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Morphology of the spleen and its ligamentous apparatus

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Abstract

Background: Knowing structural aspects of spleen is of interest, especially in surgical interventions, both urgent and elective ones, particularly in modern times when surgical interventions wider take place with maximal preserving injured organs, including in isolated or concomitant abdominal trauma.
Material and methods: Spleen capsule histoarchitectonics was studied by histotopograms with hematoxylin and eosin, van Gieson's, Weigert's resorcinol and fuchsine staining. The following parameters were studied depending on age and gender by morphometric method: spleen form, linear dimensions of spleen and its ligaments. Descriptive statistics allowed presenting results in tables.
Results: In teenagers (age Group VII), the most frequent form of the spleen is the intermediate one, while in adults (Groups VIII1 and VIII2) and people of the senile age – the prolate form. Difference in spleen length is statistically significant in age Groups VII and VIII1 – 121.5±3.12 mm and 125.1±3.08 mm respectively in men; 94.7±2.09 mm and 85.8±2.11 mm – in women ($p<0.001$). Difference in the spleen width depending on gender is statistically significant for Group VII – 77.2±2.11 mm in men and 61.6±2.25 mm in women; in age Group VIII1 – 78.1±2.07 mm in men and 59.2±2.16 mm in women. For the examined age group the mean height of the gastrolienal ligament is 51.8±0.81 mm for men, and 45.9±1.00 mm for women.
Conclusions: The capsule of spleen is formed by collagen fiber fascicles, elastic fibers as well as relatively few myocytes. The height of the gastrolienal ligament is bigger in men than in women. Spleen dimensions decrease with aging.
Key words: spleen, capsule, ligaments, form of spleen.

Introduction

Industrial development, agricultural mechanization, sports promotion in population, increasing number of tourists lead to growth of injury cases that in recent years hold an important place in mortality. According to WHO data, each year 8-10 million patients are admitted to hospitals with various injuries [1].

In the Republic of Moldova, injury incidence constitutes 4946.3 cases per 100 000 people, and in mortality structure

injuries constantly occupy the 3rd place, along with cardiovascular and oncologic diseases [2]. Serious concomitant chest and abdominal trauma is one of the severest conditions, both during military conflicts and peaceful daily life. According to literature data, its rate ranges between 4 - 5% [3] and 10% [4]. In recent years, there is a tendency of this rate to increase up to 18% [5, 6, 7].

Frequency of spleen injuries is increasing in recent times [8]. According to reports, their rate is growing, the incidence varying from 15.5% [3] in closed injuries to 58.17% in open abdominal traumas among all concomitant thoracoabdominal lesions [9].

Knowing structural aspects of spleen is of interest, especially in surgical interventions, both urgent and elective ones, particularly in modern times when surgical interventions wider take place with maximal preserving injured organs, including in isolated or concomitant abdominal trauma. The present research objective is elucidation of some peculiarities of spleen structure and ligaments.

Material and methods

Spleen capsule histoarchitectonics was studied by histotopograms with hematoxylin and eosin, van Gieson's, Weigert's resorcinol and fuchsine staining.

The following parameters were studied depending on age and gender by morphometric method:

- Linear dimensions of spleen ligaments (in 65 cadavers);
- Spleen form in humans (in 273 cadavers: 154 men and 119 women);
- Spleen dimensions (184 gross specimens from adults (106 men and 78 women)).

Descriptive statistics allowed presenting results in tables.

Results and discussion

In the abdominal cavity the spleen is situated in the superior part and contacts with the diaphragm, stomach, tail of the pancreas, left angle of the colon, left adrenal gland, and left kidney.

The spleen is covered with a fibrous capsule that coalesces to its exterior with the peritoneum. The structure of the conjunctive layers of the spleen is based on some morphofunctional particularities that ensure, on the one hand, its tenacity, and on the other hand offer to the organ possibilities of extension. The parenchyma and conjunctive stroma of the spleen are integrated components. The conjunctive skeleton represents a conjunctivoelastical bioconstruction that executes the trophic function, is used as a support for the organ, maintains the specific form of the spleen, ensuring the pulp cells an intimate contact, creating an optimal biological environment based on distribution of nutritive substances and metabolism products elimination through the vascular tree.

According to publications [10, 11], the stroma represents a complex structure, formed from the organ capsule, intrasplenical perivascular layers, trabecules made of conjunctive tissue and a reticulate matrix for the red pulp and lymphoid follicles that form the white pulp.

The authors [12, 13, 14] describe outside the spleen a serous layer, under which can be found the fibrous layer, called classically splenic capsule. The capsule is very brittle, well defined, composed of dense connective tissue. It contains elastic fibers and myocytes among rare collagen fibers. From the capsule conjunctive trabecules leave into its inside, gradually branching and intersecting, forming incompletely demarcated spaces that communicate and house the splenic parenchyma.

M. Raica et al. (2009) believe that in humans, smooth muscle cells almost miss in the capsule structure, and therefore the spleen does not act as a blood reservoir. The stroma of red and white pulp, in turn, is formed by reticular tissue, representing a three-dimensional network forming the supporting structure and providing a functional microenvironment for the parenchyma.

In our study, the spleen exterior is defined by a well-shaped capsule with rectilinear and, more rarely, sinuous trajectory. The capsule introsusceptions in most cases do not fall deeply in the organ, but when forming deep fissures their walls are formed by fibrous tissue.

The thickness of the capsule varies from one sector to another of the spleen, and this is observed in all age groups. The course and thickness of the capsule do not depend on the organ shape or gender. Sometimes on the same organ, along the straight path of the capsule, thickenings are observed with changes in the trajectory path and fibrous layer thickness.

The visceral peritoneum covers entirely the spleen, excluding the hilum of the organ; it accretes intimately with organ's fibrous tunic. It should be noted that the peritoneum is characterized by a less pronounced development of networks of elastic fibers in relation to the well-developed collagen fibers, which is a basic structure of this anatomic formation, with a specific elasticity. They, to the extent of their physical and mechanical properties, cause quite high tenacity of serous tunic of the organ. In the visceral peritoneum spleen ligaments are inserted possessing a number of important functions for the organ [16, 17, 18, 19].

