the right hand. The experimental results confirming the research conclusions are described. Medical recommendations on the implementation one of the basic clinical procedures – arterial pressure measurement are made.

Key words: biomechanics, arterial pressure, aortic arch, left-hander.

INTRODUCTION

At present, there is a certain concept in medicine about ratio of functioning of the right and left human organs. For example, usually it is assumed, there is no difference on which hand measuring cuff is fixed in arterial pressure determination: at left or right hand [1]. Some people assume that (see, for example [2]) it is better to conduct measurements at hand with higher values of arterial pressure.

In medical practice, it is defined that arterial pressure is subject to sharp fluctuations even in short time intervals. Level of arterial pressure depends on many factors. During the day, the difference in indications in healthy people can make 30–50 mm Hg in systolic (upper) pressure and 10 mm Hg in diastolic (lower) pressure. Dependence of arterial pressure on different factors is individual at each person. One hour before carrying out of pressure measurement, an eating, 1.5–2 hours a smoking, a drinking of tonics, an alcohol must be excluded. This requirements have created uncertain relation to this most important parameter of the human body condition.

Author's experience with many calculations of pressure in the arteries, blood-filled and supported by the stent, in the software package *ANSYS* allows making more certain notion about possible character of pressure distribution in aortic arch and arteries departing from it.

THE HISTORICAL FACTS

There are many of the biomechanical facts developed for a long time: those are objects, conditions, and other definitions, which set a number of questions.

Question 1. Why is a men's shirts pocket for trifles made on a left side?

Question 2. Why is a men's jackets pocket for trifles made on the left side too?

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Question 3. Why is in the Great Britain left-side car movement and a steering-wheel on the right side of the car?

Question 4. Why is the human left hand weaker than the right one?

Question 5. Why does the population write basically by the right hand?

Question 6. Why are believers cross themselves by right hand fingers?

You can ask a lot of similar "why", although answers to these questions are not determined and ambiguous. This is historically happened.

Correct answer to the first question is: "This is because the right hand does this movement and not conveniently to do it by the left hand to the left pocket, it is possible to miss and to lose the document or something else".

Correct answer to the second question is the same as the first one.

Correct answer to the third question is: "This is because in the Great Britain in the Middle Ages knightly tournaments had the honor and glory, in which knights in heavy fighting armour and with a spear raced on horses towards each other to knock down the opponent off his horse. This is a hard task, thus all body resources were used and the spear was kept always in the right hand as stronger".

When in England cars have emerged, the English entrusted traditionally a wheel as a spear, to the right hand as stronger, and the first cars were tested at these venues for tournaments with these "traffic lanes".

The main question is: "Why is the right hand stronger and more skilfull than left, and why is a person doing by the right hand both all kinds of heaviest and most delicate and responsible works?"

Biomechanics of the right and left hands

In the Fig. 1, the general scheme of human blood circulation (there are such variants of development) [3] is presented. You can see in this figure, that after the output from the heart a blood moves in the aorta to several large arteries.

Aorta, *aorta*, is the largest arterial vessel in human body. It leaves the left mitral valve of the heart, its beginning is in the aorta aperture, *ostium aortae*. All arteries forming the greater arterial circle of blood circulation depart aside from the aorta. The aorta is divided into the ascending aorta, *aorta ascendens*, aortic arch, *arcos aortae*, and descending aorta, *aorta descendens*. Further, the aorta runs to a divergence in artery of the left and right feet (Fig. 1).

Aorta descendens, in turn, is divided into the chest aorta, *aorta thoracicis*, and abdominal aorta, *aorta abdominalis*.

The ascending aorta, *aorta ascendens*, is continuation of *conus arteriosus* of the left ventricule and begins from the *ostium aortae*. Behind the left half of the breast at the level of the third costal interspace, it goes upwards, a little to right and forward and reaches cartilage level of the second rib to the right where it is being continued in the aortic arch.

The aortic arch, *arcus aortae*, is directed by convexity upwards and goes in front to back, passing to the descending aorta. The aortic arch has a direction from the cartilage of the second rib on the right to the left body surface near III–IV chest vertebrae. Three or four large vessels depart from the aortic arch (Fig. 2): 1) the right subclavian artery, *a. subclavia dextra*; 2) the right common carotid, *a. carotis communis dextra*; 3) the left common carotid, *a. carotis communis sinistra*; 4) the left subclavian artery, *a. subclavia sinistra*. The initial part of the aorta is the ascending aorta. It represents a large vessel with diameter of 4 cm and length of about 6 cm, which goes upwards and to the left and at the level of the right chest-clavicular joint, the right subclavian artery departs aside from it.

The calculation results of the blood parameters in arteries of the right and left hands in this location in the aortic arch will be presented below.

It is obvious that the higher is the pressure in the artery, the faster is speed of blood stream in it, the faster is exchange of blood in the muscles, the fresher is blood, the more oxygen to muscles is brought.

