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THE GREATER OMENTUM AS A PERIPHERAL ORGAN OF THE IMMUNE SYSTEM: MORPHOLOGICAL AND FUNCTIONAL ASPECTS

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ABSTRACT

Introduction. The greater omentum, despite its apparent simplicity at first glance, is a complex anatomical structure with multiple functions. Active involvement of the greater omentum in the protection of the abdominal cavity, along with its unique plastic properties, makes it an important subject of study for surgeons and researchers. Moreover, the presence of specialized lymphoid structures in the greater omentum highlights its significant role in the body’s immune system.

Methods. The analytical review was conducted based on published articles, books, educational manuals and monographs. The literature search was performed on the global Internet using scientific databases such as Google Scholar, Web of Science and PubMed, as well as the electronic library of Poltava State Medical University.

Results and Discussion. The greater omentum is not merely a fatty fold in the abdominal cavity but a complex organ with numerous functions. Although it has been known to humanity since the ancient times, its detailed study has begun recently. This organ consists of several layers of peritoneum and contains a significant amount of adipose tissue, blood vessels, nerves and lymphoid structures known as “milky spots.” It is the milky spots that endow the greater omentum with immune properties, helping the body combat infections. In addition to its immune function, the greater omentum performs several other critical roles: it protects internal organs from damage, participates in metabolic processes and can even be used in surgery for tissue reconstruction. The shape and size of the greater omentum can vary among individuals, depending on the unique characteristics of their bodies. With age, the structure and functions of this organ also undergo changes. Despite numerous studies, the greater omentum still holds many mysteries. Further research into this organ will allow for a deeper understanding of

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the processes occurring in the human body and the development of new methods for treating various diseases.

Conclusions. The analysis of the presented data provides a detailed understanding of the greater omentum as a dynamic organ that plays a key role in the functioning of the abdominal cavity. Derived from the peritoneum, it is not merely a passive element but an active participant in numerous physiological processes. The mobility of the greater omentum, facilitated by its structure, allows it to function as a protective "apron," shielding internal organs from damage and infection. Additionally, its proximity to many organs of the digestive system contributes to maintaining homeostasis within the abdominal cavity. The presence of milky spots gives the greater omentum immunological properties. These structures act as specialized "outposts" of the immune system, continuously monitoring the antigenic composition of the abdominal cavity. Their location within the greater omentum underscores the importance of this organ in providing local immunity.

Keywords: greater omentum, peritoneum, milky spots, mesothelium, lymphoid tissue, adipose tissue.

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ВЕЛИКИЙ ЧЕПЕЦЬ ЯК ПЕРИФЕРІЙНИЙ ОРГАН ІМУННОЇ СИСТЕМИ: МОРФОЛОГІЧНІ ТА ФУНКЦІОНАЛЬНІ АСПЕКТИ

Вступ. Великий чепець, незважаючи на свою простоту на перший погляд, є складним анатомічним утвором з багатьма функціями. Активна участь великого чепця у захисних процесах черевної порожнини, а також унікальні пластичні властивості роблять його важливим об'єктом дослідження для хірургів та вчених. Крім того, наявність у великому чепці спеціалізованих лімфоїдних структур свідчить про значну роль в імунній системі організму.

Методи. Проведено аналітичний огляд, який базується на опублікованих статтях, книгах, навчальних посібниках та монографіях. Літературний пошук здійснювався у всесвітній мережі «Інтернет» у науково-метричних базах даних Google Scholar, Web of Science та PubMed, а також в електронній бібліотеці Полтавського державного медичного університету.

Результати та обговорення. Великий чепець – це не просто жирова складка в черевній порожнині, а складний орган з численними функціями. Він був відомий людям ще з давніх часів, але його детальне вивчення почалося відносно недавно. Цей орган складається з кількох шарів очеревини і містить велику кількість жирової тканини, судин, нервів та лімфоїдних утворень – молочних плям. Саме молочні плями надають великому чепцю імунних властивостей, допомагаючи організму боротися з інфекціями. Крім імунної функції, великий чепець виконує ряд інших важливих ролей: він захищає внутрішні органи від пошкоджень, бере участь в обміні речовин і може навіть використовуватися в хірургії для реконструкції тканин. Форми і розміри великого чепця можуть відрізнятися у різних людей, що пов'язано з індивідуальними

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особливостями організму. З віком структура і функції цього органу також змінюються. Незважаючи на численні дослідження, великий чепець все ще зберігає багато таємниць. Подальше вивчення цього органу дозволить глибше зрозуміти процеси, що відбуваються в організмі людини, і розробити нові методи лікування різних захворювань.