On the whole length of ligaments insertion on the splenic capsule, regardless of age, in the peritoneum there are nerves, blood vessels of different caliber, which link them with the organ. Very thin collagen fibers of the splenic ligaments and external tunic of vessels participate in the formation of the outer layer of the capsule. In the sectors of transition from the peritoneum to the splenic capsule surface, where an obvious tension force influences the organ, histotopography of the colagenoelastical elements modifies, the fascicles become thicker. Collagen fibers are well developed, wavy, forming fascicles composed of connective elements arranged free, easily expandable. In the hilum region, the capsule is strengthened with collagen fibers oriented in all directions, leaving from the pancreaticolienal ligament, accompanying blood vessels.

The visceral peritoneum on the diaphragmatic surface accretes intimately with the thin outer layer of the capsule, with collagen fibers stacked compact, almost without gaps, oriented parallel to the organ surface.

There is not a single opinion in the literature on the number of layers of tissue capsule and their composition. Ac-

cording to some data [20, 21], connective tissue membrane of the spleen presents a heterogeneous formation that consists of two slides with different origin. The external lamella is the peritoneum's visceral tunic and the internal one - a thin sheet of connective tissue, strong and low-stretching - fibrous tunica that accretes outward with the peritoneum. It consists of a network of collagen fibers, elastic fibers, and smooth muscle cells, the last ones giving the possibility of contraction

A. P. Sorokin et al. (2009) suggest that the splenic capsule consists of three layers: external, medium, and internal - which is adjacent to the splenic pulp. The outer layer thickness is 18-45.15 mkm. It consists of thin collagen fibers (1.5x1.5 - 14x25 mkm) with diverse orientation. The medium spleen layer is the thickest (38.7 – 85.5 mkm), its fibers become thicker and bed compact spaces. The profound layer is at the border with the organ parenchyma, having a thickness of 19.9-57 mkm. Collagen fibers of 1.5 to 8.5 mkm lie freely having various orientations.

According to own data, taking into account size and character of fibrous fascicles, we distinguish only 2 layers of the capsule: external and internal. The outer layer of the capsule is composed of well-developed collagen bundles, wavy, stacked compact with parallel orientation on the surface of the organ. The thickness and orientation of collagen bundles are very individual. They pass into free spaces and interweave with collagen fibers from the inner layer of the capsule, increasing the thickness of this portion.

On the visceral surface of the spleen, the external layer of the capsule becomes more compact. The collagen fibers are situated freely, with evident spaces between them. The fascicle trajectory can be oblique or perpendicular to the longitudinal axis of the organ. At the border with the visceral peritoneum, in the outer layer of the capsule, blood and lymphatic vessels are present. Perivascular collagen fibers are well-developed and represented by conjunctive fascicles.

The internal layer of the capsule situated at the border with the pulp of the organ has thin collagen fibers, situated freely with different space orientation. In the center of the layer their direction is parallel with the surface. At the periphery of the layer, the fibers associate in bundles, their density rises around the blood vessels. The direction of the collagen fibers of the internal part when passing into the parenchyma of the spleen is obliquely perpendicular.

In the capsule elastic fibers are present, arranged compactly, sometimes with free spaces in the peripheric portion, filled in with fundamental substance and blood vessels in the peripheric zone. The central part of the capsule is formed of corrugated fascicles, arranged freely, although sometimes compactly, passing to the perpendicular direction to the splenic surface.

The collagen fibers from the capsule spread into the depth of the spleen in the form of conjunctive tracts named *splenic trabecules*. The trabecules contain more contractile elements than the capsule, go through the organ, representing not only attachment structures of the reticular stroma and parenchyma, but also the storage of the blood vessels.

In some cases the splenic trabecules are formed by the confluence of two conjunctive branches with their origin in the internal layer of the capsule. The branches unite near the capsule, forming a thick and long trabecule, or they penetrate deeply into the parenchyma and confluent there. In other cases, the internal layer of the capsule is well-developed, formed of corrugated thick collagen fibers that unite in bundles, and change the orientation into transversal forming incipient trabecules. Sometimes the trabecules start from a thickening of the internal layer of the capsule, modifying the thickness and architectonics of the internal layer.

Dimensions, form and direction of the trabecules in the parenchyma of the spleen vary a lot. In some cases, a trabecule begins with 2-3 thin fascicles that do not change evidently the architectonics of the internal layer. In the depth of the organ, the trabecule forks and thickens. The trabecules are oriented into the parenchyma of the spleen in different directions and contain 9-12 vessels in their structure. They go through the organ representing not only attachment structures of the reticular stroma but also serve as storage for blood, lymphatic vessels and nerves.

Along with collagen fascicles, in the structure of the trabecules a well-developed net of elastic fibers exists. The elastic fibers form circular perivascular fascicles in the vessel tunics where they strengthen the trabecular structure.

According to authors [22, 23, 24], in some animals the spleen is encapsulated in a musculofiber membrane. In the hilum, on the medial surface of the spleen, the origin capsule branches into trabecules that accompany nerves and vessels in the interior of the spleen. These trabecules are formed of collagen, elastic fibers, doubled by the smooth muscular fibers, thereby forming a skeleton that offers contractility to the spleen. In humans, in the structure of the internal layer of the capsule and in trabecules, number of myocytes is low [25, 26].

The spleen is somehow a mobile organ, especially when performing respiratory movements. The organ is held in place by the peritoneal contacts, by the thorax aspiration and partially by the abdominal pressure, established by the tonic contraction of the abdominal muscles. Its mobility is conditioned concurrently by the stomach and transverse colon mobility. The visceral peritoneum covers the spleen on all its sides, except the hilum and the ligament fixation line, growing intimately with its fibrous tunica, forming the ligaments of the organ.

C. Enculescu (2006) determined that the development of the spleen causes several plicae at the level of the dorsal mesogastrium, that will further participate in the formation of the greater omentum by their transformation into ligaments: phrenicosplenic plica with the development of the phrenicosplenic ligament, pancreaticosplenic, splenorenal and gastrosplenic plicae, the latter developing into the gastrosplenic ligament.