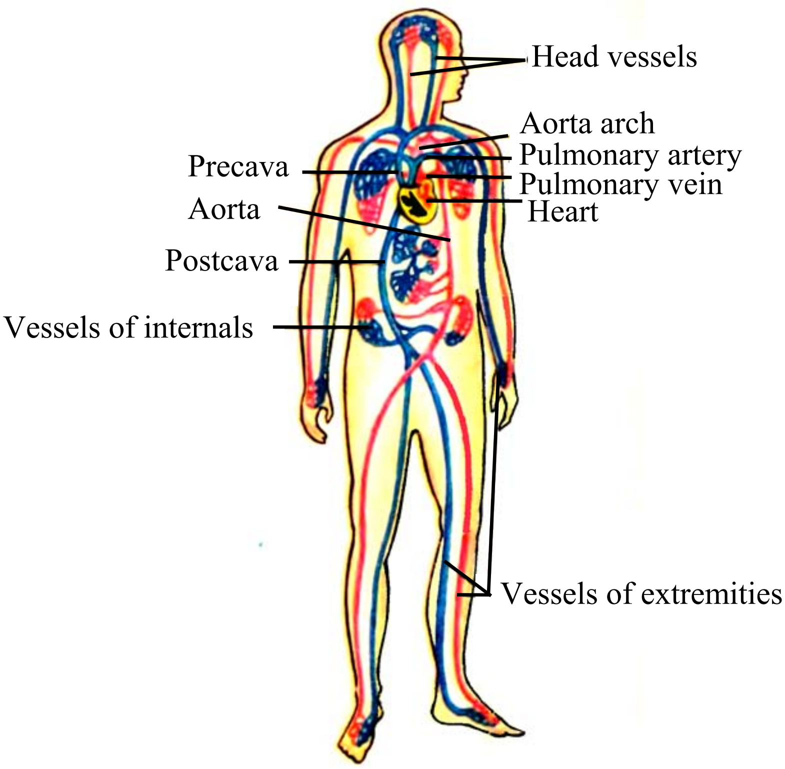

Fig. 1. The general scheme of human blood circulation [3]

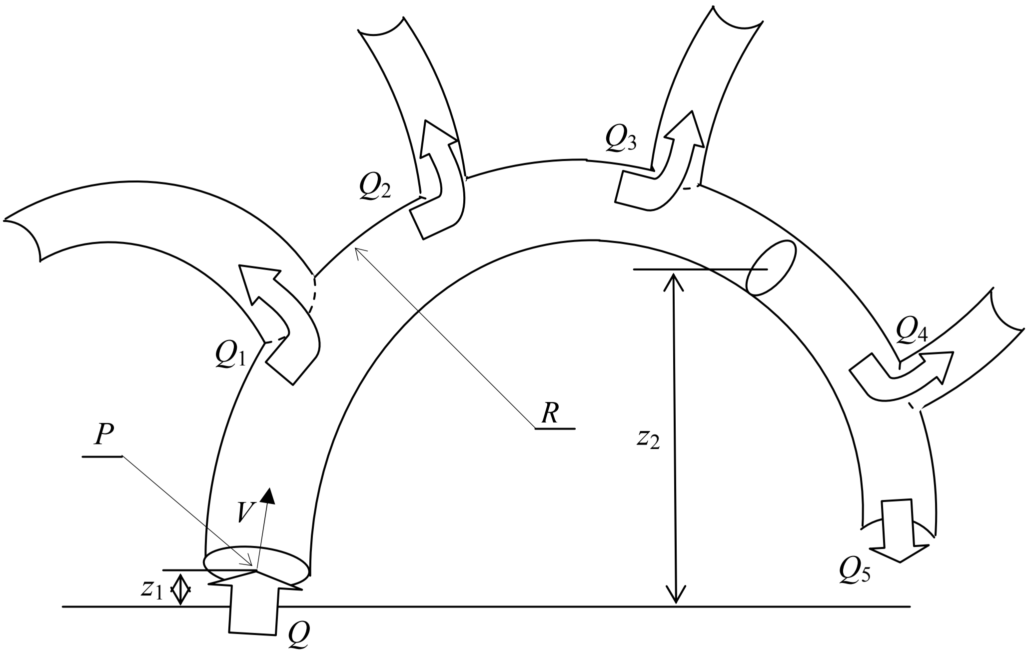

Fig. 2. The scheme of the aortic arch: Q is blood stream from the heart; Q_1 is stream in the artery of the right hand; Q_2–Q_3 are streams to vessels of the head; Q_4 is stream to the left hand; Q_5 is blood stream in the inferior branch of the aorta; R is radius of the aortic arch; z is arrangement height of the centre of gravity of section over by any way chosen horizontal plane (comparison plane); z_1 is the first section – initial; p is pressure (absolute or superfluous); V is average velosity in the centre of section

On the contrary, the less is pressure at the artery entrance, the more slowly speed of blood stream in organ, the more stagnant is saturation of carbon dioxide in the muscle, the weaker is the muscle.