Висновки. Аналіз представлених даних дозволяє сформувати детальне уявлення про великий чепець як про динамічний орган, який відіграє ключову роль у функціонуванні черевної порожнини. Будучи похідним очеревини, він не просто пасивний елемент, а активний учасник багатьох фізіологічних процесів. Мобільність великого чепця, забезпечена його будовою, дозволяє йому виконувати роль своєрідного "фартуха", захищаючи внутрішні органи від пошкоджень та інфекцій. Крім того, його розташування в безпосередній близькості до багатьох органів травної системи сприяє підтримці гомеостазу в черевній порожнині. Наявність молочних плям надає великому чепцю імунологічних властивостей. Ці структури діють як спеціалізовані "пости" імунної системи, постійно контролюючи антигенний склад черевної порожнини. Їхнє розташування в товщі великого чепця підкреслює важливість цього органу в забезпеченні місцевого імунітету**.**

Ключові слова: великий чепець, очеревина, молочні плями, мезотелій, лімфоїдна тканина, жирова тканина.

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INTRODUCTION

The human greater omentum is a complex anatomical structure that remains a subject of in-depth study and research in the fields of medicine, biology and anatomy [1, 2].

Few publications dedicated to the study of the morphofunctional characteristics of the greater omentum has been found to date. However, the interest of researchers in the anatomical and physiological properties of the greater omentum is not accidental. Its active involvement into protection of the abdominal cavity on the one hand, and its decisive role in the development of inflammation and adhesion formation in the postoperative period on the other hand, as well as its unique plastic properties that allow for wide use in reconstructive surgeries in children, and in the surgical removal of abdominal organ tumors, has long been a matter of great concern for pediatric surgeons and scientists to this organ [3, 4].

Additionally, interest in studying the morphofunctional aspects of the greater omentum is driven by the existing concept of its relationship to the peripheral part of the immune system due to the presence of specialized lymphoid structures known as milky spots. It has been established that these formations are responsible for immune surveillance of the antigenic composition, processes of renewal and maintenance of the quantitative stability of peritoneal fluid, as well as actively participating in various pathological processes of abdominal organs [5, 6].

However, structural-functional aspects and the role of the greater omentum in the body require further in-depth study.

Purpose. To examine the main aspects of the morphological structure of the greater omentum through the analytical review.

METHODS AND MATERIAL

This analytical review is based on published articles, books, educational manuals and monographs. The literature search was performed on the global Internet using scientific databases such as Google Scholar, Web of Science and PubMed, as well as the electronic library of Poltava State Medical University.

RESULTS AND DISCUSSION

The greater omentum has piqued the interest of scientists since ancient times, even before the Common Era. The first mention of the greater omentum dates back to the 8th century BCE and is attributed to Homer.

Pliny (23–79 CE) used the term “omentum” to refer to the fatty membrane covering the stomach and intestines. Galen (128–199 AD) provided the first comprehensive description of the omentum, describing it as the “folds of the peritoneum consisting of two sheets of varying sizes that resemble a pouch or bag.” Andreas Vesalius (1514–1564) described the superficial and deep layers of the omentum, its blood supply and suggested the presence of glands within it that produce fluid [7].

The anatomical structure of the greater omentum, as well as its age-related and morphometric characteristics, requires further in-depth study, given its clinical relevance and the exceptionally important practical implications of this information.

Near the lesser curvature of the stomach, the peritoneal sheets separate and transit to the anterior and posterior walls of the stomach. They rejoin at the greater curvature, forming the greater omentum, which extends to the transverse colon, descends to cover the loops of the small intestine, then ascends, fusing with the transverse colon and its mesentery before transitioning into the parietal peritoneum of the posterior abdominal wall. The lower edge of the greater omentum may extend below the level of the umbilicus and sometimes descends to the entrance of the lesser pelvis. Morphologically, the greater omentum consists of two parts: the gastrocolic portion and the “apron”, a freely hanging part below the transverse colon [8, 9, 10].

Various origins of the greater omentum have been described, including: from the duodenum; from the ascending colon near its right flexure; from the pylorus of the stomach; from the spleen and posterior abdominal wall, *lig. gastrolienale*; from the diaphragm, *lig. phrenicocolicum*; from the gallbladder; from the head of the pancreas [11, 12].

Below the transverse colon, the greater omentum consists of four layers of peritoneum, which pair up to form its anterior and posterior sheets. After birth, these sheets fuse, and the cavity between them becomes obliterated. The anterior and posterior duplications of the greater omentum typically fuse below the pyloric part of the stomach and the transverse colon. The posterior duplication begins at the posterior abdominal wall and fuses with the transverse colon, except for the part forming the phrenicosplenic ligament.