G. I. Vind (1999), examining the spleen ligaments in the context of their embryonic development, considers that the first formation to appear is the gastrolienal ligament. This ligament starts from the greater curvature of the stomach, has a trapezoid form, narrows in the cardiac portion of the

stomach and largens at its inferior portion. The fascia that appeared because of blending the left surface of the dorsal mesogastrium and the posterior parietal peritoneum, passes between the pancreas and the renal fascia. The lateral margin of this blended fascia passes immediately into the posterior margin of the spleen and is called *splenorenal ligament*. The superior part of the blended structure is directed upper than the kidney, and unites the spleen with the diaphragm. This part is called the *phrenicolienal ligament.* Usually, there is a junction between the inferior pole of the spleen and the left flexure of the colon, called the *splenocolic ligament.*

The dorsal embryonic mesogastrium is responsible for the production of the splenic ligaments [12, 32, 33, 34, 35]. After the separation into two plicae, the mesogastrium surrounds the organ, forming 2 main ligaments: gastrosplenic and splenorenal. The following ligaments differentiate from them: splenophrenic, splenocolic, pancreaticosplenic, phrenicocolic, pancreaticocolic, and the presplenic plica. The last ones are named minor ligaments, but they can cause problems in surgery. According to author [36], in 70% of 3-month embryos, the pancreaticosplenic ligament is already formed.

N. P. Bisenkov et al. (1978), A. P. Sorokin et al. (1989) considered that the permanent ligaments of the spleen, well-contoured are the gastrolienal, phrenicolienal, phrenicocolic. From the embryologic point of view, the phrenicolienal ligament is formed as a secondary accreting of the dorsal mesogastrium with the posterior layer of the parietal peritoneum, and from the surgical point of view the ligament represents the mesentery of the spleen, represented by two layers of peritoneum. In case of a high number of ligaments, besides those named anteriorly, the authors distinguish the colicolienal, supplementary gastrolienal, and splenorenal ligaments.

The number of splenic ligaments may vary between 3 and 7 [38]. The minimal number is found in 37% of cases (as a rule, in people with a wider thoracic cavity), and the maximal number – in 12% of cases (as a rule, in people with a narrower thoracic cavity).

The anatomy of the splenic ligaments was also studied by authors [39]. The authors describe 4 main ligaments of the organ: gastrolienal, colicolienal, phrenicocolic and phrenicolienal. The gastrolienal ligament has 2 parts. In the superior part, where the spleen is close to the stomach, the collagen fibers are denser. The authors consider that the term "splenorenal ligament" is uncertain, because besides the peritoneal coverage, there are 3 structures between the spleen and the left kidney: collagen tissue with adipose perirenal tissue, prerenal fascia and an adipose capsule (perirenal adipose tissue). It is important for the surgeon to know the direction of the collagen fibers in the splenic ligaments. In all the ligaments, most fibers come from 2 directions: laterocranial – mediocaudal and mediocranial – laterocaudal.

According to [40], the left phrenicocolic ligament, unlike the right one, is better contoured and can be met in all cases. The phrenicocolic ligament unites with the splenocolic one, and their separation can only be conventional. If the left phrenicocolic ligament is well-developed, the splenocolic ligament can also be noticed, both having a common area of fixation on the transverse colon.

Any kind of abnormal ontogenesis of the main splenic ligaments manifests as their diminution, elongation or absence. The authors [16, 41, 42, 43, 44, 45, 47, 52] consider that the gastrolienal, splenorenal, phrenicolienal and splenocolic ligaments maintain the spleen in the normal position. The main ligaments that prevent ptosis are gastrolienal and splenorenal. The phrenicolienal ligament only limits moving the spleen down [46, 47, 48, 49, 50, 51].

Gastrolienal ligament represents in our study a duplicature of the peritoneum. Its anterior layer leaves from the vertical portion of the greater curvature of the stomach (that forms the bottom of the stomach) to the left and posteriorly, reaching the hilum of the spleen. The uniting of the anterior layer of this ligament with the spleen takes place from near the posterior pole of the organ till the anterior margin of the hilum, and sometimes till the anterior pole, alongside the anterior margin of the spleen. The posterior layer covers the hilum on the gastric surface and is a part of the omental bursa peritoneum. Inferiorly, the gastrolienal ligament transforms into the gastrocolic ligament. The dimensions of the gastrolienal ligament depend on age and gender. Linear dimensions of the ligament have been determined in 3 points: 1) from the stomach to the posterior pole of the spleen; 2) in the splenic hilum region; 3) from the stomach to the anterior pole of the spleen.

Table 1

Height of the gastrolienal ligament in age Group VII, mm

Gender	Group VII									Mean value in the group
	Height			Height			Height			
	At the posterior pole			At the hilum			At the anterior pole			
	min	max	mean	min	max	mean	min	max	mean	
M	28	46	36.8±0.96	42	62	51.7±0.84	52	82	66.9±0.82	51.8±0.81
F	22	45	33.6±1.02	33	60	46.8±1.00	50	65	57.5±0.99	45.9±1.00
t			2.2845			3.7519			7.3124	4.5847
p			<0.05			<0.01			<0.001	<0.01
Total	22	46	35.2±0.99	33	62	49.3±0.92	50	82	62.2±0.81	48.9±0.91

Table 2

Height of the gastrolienal ligament in age Group VIII$_1$, mm

Gender	Group VIII$_1$									Mean value in the group
	Height			Height			Height			
	At the posterior pole			At the hilum			At the anterior pole			
	min	max	mean	min	max	mean	min	max	mean	
B 12	17	26	21.4±1.08	22	42	31.8±1.12	26	61	46.4±1.14	33.2±1.11
F	23	62	42.2±2.32	28	73	50.3±2.16	36	86	60.6±2.18	51.0±2.22
t			8.1279			7.6035			5.7722	7.1715
p			<0.001			<0.001			<0.001	<0.001
Total	17	62	31.8±1.72	22	73	41.1±1.64	26	86	53.5±1.66	42.1±1.67

Table 3

Height of the gastrolienal ligament in age Group VIII$_2$, mm

Gender	Group VIII$_2$									Mean value in the group
	Height			Height			Height			
	At the posterior pole			At the hilum			At the anterior pole			
	min	max	mean	min	max	mean	min	max	mean	
B	8	45	26.2±1.09	12	60	35.6±1.18	14	75	44.1±1.04	35.3±1.10
F	12	42	26.8±1.24	18	56	36.8±1.22	20	78	48.8±1.13	37.5±1.19
t			0.3634			0.7070			3.0604	1.3576
p			>0.05			>0.05			<0.01	>0.05
Total	8	45	26.5±1.17	12	60	36.2±1.20	14	78	46.5±1.09	36.4±1.15

Table 4

Height of the gastrolienal ligament in age Group IX, mm

Gender	Group IX									Mean value in the group
	Height			Height			Height			
	At the posterior pole			At the hilum			At the anterior pole			
	min	max	mean	min	max	mean	min	max	mean	
B	15	40	27.7±1.06	20	62	40.6±1.02	26	78	51.8±1.06	40.0±1.05
F	14	50	31.8±1.20	18	75	45.5±1.14	20	80	48.6±1.12	41.9±1.15
t			2.5607			3.2032			2.0751	1.2201
p			<0.05			<0.01			<0.05	>0.05
Total	14	50	29.8±1.12	18	75	43.1±1.08	20	80	50.2±1.09	43.0±1.09

The information on mean values of the ligament dimensions depending on gender in age Group VII is presented in table 1.