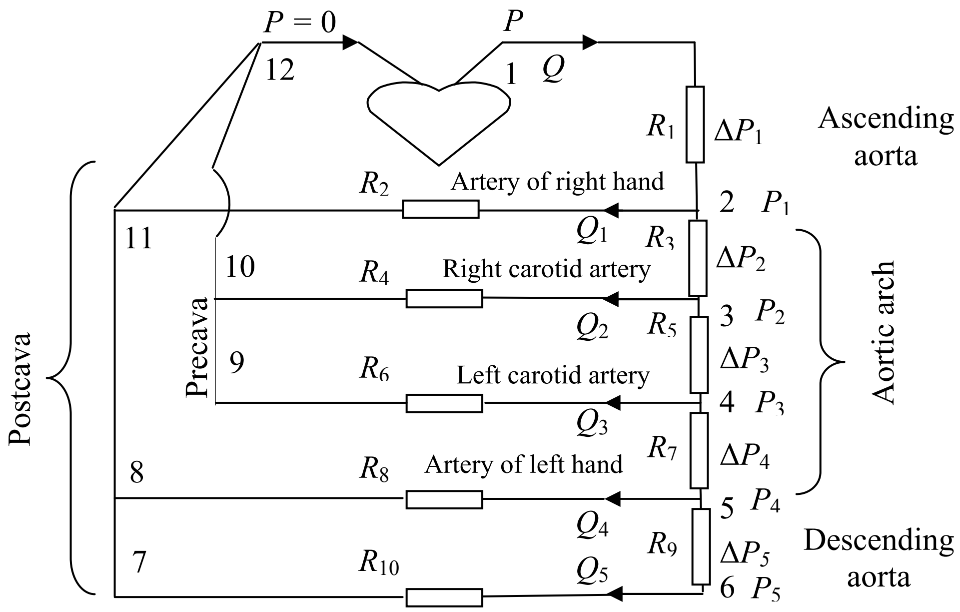

Fig. 3. The haemodynamic scheme of blood circulation in the greater arterial circle (by method of electrohydraulic analogies)

For example, during run at the stadium or in a life, the pulse of running man becomes more frequent to bring oxygen to the muscles participating in run as much as it possible, and to take away from them carbon dioxide faster. If there is insufficient oxygen, then runner is just suffocating.

The human blood represents a liquid and its movement can be investigated by the liquid movement methods.

In biomechanics, the principles of hemodynamics studying blood movement mechanisms in cardiovascular are known. Laws of consecutive and parallel of vessels resistance connection are successfully applied. “The tree of a human” made by A. Noordergraaf, for the basic blood vessels (see e.g. [4]) is known.

The aortic arch with the arteries departing from it and system of the arteries departing from the aorta can be presented by the method of electrohydraulic analogies by the scheme of active resistance (Fig. 3). For calculation of the general peripheral resistance of vessels in the greater arterial circle, the special formula (3) (see below) is obtained.

In the scheme of Fig. 3, there are following designations:

point 1 is the exit from the heart (*ostium aortae*), the beginning of the ascending aorta (*aorta ascendens*);

point 2 is the beginning of the right subclavian artery (*a. subclavia dextra*);

point 3 is the beginning of the right common carotid (*a. carotis communis dextra*);

point 4 is the beginning of the left common carotid (*a. carotis communis sinistra*);

point 5 is the beginning of the left subclavian artery (*a. subclavia sinistra*) and the beginning of the descending aorta (*aorta descendens*);

point 6 is the beginning of aorta's other part and the arteries connected with it;

points 7, 8, 11 are points of corresponding veins exit in the postclava;

points 9, 10 are points of corresponding veins exit in the precava;

point 12 is the confluence of the precava and postclava.

In haemodynamics, it is considered that in points 7–12 pressure $P = 0$.

Q is a stream from the aorta bulb (*ostium aortae*);

Q_1 is stream in the right subclavian artery;

Q_2 is stream in the right common carotid artery;

Q_3 is stream in the left common carotid artery;
Q_4 is stream in the left subclavian artery;
Q_5 is stream in aorta's other parts and the arteries connected with them.
ΔP_1 is pressure drop between points 1 and 2;
ΔP_2 is pressure drop between points 2 and 3;
ΔP_3 is pressure drop between points 3 and 4;
ΔP_4 is pressure drop between points 4 and 5;
ΔP_5 is pressure drop between points 5 and 6.
Thus, the general stream is

$$Q = Q_1 + Q_2 + ... + Q_n = \sum_{i=1}^{n} Q_i . \tag{1}$$

The parameters on the input of the scheme (Fig. 3) are stream Q, average pressure P, and the general peripheral resistance of vessels R, which are connected by known relations.

$$Q = \frac{P}{R} \quad \text{and} \quad P = QR . \tag{2}$$

Here, Q and P are set as known values, but R is unknown.