Based on metric parameters such as length and width, three variations of the greater omentum have been described: long and wide; short and narrow; intermediate [13, 14, 15]. According to Lieberman D., the morphometric characteristics of the greater omentum in adults exhibit certain variations. He states that the length of the greater omentum ranges from 14 to 36 cm, while the width ranges from 26 to 46 cm [7]. Other reported ranges of metric characteristics: length from 15 to 17 cm, width from 18 to 29 cm and thickness from 2.78 to 2.90 cm. The average surface area of the greater omentum in children varies from 0.2 to 0.6 m², while in adults, it ranges from 0.4 to 0.81 m², constituting nearly half of the total peritoneal surface area [16].

In rats, the greater omentum is smaller in size but rich in milky spots – the specific regions of lymphoid tissue that actively participate in immune defense. Morphometric parameters such as length and thickness are significantly smaller in rats, but the structure of the adipose tissue is similar, with connective tissue layers surrounding blood vessels and nerves [17, 18, 19].

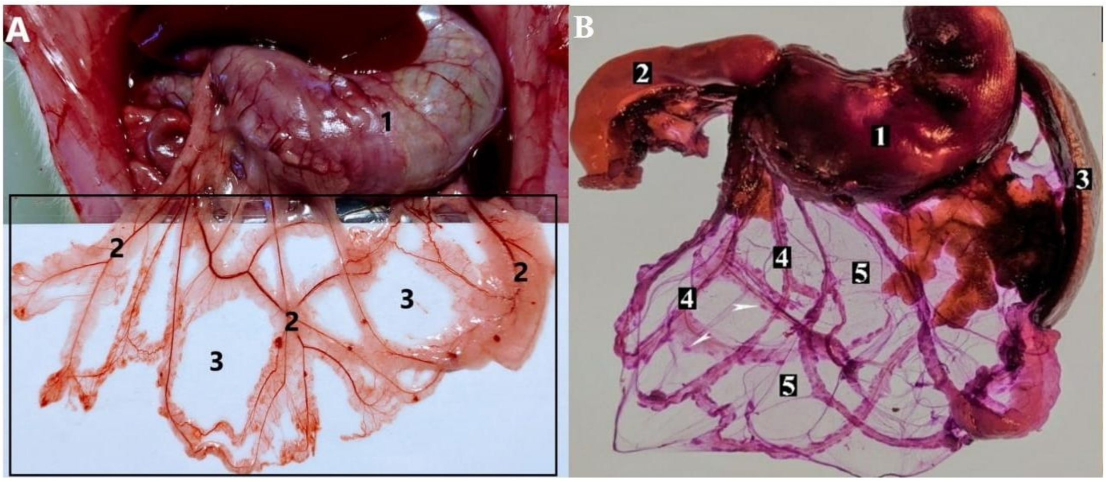

Figure 1. Whole-mount specimens of the white rat greater omentum (authoring preparations)

A (the external boundaries of the greater omentum outlined with a rectangular frame): 1 – stomach; 2 – vascular-fatty arcades; 3 – serous-reticular bridges;

B (macroimage, 2× magnification; H&E stain): 1 – stomach; 2 – duodenum; 3 – spleen; 4 – vascular-fatty arcades; 5 – serous-reticular bridges. The arrows indicate stained milky spots

Domestic researchers have identified various forms of the greater omentum in adult humans. Through numerous studies, the main forms have been distinguished. The most common form observed in anatomical analyses is rectangular, followed by the triangular form, while the irregular form of the greater omentum is less frequently encountered [20].

Some researchers propose an alternative classification of the forms of the greater omentum, associating its shape with a person's body type. They suggest that the shape of the greater omentum is determined by its free portion, classifying it as unilobar, bilobular or multilobular. The division of the omentum into lobes is typically asymmetrical, with the narrower fragment most often located on the right. The base of each lobe is generally situated below, and rarely above, the transverse colon, with the lower edges of the lobes being rounded [21].