Based on the information presented in Table 1, we can conclude that for the examined age group the mean height of the gastrolienal ligament is 51.8±0.81 mm for men and 45.9±1.00 mm for women. The difference depending on gender is statistically significant (p<0.01).

Table 2 reflects the information on mean values of the ligament height depending on gender in age Group VIII1. Based on the information in the table, we can state that the mean height of the gastrolienal ligament in men is smaller (33.2±1.11 mm) than in women (51.0±2.22mm). The difference depending on gender is statistically significant for the age group analyzed (p <0.001).

The examination results for the second period of maturity (age Group VIII$_2$) are presented in table 3. According to the results, we can conclude that for this age group the mean height of the gastrolienal ligament is 35.2±1.10 mm for men,

Table 5

Height of the gastrolienal ligament, mm

Gender	Group X									Mean value in the group
	Height			Height			Height			
	At the posterior pole			At the hilum			At the anterior pole			
	min	max	mean	min	max	mean	min	max	mean	
B	12	38	24.1±1.08	16	60	37.7±1.16	20	75	47.2±1.04	36.3±1.09
F	12	40	25.4±1.11	20	55	37.2±1.20	24	69	46.8±1.22	36.5±1.18
t			0.8394			0.296			0.2495	0.124
p			>0.05			>0.05			>0.05	>0.05
Total	12	40	24.8±1.09	16	60	37.5±1.14	20	75	47.0±1.02	36.4±1.08

and 37.5±1.19 mm for women. The difference depending on gender is not statistically significant (p>0.05).

Information on mean values of the gastrolienal ligament height depending on gender for advanced age is presented in table 4. The results prove that the mean value of the gastrolienal ligament height in the lot is 40.0±1.05 mm in men, being higher in women – 41.9±1.15 mm. The difference depending on gender is not statistically significant (p>0.05) in Group IX.

Table 5 presents the results of morphometric study of the gastrolienal ligament depending on gender in people of the senile age (75-90 years). Based on the information presented in table 5, we can state that the mean value for both genders is almost equal: 36.3±1.09 mm in men and 36.5±1.18 mm in women. The difference depending on gender is not statistically significant (p>0.05) in Group X.

The phrenicolienal ligament is composed of 2 layers of peritoneum that begin from the lumbar part of the diaphragm. The dorsal layer passes from the left to the right and anteriorly, getting close to the diaphragmatic surface or the posterior margin of the spleen, where it passes on its renal surface. This ligament covers the tail of pancreas and all splenic vessels, including the root of the left gastroepiploic artery. The ligament with its dorsal layer continues down covering a part of the left kidney and forming the splenorenal ligament. The ventral layer of the ligament from the lumbar part of the diaphragm continues to the left, covering the left adrenal gland, comes close to the splenic hilum, where it grows together with the dorsal layer of the mentioned ligament.

The inferior portion of the anterior layer of the phrenicolienal ligament that spreads from the tail of pancreas till the splenic hilum is named the pancreaticosplenic ligament.

The size of the pancreaticolienal ligament depends on the pancreas localization. According to [53], the tail of pancreas touches the spleen in 27% of cases and is situated at a distance of 1 cm from the spleen in 73% of cases.

A. Rosen et al. (1988), having analyzed results of 32 CTs and 37 autopsies, noticed that in 29,7% of autopsies and 25% of CTs, the tail of pancreas was adjacent to the splenic hilum.

If the tail of pancreas is shorter and further from the spleen, posterior layer of the peritoneum forms phrenicolienal or renolienal ligament [55].

The splenorenal ligament is formed of 2 peritoneal layers. The anterior layer that belongs to the omental bursa comes from the posterior wall of the bursa and reaches the hilum of the spleen where it is attached. The posterior layer passes from the anterior surface of the left kidney and reaches the splenic hilum.

Linear parameters and forms of the ligaments are various: long, short, narrow, wide. All these peculiarities determined in the embryonic period can be quite insignificant or may cause splenic ptosis, torsion or deviation. Someway, motility of the spleen depends on elasticity of the splenic ligaments and length of the splenic vessels.

The splenorenal ligament is 2.5-5.5 cm long, it contains between its layers the main splenic vessels (splenic pedicle) and their branches [56].

To avoid surgical complications, we should take into account the variety of forms, surfaces, limits and sizes of the spleen, as well as its relations with adjacent organs [57].

During ontogenesis and ulterior development, the form and dimensions of the spleen modify. Dimensions and pressure of the adjacent organs play an important role in the stabilization of spleen form.

In the special literature different forms of the spleen are described. Author [58], having studied 100 cadavers, describes 3 forms of the spleen: cuneate, tetrahedral and triangular. In the opinion of [37], the organ can have 2 marginal forms: short and wide (oval or almost circular on the diaphragmatic surface) spleen and the other form is narrow and long. Other authors [57] describe 3 forms of the spleen: cuneate (44%), tetrahedral (42%) and triangular (14%).