If separate resistances of each artery (Fig. 3) are known, then general resistance R between points 1 and 12 can be found by formula (3)

$$R = R_1 + \cfrac{1}{\cfrac{1}{R_2} + \cfrac{1}{R_3 + \cfrac{1}{\cfrac{1}{R_4} + \cfrac{1}{R_5 + \cfrac{1}{\cfrac{1}{R_6} + \cfrac{1}{R_7 + \cfrac{1}{\cfrac{1}{R_8} + \cfrac{1}{R_9 + R_{10}}}}}}}}}, \tag{3}$$

where R_1 is resistance of the ascending aorta (from the aortic bulb to point 2), length of the ascending aorta usually is about 60 mm, diameter of the aortic bulb is about 25–30 mm;
R_3 is resistance in the aortic arch between points 2 and 3;
R_5 is resistance in the aortic arch between points 3 and 4;
R_7 is resistance in the aortic arch between points 4 and 5;
R_9 is resistance of the descending aorta;
R_2 is resistance in the right subclavian artery;
R_4 is resistance in the right common carotid artery;
R_6 is resistance in the left common carotid artery;
R_8 is resistance in left subclavian artery;
R_{10} is resistance in other parts of the aorta and the arteries connected with them.

The formulas of kind (3) are known in mathematics and are calculated recurrently (see [4, 5]).

Each of resistance in formula (3) can be determined by Poiseuille's formula (4)

$$R_i = \frac{8 l_i \eta}{\pi r_i^4}, \tag{4}$$

where l_i is length, r_i is radius of corresponding artery; η is viscosity of blood.

Resistance values R_1, R_3, R_5, R_7, and R_9 are small, but they take place and can be calculated by diameter value and each of aorta sites length.

The basic resistances influencing mainly on blood streams in the arteries are R_2, R_4, R_6, R_8, and R_{10}.

Resistance R is very important for a human body and for the further calculations, because it is used in all below-mentioned formulas (5–16). Knowing it, one can be calculated blood pressure drop ΔP_1 between the aortic bulb and the right subclavian artery beginning:

$$\Delta P_1 = Q\,R_1, \tag{5}$$

whence pressure

$$P_1 = P - \Delta P_1 = Q\,(R - R_1). \tag{6}$$

Knowing pressure P_1 and resistance of the right subclavian artery R_2, one can be calculated stream value Q_1 through the right subclavian artery:

$$Q_1 = \frac{P_1}{R_2} = \frac{Q(R - R_1)}{R_2}. \tag{7}$$

Besides, same pressure P_1 participates in creation of streams Q_2, Q_3, Q_4, and Q_5. But at first, it is necessary to determine pressure drop value ΔP_2 between points 2 and 3:

$$\Delta P_2 = (Q - Q_1)\,R_3. \tag{8}$$

Then, pressure is

$$P_2 = P_1 - \Delta P_2 = Q\,(R - R_1) - (Q - Q_1)\,R_3. \tag{9}$$

Knowing P_2, one can be calculated a stream in the right common carotid Q_2:

$$Q_2 = \frac{P_2}{R_4} = \frac{Q(R - R_1)}{R_4} + \frac{(Q - Q_1)R_3}{R_4}. \tag{10}$$

Pressure P_2 is used for pressure drop determination between points 3 and 4

$$\Delta P_3 = (Q - Q_1 - Q_2)\,R_5. \tag{11}$$

Pressure P_3 is

$$P_3 = P_2 - \Delta P_3 = Q\,(R - R_1) - (Q - Q_1)R_3 - (Q - Q_1 - Q_2)\,R_5. \tag{12}$$

By value of pressure P_3, we find stream Q_3

$$Q_3 = \frac{P_3}{R_6} = \frac{P_2 - \Delta P_3}{R_6} = \frac{Q(R - R_1)}{R_6} + \frac{(Q - Q_1)R_3}{R_6} + \frac{(Q - Q_1 - Q_2)R_5}{R_6}. \tag{13}$$

Then, we find ΔP_4 and P_4

$$\Delta P_4 = (Q - Q_1 - Q_2 - Q_3)\,R_7 \tag{14}$$

and

$$P_4 = P_3 - \Delta P_4 = Q\,(R - R_1) - (Q - Q_1)R_3 - (Q - Q_1 - Q_2)\,R_5 - (Q - Q_1 - Q_2 - Q_3)\,R_7. \tag{15}$$

With expressions (15) and (6), we can find required relation between pressure at the left and right hands ξP

$$\xi P = \frac{P_4}{P_1} = \frac{Q\,(R - R_1) - (Q - Q_1)R_3 - (Q - Q_1 - Q_2)\,R_5 - (Q - Q_1 - Q_2 - Q_3)\,R_7}{Q\,(R - R_1)}. \tag{16}$$