According to the results of studies [10], the basic forms of the spleen are: discoid, ellipsoid and mixed. The semilunar, unsymmetrical disc, triangular, oval with a sharp anterior pole, oval with a sharp posterior pole forms are named *transitional*. More often (25%) the oval form with a sharp anterior pole is observed, in 16% of cases – unsymmetrical disc form, in 14,5 % – ellipsoid form, in 11,5% – oval form with a sharp posterior pole. And just in 10.5% of cases the semilunar form was

Table 6

Frequency of spleen form types depending on gender

Spleen form	Men, n=154		Women, n=119		t	p
	Abs.	P±ES (%)	Abs.	P±ES (%)		
Prolate <63.0%	79	51.3±4.03	45	37.8±4.44	2.2506	<0.05
Intermediate 63.0-75.0%	57	37.0±3.89	51	42.9±4.54	0.9872	>0.05
Round 76.0% >	18	11.7±2.59	23	19.3±3.62	1.7081	>0.05
Total	154	56.4±3.99	119	43.6±4.55	2.1149	<0.05

Table 7

Frequency of spleen form types in age Group VII

Spleen form	Men, n=16		Women, n=10		t	p
	Abs.	P±ES (%)	Abs.	P±ES (%)		
Prolate <63.0%	7	4.5±1.67	3	2.5±1.43	0.9092	>0.05
Intermediate 63.0-75.0%	8	5.2±1.79	7	5.9±2.16	0.2496	>0.05
Round 76.0% >	1	0.6±0.62	0		0.9641	>0.05
Total	16	10.3±2.45	10	8.4±2.54	0.5381	>0.05

observed, in 8,5% – discoid form, more rarely the mixed and triangular forms are seen – 8% and 6% respectively.

The forms of the spleen are variable because this is a soft parenchymatous organ, changed by the influence of dimensions and form of the adjacent organs; usually it has the form of a grain of coffee [33, 14].

Thus, studying diversity of the spleen forms has a long history. In recent years, timeliness of the problem increases due to progress of surgical techniques related with the parenchymatous organs, in tomographic investigations for diagnostication and treatment.

The study object has become the spleen form in humans and its individual variations studied in different periods of the ontogenesis and depending on gender. Analyzing the results obtained in this chapter, we stated the prolate, round and intermediate form of the spleen.

Based on the information presented in table 6, we can conclude that the most frequent form of spleen in men is the prolate one. It is in 79 (51.3±4.03%) observations of 154 included in study group I; this nr is almost a half of the analyzed cases. In women the most frequent form is the intermediate one. It is in 51 (42.9±4.54 %) observations of 119 included in study group II. The difference depending on gender for the prolate form is statistically significant – p<0.05 (women – 37.8±4.44 % of cases, men – 51.3±4.03%). For the intermediate form the difference depending on gender is not statistically significant – 42.9±4.54% of cases in women and 37.0±3.89% in men (p>0.05). The frequency of the round form was higher in women than in men – 23 (19.3±3.62%) and 18 (11.7±2.59%) observations respectively.

Based on the analysis of the results obtained regarding diversity of the spleen forms depending on gender, the material was studied depending on age of the deceased people. According to the information in table 7, in the teen age (age Group VII) the most frequent form of spleen is the intermediate one. It encounters 8 (5.2±1.79 %) observations in men and 7 (5.9±2.16 %) in women. The prolate form had a much higher frequency in men than in women – 7 (4.5±1.67 %) and 3 (2.5±1.43 %) observations respectively. The difference depending on gender is not statistically significant (p>0.05) for both forms. In the analyzed group, the round form is rare – 1 (0.6±0.62 %) observation in men and no cases in women.

Analyzing the obtained results; we concluded that in adults (Groups $VIII_1$ and $VIII_2$) the prolate form of the spleen has the highest frequency (tables 8, 9). According to the information in *Table 8* (age Group $VIII_1$), the prolate form is in 18 (11.7±2.59%) observations in men and 2 (1.7±1.19%) in women. The difference depending on gender is statistically significant (p<0.001). In age Group $VIII_2$, the number of observations of the prolate form is much higher than in the previous age group. It is in 29 (18.8±3.15%) observations in men and 10 (8.4±2.54%) in women. For the prolate form of the spleen, the difference depending on gender is statistically significant (p<0.05) in age Group $VIII_2$. The second form by frequency is the intermediate form. In age Group $VIII_1$, it is in 10 (6.5±1.99 %) observations in men and much less in women – 2 (1.7±1.19%). In age Group $VIII_2$ the intermediate form was seen more often: 22 (14.3±2.82%) observations in men and much less – 8 (6.7±2.29%) in women. In both age groups, the differences depending on gender is statistically significant (p<0.05). The round form was more rarely observed than the previous 2 forms. In women of age Group $VIII_1$ 4 (3.4±1.66%) observations were registered and only one case (0.6±0.62 %) in men.

In the second period of maturity (age Group $VIII_2$) the round form was observed in 8 women (6.7±2.29 %) and just

Table 8

Frequency of spleen form types in the 1st period of adulthood (Group VIII$_1$)

Spleen form	Men, n=29		Women, n=8		t	p
	Abs.	P±ES (%)	Abs.	P±ES (%)		
Prolate <63.0%	18	11.7±2.59	2	1.7±1.19	3.5109	<0.001
Intermediate 63.0-75.0%	10	6.5±1.99	2	1.7±1.19	2.0751	<0.05
Round 76.0% >	1	0.6±0.62	4	3.4±1.66	1.5783	>0.05
Total	29	18.8±3.15	8	6.7±2.29	3.1071	<0.01

Table 9

Frequency of spleen form types in the 2nd period of adulthood (Group VIII$_2$)

Spleen form	Men, n=154		Women, n=119		t	p
	Abs.	P±ES (%)	Abs.	P±ES (%)		
Prolate <63.0%	29	18.8±3.15	10	8.4±2.54	2.5698	<0.05
Intermediate 63.0-75.0%	22	14.3±2.82	8	6.7±2.29	2.0909	<0.05
Round 76.0% >	6	3.9±1.56	8	6.7±2.29	1.0099	>0.05
Total	57	37.0±3.89	26	21.8±3.78	2.8003	<0.01

Table 10

Frequency of spleen form types in the elderly

Spleen form	Men, n=28		Women, n=42		t	p
	Abs.	P±ES (%)	Abs.	P±ES (%)		
Prolate <63.0%	13	8.4±2.24	14	11.8±2.96	0.9172	>0.05
Intermediate 63.0-75.0%	9	5.8±1.88	23	19.3±3.62	3.3098	<0.001
Round 76.0% >	6	3.9±1.56	5	4.2±1.84	0.1244	>0.05
Total	28	18.1±3.10	42	35.3±4.38	3.2040	<0.01

Table 11

Frequency of spleen form types in the senile age

Spleen form	Men, n=24		Women, n=33		t	p
	Abs.	P±ES (%)	Abs.	P±ES (%)		
Prolate <63.0%	12	7.8±2.16	16	13.4±3.12	1.4746	>0.05
Intermediate 63.0-75.0%	8	5.2±1.79	11	9.2±2.65	1.2512	<0.05
Round 76.0% >	4	2.6±1.28	6	5.0±1.99	1.0109	>0.05
Total	24	15.6±2.92	33	27.7±4.10	2.4019	<0.05

Note: the organ form types were studied by the spleen index: SI = (spleen width / spleen length)*100%. When SI is < 63.0%, spleen form is prolate, 63.0 – 75.0% - intermediate, > 76.0% - round form (A. K. Inakov, 1985).

6 (3.9±1.56%) in men. For the round form of the spleen, the difference depending on gender is not statistically significant (p>0.05) in both age groups.

According to the information in table 10, in the advanced age group, in men the prolate form of the spleen is observed in 13 (8.4±2.24%) cases. In women this form was seen in 14 (11.8±2.96%) cases. The difference depending on gender is not statistically significant (p>0.05). The intermediate form of the organ was seen more often in women – 23 (19.3±3.62%) observations and more rarely in men – 9 (5.8±1.88%) observations. The difference depending on gender is statistically significant (p<0.001). As for the round form, in age Group IX, more observations were registered in men – 6 (3.9±1.56%) cases and 5 (4.2±1.84%) – in women. For the round form, the difference depending on gender is not statistically significant (p>0.05).

The results obtained in age Group IX are presented in table 11. Based on the obtained information, we can conclude that the most frequent form of spleen was the prolate one. It is in 16 (13.4±3.12%) observations in women and 12 (7.8±2.16%)

Table 12

Length of spleen depending on gender

Age groups*	Men, n = 106		Women, n = 78		t	p
	Abs.	M1 ± ES1 (mm)	Abs.	M2 ± ES2 (mm)		
VII	16	121.5 ± 3.12	10	94.7 ± 2.09	7.1365	< 0.001
VIII1	20	125.1 ± 3.08	8	85.8 ± 2.11	10.527	<0.001
VIII2	30	119.2 ± 3.16	20	113.9 ± 2.14	1.3887	> 0.05
IX	20	124.1 ± 3.41	20	122.2 ± 2.12	0.4732	> 0.05
X	20	105.5 ± 2.54	20	109.1 ± 2.08	1.0966	>0.05
Total	106	119.2 ± 1.26	78	105.1 ± 2.07	5.8185	<0.001

Table 13

Width of spleen depending on gender

Age groups*	Men, n = 106		Women, n = 78		t	p
	Abs.	X1 ± ES1 (mm)	Abs.	X2 ± ES2 (mm)		
VII	16	77.2 ± 2.11	10	61.6 ± 2.25	5.0574	<0.001
VIII1	20	78.1 ± 2.07	8	59.2 ± 2.16	6.3174	<0.001
VIII2	30	79.0 ± 2.08	20	79.1 ± 2.17	0.0333	>0.05
IX	20	84.5 ± 2.19	20	80.0 ± 2.19	1.4971	>0.05
X	20	71.4 ± 2.14	20	69.8 ± 2.35	0.5034	>0.05
Total	106	78.2 ± 2.22	78	69.9 ± 2.15	2.6857	< 0.01

Note*: The periods of ontogenesis are classified on the basis of periodization approved by Institute of Age Physiology of the Academy of Sciences of USSR (by A. A. Markosyan (1969), S. B. Tikhvinskiy, S. V. Khruschev (1991)), as well as the one proposed by R. Robacki (quoted by M. Ștefaneț et al., 2000). Women: VII – 16-20 years, $VIII_1$ – 21-35 years, $VIII_2$ – 36-55 years, IX – 56-74 years, X – 75-90 years. Men: VII – 17-21 years, $VIII_1$ – 22-35 years, $VIII_2$ – 36-60 years, IX – 61-74 years, X – 75-90 years.

in men. The difference depending on gender is not statistically significant (p>0.05). The 2nd most frequent form in age Group IX was the intermediate one: 11 (9.2±2.65%) cases in men and 8 (5.2±1.79%) in women. The difference depending on gender is statistically significant (p<0.05). The round form is rarely seen in the elderly: 6 (5.0±1.99%) observations in women and 4 (2.6±1.28 %) in men. The difference depending on gender is not statistically significant (p>0.05).

When describing the structural particularities of every organ a special place is occupied by the linear parameters. They become one of the main criteria when determining the presence of pathological processes, determining at the same time clinical symptoms of a disease, because structure and functional condition of the tissular substrate – morphophysiological assembly – is a unitary process that ensures the vitality of each organism [59].

Linear dimensions and weight of the spleen may vary a lot, especially in pathological processes: it is bigger in tuberculosis, malaria, typhoid fever, syphilis [60, 27]. In terms of individual variability of the spleen its linear dimensions (length, width) are understood that have a variability range. The spleen dimensions were studied by gross specimens from adults depending on age and gender. The information concluded on mean values of the spleen dimensions depending on age, gender and number of case studies is presented in tables 12, 13.

Based on the obtained information (table 12), we can conclude that the difference depending on gender is statistically significant, the mean value – 119.2±1.26 mm in men included in study group I, and 105.1±2.07 mm in women included in study group II (p<0.001). The difference is also statistically significant for the spleen length in age Groups VII and $VIII_1$ – 121.5±3.12 mm and 125.1±3.08 mm respectively in men; 94.7±2,09 mm and 85.8±2.11 mm in women (p<0.001). In Groups $VIII_2$, IX, the difference depending on gender is not statistically significant (p>0.05). The length of the organ in men is a little bit larger than in women (119.2±3.16 mm and 113.9±2.14 mm; 124.1±3.41 mm and 122.2±2.12 mm).

The analysis of results presented in *Table 13* shows the difference in the spleen width depending on gender that is statistically significant for Group VII – 77.2±2.11 mm in men and 61.6±2.25 mm in women; in age Group $VIII_1$ – 78.1±2.07 mm in men and 59.2±2.16 mm in women. The difference depending on gender is statistically significant (p<0.001). In Groups $VIII_2$, IX and X the difference is not statistically significant (p<0.05). The width values in men are almost equal to those in women.

Conclusions

The capsule of spleen is formed by collagen fiber fascicles, elastic fibers as well as relatively few myocytes.