Also, it is possible to find the flow through the left subclavian artery Q_4

$$Q_4 = \frac{P_4}{R_8}. \tag{17}$$

CHANGES IN HUMAN ARTERIAL PRESSURE AT THE MOMENT OF ITS MEASUREMENT USING KOROTKOV'S METHOD

Method of N.S. Korotkov was developed in 1905 and was recognised as an official method of clinical measurements of arterial pressure for further diagnostics. However, the tonometer cuff completely stops a blood circulation in the right or left hand (in an artery, arterioles, capillaries and veins) at the instant of measurement. So, normal distribution of pressure in blood circulation system is essentially broken. Blood stream has not any influence on artery with cuff because blood flows past of it. Fig. 3 illustrates the expression for full peripheral resistance R_R at the right hand at the instant of measurement with conditions $R_2 = \infty$ and stream $Q_1 = 0$.

$$R_R = R_1 + \cfrac{1}{0 + \cfrac{1}{R_3 + \cfrac{1}{\cfrac{1}{R_4} + \cfrac{1}{R_5 + \cfrac{1}{\cfrac{1}{R_6} + \cfrac{1}{R_7 + \cfrac{1}{\cfrac{1}{R_8} + \cfrac{1}{R_9 + R_{10}}}}}}}}}. \qquad (18)$$

Calculation of peripheral resistance of arteries

Blood vessel, resistance	Length*, cm	Internal radius, cm	Resistance R_i in formula (4), g/(cm^4·sec)
Ascending aorta, *aorta ascendens*, R_1	8.0	1.5	0.149
Right subclavian artery, *a. Subclavia dextra*, R_2	162	0.88	25.452
Aortic arch (beginning), *arcus aortae*, R_3	3.5	1.45	0.0746
Right common carotid artery, *a.carotis communis dextra*, R_4	95	0.75	28.289
Aortic arch (middle), *arcus aortae*, R_5	4.2	1.35	0.119
Left common carotid artery, *a.carotis communis sinistra*, R_6	95	0.75	28.289
Aortic arch (ending), *arcus aortae*, R_7	3.5	1.25	0.1351
Left subclavian artery, *a. subclavia sinistra*, R_8	162	0.83	32.162
Thoracic aorta, *aorta thoracalis*, R_9	4.5	1.24	0.179
Abdominal aorta and other arteries of the greater arterial circle, R_{10}	116.2	1.23	4.784

* The length of subclavian arteries, carotid, and other arteries corresponds to length of its blood circulation: (l_{R_1} is the length of the ascending aorta plus distance to an input in the right subclavian artery, $l_{R_2} = l_{R_8}$ is the double length from the aorta to tips of hands fingers, $l_{R_4} = l_{R_6}$ is the double length from the aorta to head top, $l_{R_{10}}$ is the length with short sites of blood stream in gastroenteric path and in kidneys that absorb a lot of blood). According to formula (4), value of blood viscosity was used $\eta = 3.7\ 10^{-2}$ g/(cm·sec)

The situation for pressure measurement at the left hand is similar to the situation for right hand blood circle and $R_8 = \infty$, $Q_4 = 0$. The expression for general peripheral resistance R_L is

$$R_L = R_1 + \cfrac{1}{\cfrac{1}{R_2} + \cfrac{1}{R_3 + \cfrac{1}{\cfrac{1}{R_4} + \cfrac{1}{R_5 + \cfrac{1}{\cfrac{1}{R_6} + \cfrac{1}{R_7 + \cfrac{1}{0 + \cfrac{1}{R_9 + R_{10}}}}}}}}}. \tag{19}$$

Expressions (18) and (19) with parameters from table gives us results $R_R = 3.69169$ g/(cm^4·sec) and $R_L = 3{,}53929$ g/(cm^4·sec).Thus, we have a relation of the full peripheral resistances for three different kinds of the scheme (Fig. 3)

$$R < R_L < R_R,$$

$$3.2587 < 3.53929 < 3.69169.$$

This inequality definitely asserts that arterial pressure of any hand in human body raises during measurement.

Experimental results

The data of a man with growth of 175 cm and weight of 75 kg are usually taken for numerical calculations of various hemodynamic parameters. For ξP calculations of such person with expression (16), we can use parameters from table.

Calculation of resistance R with (3) gives $R = 3.2587$ g/(cm^4·sec) .

The heart of an average man in a rest pumps about 5 litres of blood per minute ($Q = 83.3$ ml/sec). Measurements of local blood circulation system [8] in rest show that the brain obtains about 14% of full blood volume per minute, the heart about 3.5–5%, the top extremities 20%, the gastroenteric path 23%, kidneys 22%, skin 4%, and the others (bones, fatty fabric, connecting fabric, etc.) obtain about 14%. The value of volume blood flow in *aorta thoracalis* is 3.02 l/min.

So, resistances R_3–R_7 have influence on the difference between blood streams in the right and left hands (Fig. 3). Both carotids R_4 and R_6 take about 0.8 l/min of volume blood flow. It reduces a blood stream, so pressure at the left subclavian artery becomes lower than at the right hand.

Calculations with expression (2) give the value of pressure $P = 271.449$ ml·g/(sec^2·cm^4).

Calculations with (5)–(17) give $Q_1 = 10.177$ ml/min, $Q_2 = 8.964$ ml/sec, $Q_3 = 8.694$ ml/sec, $Q_4 = 7.414$ ml/sec, $P_1 = 259.037$ ml·g/sec^2·cm^4, $P_4 = 238.454$ ml·g/sec^2·cm^4.

The most interesting parameter is the relation between pressure at the entrance into the left subclavian artery and at the entrance into the right subclavian artery for usual (not left-hander) man

$$\xi P = \frac{P_4}{P_1} = 0.92, \tag{20}$$

and relation between blood streams through subclavian arteries of the left and right hand is

$$\xi Q = \frac{Q_4}{Q_1} = 0.729. \tag{21}$$

Arterial pressure of the average healthy man was measured by an automatic digital tonometer "*UA–*777 *DIGITAL PRESSURE MONITOR*" [2] for checking results of expression (20). It excludes subjective visual mistake in measurement by arrow devices. Conditions of arterial pressure measurements are standard and correspond to [2]. It was a warm sunny day without a wind, air pressure was about 760 mm Hg.

Standard man position (a cuff on the right forearm, sitting and the hand on the table) gives the following result: 143/70-62.

The measurements at the left hand (with similar conditions) gave result: 124/70-62. Both measurements were performed with an interval of 2 minutes

The relation between pressure is

$$\xi P = \frac{AP_L}{AP_R} = \frac{124}{143} = 0.87, \tag{22}$$

where AP_R and AP_L is the arterial pressure measured accordingly at the right and left hand.

Thus, there is an essential distinction of the pressure measured at the left and right hands. Arterial pressure measured at the left hand comprises only 87% from pressure at the right hand, as we wished prove. The fact is rather important, that at the relation of pressures at an input of subclavian arteries equal to 0.92, the relation of streams of blood through these arteries has given size 0.729.

Thus according to formula (20), it is visible that pressure in the arch of the aorta after passage of blood of a way from the artery of the right hand to the artery of the left hand falls. Sizes of streams of blood departing to the arteries (21) change more considerably. As this takes place, the blood stream in the artery of the left hand almost 27% less than the same parameter in the artery of the right hand.

It is necessary to notice that the relation of arterial pressures at measurements by the physical device in forearms of hands (20) differs from vascular pressure at inputs in corresponding arteries of the scheme (Fig. 3) of electrohydraulic analogies (20). To measure now *in situ* the pressure which is equivalent to (20), is not possible.

Features of the described movement of blood can be investigated and by means of finite element method in program complex *ANSYS* in the environment of *FLOTRAN* [7].

Such research allows us also with some approximation but very informative to demonstrate distribution of speeds of motion, pressure and set of other parameters in three-dimentional space.

In Fig. 4, the example of distribution of total speed (VSUM) in a site of the arch of the aorta is presented where the right subclavian and the right common carotid arteries are located. It is visible that unlike exact mathematical calculation where average pressure and speed in cross-section of stream at the input of an artery are used, there is a presence of features of distribution of speed of the stream with increase of speeds near external (larger) radius in comparison with the speed near internal (smaller) radius. Besides, there are peculiarities of the stream round places of the input of the stream in departing arteries.

Statement and the solution of the boundary value problem of haemodynamics of the blood stream in the aorta arch are executed by the first variant of the solution in *FLOTRAN* item 6.1.3 [7] (with rigid walls). The model has been constructed on a bow-shaped artery with average radius of the arch 10 cm and departing arteries according to given table. The boundary value problem has been put, boundary conditions have been set and unstructured tetrahedron mesh was constructed.

Blood parameters: density is 1.067 g/cm^3, constant viscosity is η = 3.7 10^{-2} g/(cm·sec). Speed at the input into the ascending aorta, *aorta ascendens*, is a constant over the area of entrance cross-section 20 cm/sec (the stream yet has not generated a parabola of speed). Mesh nodes at the entrance surface are fixed $U_x = U_y = U_z = 0$, pressure at the exit $P_к = 0$ (cava). Components of speed on walls (a sticking condition) $V_x = V_y = V_z = 0$.