In teenagers (age Group VII), the most frequent form of the spleen is the intermediate one, while in adults (Groups $VIII_1$ and $VIII_2$) and people of the senile age – the prolate form of the spleen.

As for spleen length, the difference is statistically significant in age Groups VII and $VIII_1$ – 121.5±3.12 mm and 125.1±3.08 mm respectively in men; 94.7±2.09 mm and 85.8±2.11 mm – in women ($p<0.001$). Difference in the spleen width depending on gender is statistically significant for Group VII – 77.2±2.11 mm in men and 61.6±2.25 mm in women; in age Group $VIII_1$ – 78.1±2.07 mm in men and 59.2±2.16 mm in women.

References

1. Paladii I. Diagnosticul şi tratamentul traumatismelor abdominale [Diagnostication and treatment of abdominal trauma]. Anale ştiinţifice ale USMF „Nicolae Testemiţanu". Probleme clinico-chirurgicale [Scientific Annals of SUMPh „N. Testemitanu". Clinical surgical problems]. Vol. 4. 2001;61-64.
2. Beţişor V. Actualităţi în ortopedie-traumatologie [News in orthopedy and traumatology]. Materialele conferinţei ştiinţifice anuale a colaboratorilor şi studenţilor USMF [Materials of annual scientific conference of employees and students of SUMPh „N. Testemitanu"]. Chişinău, 1997;15-27.
3. Kozlov IZ, Gorshkov SZ, Volkov VS. Povrezhdeniya zhivota [Abdominal injuries]. Moscow, 1988;224.
4. Smolyar AN, Tкachev VV, Tkeshelashvili TT. Sochetannye raneniya shei, grudi, zhivota i cherepa [Concomitant injuries of neck, chest, abdomen and skull]. *Khirurgiya [Surgery]*. 2005;2:61.
5. Gudumak VS, Kashinskiy YuB, Marchenko VP. Mnozhestvennye sochetannaya travma, soprovozhdayushayasya shokom [Multiple concomitant trauma associated with shock]. Kishinev,1993;239.
6. Korlatyanu MA, Betsishor VK. Tyazholye sochetannye cherepnomozgovye travmy i povrezhdeniya oporno-dvigatelnogo apparata [Severe concomitant injuries of head and locomotor system]. Kishinev: Shtiintsa,1990;156.
7. Rafiev SF. Diagnostika i lechenie abdominalnykh travm [Diagnostication and treatment of abdominal trauma]. *Klinicheskaya khirurgiya* [*Clinical surgery*]. 1986;4:52-55.
8. Demidov VA. Travmy zhivota [Abdominal trauma]. Uralskaya Gosudarstvennaya meditsinskaya akademiya. Kafedra khirurgii VUF [Urals State Medical Academy. Department of Surgery], 2001. www:urmedserv.ru.
9. Belokonev VI, Terekhin AA. Osobennosti kliniki, taktiki i khirugicheskogo lecheniya povrezhdenii organov levogo poddiafragmalnogo prostranstva [Peculiarities of clinical picture, management and surgical treatment of the left subphrenic space organs]. *Khirurgiya [Surgery]*. 2006;8:38-42.
10. Sorokin AP, Polyankin NYa. Klinicheskaya morfologiya selezenki [Clinical morphology of the spleen]. M.,1989;160.
11. Kinley M, O'loughin VD. Human Anatomy. 2012.
12. Simion S. Manual de anatomie, semiologie şi practici chirurgicale [Manual of anatomy, semiology and surgical practices]. Bucureşti, 2006.
13. Nistor I, et al. Observaţii microanatomice asupra structurilor colagenice din sistemele morfofuncţionale splenice [Microanatomic observations of collagen structures in splenic morphofunctional systems]. *Revista Română de anatomie funcţională şi clinică, macro- şi microscopică şi de Antropologie [Romanian Journal of Clinical and Functional, Macro- and Microscopic Anatomy and Anthropology]*. 2004;1(3):136-139.
14. Zamfir C. Histologie specială [Special histology]. Bucureşti: Carol Davila, 2005;376.
15. Raica M, Căruntu I.D, Cîmpean A. Histologia organelor [Histology of organs]. Timişoara: UMF, 2009.
16. Zhao Z, Liu S. Sectional anatomy of the peritoneal reflections of the upper abdomen in the coronal plane. *J. Comput. Assist Tomogr.* 2005;29(4):430-7.
17. Hedeshian MH, Hirsh MP, Danielson PD. Laparascopic splenopexy of a pediatric wandering spleen by creation of a retroperitoneal pocket. Laparoendosc. *Adv. Surg Tech A*. 2005;15(6):670-672.
18. Hernandez-Siverio N, Barranco Moreno A, Perez Palma I. Wandering spleen torsion. *Cir. Pediatr*. 2005;18(2):101-103.
19. Castellon-Pavon C. I, Valderrabano-G. S, Anchustegiu-M. P. Laparoscopic splenectomy due to torsion of a wandering spleen. *Cir. Esp*. 2006;80(6):406-408.
20. Kerdivarenko NV. Innervatsiya soedinitelnotkannykh obolochek nekotorykh vnutrennikh organov [Innervation of connective tissue membranes of some internal organs]. Avtoreferat [Author's summary]. Simferopol, 1961.
21. Kerdivarenko NV. O nervnom apparate fibroznoy obolochki selezenki [About nervous apparatus of the splenic fibrous membrane]. Tez. dokl. 17-i ocherednoy nauchn. Sessii KGMI po itogam nauchno-issledovatelskoy raboty za 1958 g [Reports of the 17th annual scientific session of Kishinev State Medical Institute on research results in 1958]. Kishinev, 1959;31-32.
22. Aughey E, Frye E. Comparative Veterinary Histology with Clinical Correlation. *AMIS*, 2001;247.
23. Tehver J, Grahame T. The capsule and trabeculae of the spleens of domestic mammals. *J of Anatomy*. 2002;LXV(4):473-481.
24. Dellman HD, Brown EM. Textbook of Veterinary Histology. Iowa: Blackwell Publishing, 2006;6:147-152.
25. Banks W. Applied Veterinary Histology. 3rd ed. Mosby Year Book, 1993;283-297.
26. Calhoun PS, Fishman EK. Interactive multimedia program for imaging the spleen: concept, design and development. *Radiographics*. 1999;14(6):1407-14.
27. Enculescu C. Embriologie specială [Special embryology]. Târgu Mureş: Litografia UMF, 2006.
28. Sadler TW. Langman-s medical embryology. 6-th ed. Baltimore (Md): Williams&Wilkins, 1990.
29. Shurkus VE. Razvitiye salnikovoy sumki i formiruyuschikh ee organov v embriogeneze cheloveka [Development of the omental bursa and organs that form it in human embryogenesis]. *Arkhiv AGE [Archive AGE]*. 1980;8:84-91.
30. Popova RA, Popov GA. Osobennosti topografii salnikovoy sumki v period prenatalnogo ontogeneza [Peculiarities of omental bursa topography in the prenatal ontogenesis period]. *Morfologiya [Morphology]*. 2008;133(3):91-92.
31. Vind Gary J. Prikladnaya laparoskopicheskaya anatomiya: bryushnaya polost i malyi taz [Applied laparoscopic anatomy: abdominal cavity and lesser pelvis]. M.,1999;366.
32. Skandalakis PN, Colborn GL. The surgical anatomy of the spleen. *Surgical clinics of north America*. 1993;73(4):1-21.
33. Ranga V. Anatomia omului. Viscere [Human anatomy. Viscera]. Bucureşti: Cerma,1994.
34. Ranga V. Tratat de anatomia omului [Treatise of human anatomy]. Bucureşti, 1990.
35. Bolshakova OP, Semenov GM. Praktikum. Operativnaya khirurgiya i topograficheskaya anatomiya [Practical course of operative surgery and topographical anatomy]. Moskva, 2001.
36. Laputiev SA. Soedinitelnotkannye struktury podzheludochnoy zhelezy i ikh nervnyi apparat u cheloveka v prenatalnom ontogeneze i u novorozhdennykh [Conjunctive tissue structures of the pancreas and their nervous apparatus in humans in prenatal ontogenesis and in newborns]. Avtoreferat [Author's summary]. Yaroslavl, 1986.
37. Bisenkov NP, Dyskin EA, Zabrodskaya VF. Khirurgicheskaya anatomiya zhivota [Surgical anatomy of the abdomen], 1978.
38. Inakov AK. Anatomiya i topografiya selezenki cheloveka v postnatalnom ontogeneze. Ontogenez i vozrastnaya anatomiya krovenosnoy i limfaticheskoy sistem cheloveka [Anatomy and topography of the spleen in humans in postnatal ontogenesis. Ontogenesis and developmental anatomy of vascular and lymphatic systems in humans]. M.,1983;32-36.
39. Ostermann PA, Schreiber HW, Lierse W. The ligament system of the spleen and its significance for surgical interventions. *Langenbecks Arch Chir*. 1987;371(3):207-216.
40. Lusi EA. K voprosu o topograficheskoy anatomii tolstykh kishok [Regarding topographical anatomy of the large intestine]. Avtoreferat dis. Ph.D. [Author's summary of thesis]. 1956.
41. Pilipenko-Shapkina AP, Sipukhin YaM, Moskvichev VG. Zakrytye travmy pecheni i selezenki u detei [Closed injuries of liver and spleen in children]. Vladivostok, 1987.