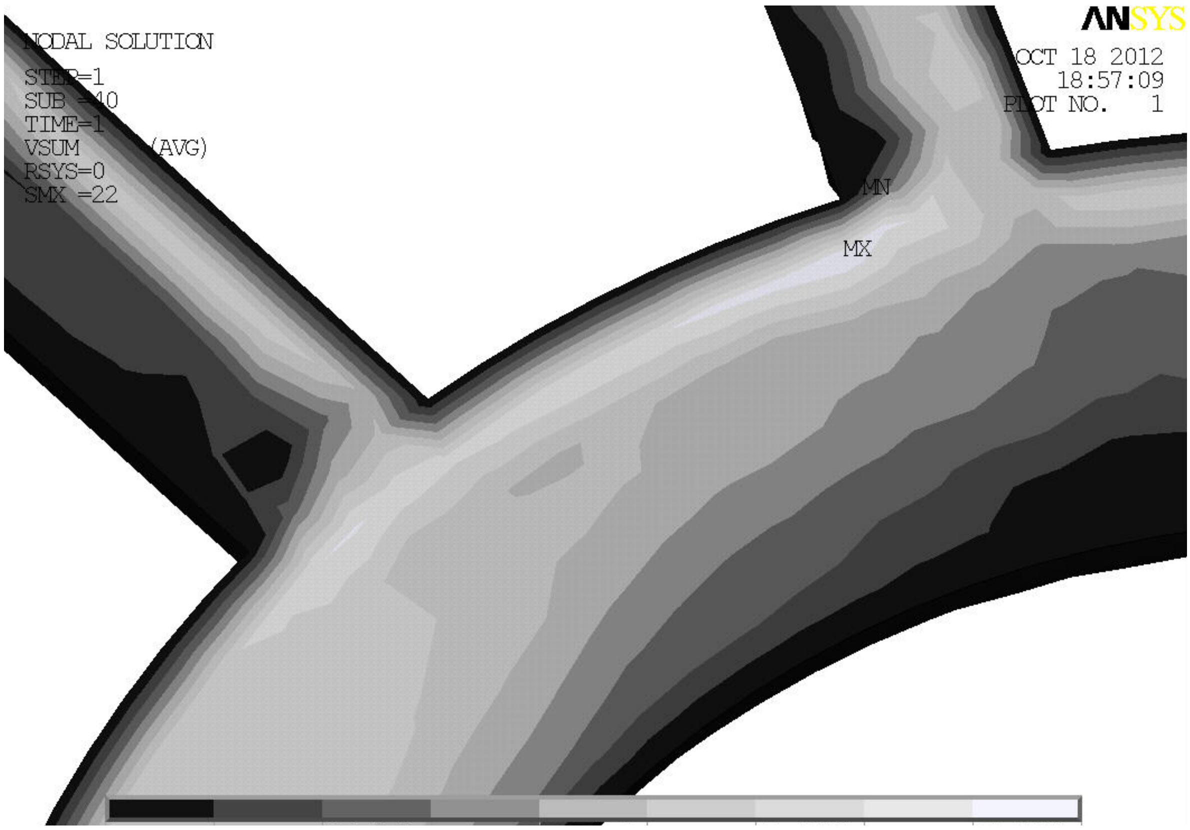

Fig. 4. Distribution of total velocities of a stream of blood over a part of the aortic arch, in the right subclavian artery and in the right common carotid artery obtained in program complex *ANSYS* 13.0

Presence of features of distribution of speeds of the stream with distinction is shown: speed near the external radius in comparison with speed near the internal (smaller) radius of the stream increases to the external radius. Besides, the features take place round places of the input of the stream into departing arteries.

QUESTION ABOUT STRENGTH AND WORK OF HANDS

Mechanical parameters of a muscle are defined by oxygen in blood. When the breath terminates even for 2–3 minutes, the muscle loses its functionality and the death comes. On the other hand, in the case of heavy physical activities, the blood minute volume raises and can reach 25 l/min. It is well known that the muscular blood stream can increase a 20 times.

There are three kinds of muscle tissues in human body (and in vertebral animals) for different movements: skeletal, cardiac, and smooth that consists from muscular fibers. There are blood vessels and nerves in every muscle.

When the muscle contracts, it operates on a bone like a lever and produces a mechanical work. Any muscular contraction is connected with energy consumption. Sources of this energy are processes of oxidation and disintegration of organic substances (carbohydrates, lipids, nucleinic acids).

Blood flow supplies muscles with oxygen and nutrients and takes away carbonic gas and other products of disintegration. The force and work level of muscle increase with increase of blood stream in it.

So, oxygen increasing in the blood stream in the right hand raises mechanical strength of the right hand in comparison with the left hand.

There are some deviations in system of the aorta and peripheral arteries.

1. The right subclavian artery and the right general carotid are departing not directly from the aorta, but from the brachiocephalic trunk (*truncus brachiocephalicus*) (*a. anonyma* (BNA)) through bifurcation.