42. Kovanov VV. Operativnaya khirurgiya i topograficheskaya anatomiya [Operative surgery and topographical anatomy]. 1995.
43. Albu I. Anatomia omului [Human anatomy]. Cluj-Napoca,1984.
44. Tagaya N, Rokkaku K, Kubota K. Splenectomy using a completely neediescopic procedure: report of three cases. Laparoendosc. *Adv Surg Tech A*. 2002;12(3):213-216.
45. Marian D. Anatomia şi semiologia chirurgicală a abdomenului [Surgical anatomy and semiology of the abdomen]. Târgu-Mureş, 2006;139.
46. Parvaiz A, Chandran S, Karim A. Torted and ruptured wandering spleen presenting as a surgical emergency in pregnancy. *Scientific World Journal*. 2004;6(4):1035-37.
47. Zarrintan S, Jamali F, Tubbs R.S. A wandering spleen presenting as a pelvic mass: case report and review of the literature. *Folia Morphology*, 2007;66(2):152-154.
48. Crosta ID, Inserra A, Pueyo C, et al. Abdominal pain and wandering spleen in young children: the importance of an early diagnosis. *J. Pediat. Surg*. 2009;44:1446-49.
49. Brrown CVR, Virgilio GR, Vazquez WD. Wandering spleen and its complications in children: a case series and review of the literature. *J. Pediatr. Surg*. 2003;38:1676-79.
50. Valls C, Mones L, Guma A. Torsion of a wandering accessory spleen: CT findings. *Abdom. Imaging*. 1998;23(2):194-5.
51. Vural M, et al. Symptomatic wandering accessory spleen in the pelvis: sonographic findings. *J Clin Ultrasound*. 1999;27(9):534-6.
52. Keith B, Allen MD. Wandering spleen: anatomic and radiologic considerations. *Southern Medical Journal*. 1992;85(10):976-984.
53. Poulin EC, Thibault C. The anatomical basis for laparoscopic splenectomy. *Can J. Surg*. 1993;36(5):484-488.
54. Rosen A, Shikiar S, Nathan H. Anatomical and computed tomographic studies of the pancreatic tail. *Acta Anat. (Basel*). 1988;131(3):188-191.
55. Constantinescu NM. Anatomie chirurgicală şi operatorie [Surgical and operative anatomy]. V. III, Abdomenul [Abdomen]. Bucureşti, 2012.
56. Rosen A, Nathan H. The lienorenal ligaments and the tail of the pancreas surgical anatomical study. *Pancreas*. 1988;1(3):104-107.
57. Scandalakis JE, Coliborn JE. Scandalakis'surgical anatomy: the embryologic and anatomic basis of modern surgery - spleen (cap. 22), PMP, 2004, MCGRAW Hill's Access Surgery – http://www. Accesssurgery.com
58. Michels NA. Blood supply and anatomy of the upper abdominal organs with a descriptive atlas. Philadelphia-Montreal: Lippincott,1995.
59. Suman S. Aspecte morfofuncționale și semnificații clinice ale complexului coledocopancreaticoduodenal [Morphofunctional aspects and clinical significance of the choledocho-pancreatico-duodenal complex]. Chişinău,2014;270.
60. Ionescu G, Szabo I. Splina [Spleen]. Cluj-Napoca, 1993;16-43.