2. The brachiocephalic trunk is departing not from the right side, but from the left one.

3. Two brachiocephalic trunks are very rare event.

It is clear that for any structure of blood system circulation are available various schemes in Fig. 3, different expressions for peripheral resistance of vessels calculations (4), and various results of resistance R at similar initial conditions Q.

BIOMECHANICS OF THE LEFT-HANDER

All told above was the evidence why the right hand is stronger than left one. But why people can be left-handers?

Various strange forms of the life can appear in different conditions. Left-handers appear in cases of deviations of the various life conditions which can influence on increase of pressure and blood stream in the left hand. In this situation, the left hand can become stronger and skillful than right one.

There are some cases of deviations.

1. Different natural deviations of the left artery lead to increase of arterial diameter. As a result, despite the left hand pressure at the aorta arch entrance is less than pressure at the right hand, the blood stream in the left hand will be greater and the muscles of the left hand will obtain more blood.

It is easy to realize because resistance of the artery extremely depends (4) on radius (in fourth degree). For example, the stream Q_4 will be more than Q_1 if the internal radius of the left subclavian artery of the left-hander will be greater by 8.2% (with value 0.898 (see table) but not with value 0.83 cm) and with conditions from table and relations between pressure (20) $P_4/P_1 = 0.9$.

2. Parents of the left-hander (the father or mother) before his birth had the job connected with the larger loading on the left hand. As a result, the left hand became more strong and skillful and their child obtained it by inheritance.

3. These changes of organs are known. For example, professional musicians playing the wind-instruments have a sharp deviation in the sizes of the lungs, because they make the lungs to do work on generation of sounds on the trumpet or the trombone. Therefore, the lungs change their sizes for getting more air reserve.

4. For some reasons, early age children are forced to do something all time by the left hand instead of doing by the right hand. With the growing up of a man, this incomprehensible habit goes to norm and he becomes the left-hander.

5. Besides, in many cases, the man needs to have both the right and left hands of equal force. For example, he needs in the weight-lifting to lift heavy barbell by both hands. He has to train many years the left hand in order to do it by equal to the right hand force, to the extent that he begins to do this by increasing the left artery diameter and arterial pressure in it.

6. Rare cases, but also are known. At right-side arrangement of the heart, automatically the right hand and left hand change roles.

MEASUREMENT OF ARTERIAL PRESSURE AT THE LEFT-HANDER

Doing a measurement of arterial pressure at the left-hander, we assume that stream $Q_4 > Q_1$, for example, $Q_4 = 11$ ml/sec. However, at the moment of measurement at the left hand, the stream stops, and the device will show smaller value of arterial pressure.

Calculation is as follows:

When measuring pressure in the left-hander at the left hand, pressure P_4 is equal to:

$$P_4 = [(Q - Q_4) - (Q_1 + Q_2 + Q_3)]\cdot(R_9 + R_{10}) = 44.465\cdot4.963 = 220.68 \text{ ml}\cdot\text{g}/(\text{sec}^2\cdot\text{m}^4),$$

and pressure $P_1 \approx 259$ ml·g/(sec^2·cm^4). That is, $P_4/P_1 = 0.85$.

When considering question of force and hands work, we proposed the proposal: the bigger is the blood stream in the muscle, the bigger work it can make, the stronger it becomes. It has been shown that because of increase of the left hand artery radius by 8.2% the blood stream through it will be more, than the blood stream through the right hand artery and for this reason the man can become the left-hander.

One managed to find two persons having criteria of the left-hander.

The first one is a woman 27 years old, growth of 168 cm, weight of 58 kg. She works fine by the left and right hands in the polygraphy enterprise on the computer and has informed on the important data, “there are many left-handers, but they hide it”. Thus, existence of the left-hander is rather delicate problem. For example, she has refused to measure arterial pressure and to name her known left-handers. It was possible to determine that she is left-hander, only by how she was writting a check to the cashier for payment for her services. She was writing the check by the left hand.

The second one is a man 51 years old, growth of 185 cm, weight of 90 kg. His pressure on device *UA*–777 at the right hand is 132×75×68, and at the left hand is 118×78×69.

The relation of pressure:

$$\xi P = \frac{AP_L}{AP_R} = \frac{118}{132} = 0.893\,.$$

Thus, there are real results confirming the research stated in the article.

Conclusions

1. This results of research proves that blood pressure at the right hand is more important than pressure at than left hand, therefore it is necessary to change the rules of arterial pressure measurements (at the forearm of the right hand but not at the left one).
2. Of course, this rule can be changed in a case of left-hander, but for this purpose it is necessary to know that the patient is a left-hander by heart position.
3. The conventional left-hander may have pressure at the entrance of the left subclavian artery less than at the entrance of the right subclavian artery and the blood stream through the left artery can be higher. So, the left hand will be more powerful and skillful. It is the main reason why this man became the left-hander.

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