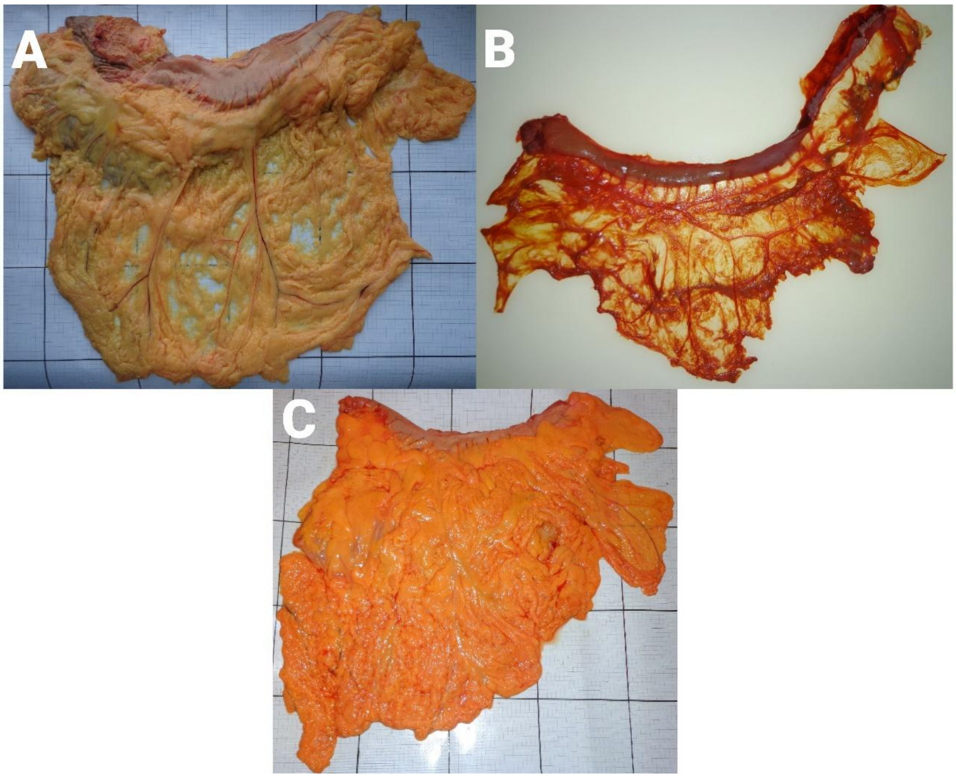

Figure 2. Whole-mount specimens of the human greater omentum (authoring preparations)
A – rectangular form of the greater omentum;
B – triangular form of the greater omentum;
C – irregular form of the greater omentum

The greater omentum, as noted above, is formed by the fusion of four layers of peritoneum, between which connective tissue, including adipose tissue, is present. Occasionally, a cavity may exist between the anterior and posterior sheets of the greater omentum in humans, a feature confirmed by both researchers of the past century and contemporary studies [1, 22].

The stroma of the organ consists of a cellular connective tissue framework, within which blood and lymphatic vessels as well as nerve fibers are located. The amount of adipose tissue varies widely. In individuals with significant visceral fat, the adipose tissue of the omentum is considerably substantial [23, 24, 25].

Publications report that one of the functions of the adipose tissue in the greater omentum is to protect the organs it covers from mechanical damage. Another important function of this organ is to facilitate the exchange of peritoneal fluid. It is known that the walls of the greater omentum in individuals with low adipose tissue content are thinner, and the serous membranes of each duplication closely adhere to one another. In such cases, perforations may form in these areas, enabling the transport of substances within the peritoneal cavity. Additionally, the superficial mesothelial cells of the serous membrane are responsible for the secretion and absorption of peritoneal fluid [26, 27, 28, 29].

The adipose tissue of the greater omentum is arranged as clusters of adipocytes (fat lobules), separated by large layers of connective tissue, as well as isolated fat cells. Within these clusters, blood and lymphatic vessels, nerve fibers and thin connective tissue trabeculae form the structural framework of the lobules. The adipose tissue surrounds the intra-omental blood vessels in a ring-like fashion, with more fat tissue often located near venules than near arterial vessels [30]. Adipose tissue is a complex hormonally active structure that plays a critical role in regulating energy balance and overall homeostasis of the human body [31, 32 , 33].

The serous membrane covering the omentum has a typical structure characteristic of serous membranes. Its surface is lined by mesothelium resting on a basal membrane, beneath which lies the connective tissue foundation of the serous membrane. This foundation consists of alternating layers of collagen and elastic fibers [34].

The serous membrane contains numerous small openings that connect the peritoneal cavity with lymphatic capillaries within the wall of the serous membrane. In the mesothelium covering the omentum, particularly in the areas of milky spots, the “stigmata” have been identified. Through these openings, fluids and immunocompetent cells constantly circulate to maintain immune homeostasis. This aligns with the concept of lymphocyte recirculation, whereby lymphocytes enter the peritoneal cavity through the “stigmata” of the mesothelium in the milky spots of the greater omentum and are removed from the peritoneal fluid via the “stomata” on the diaphragmatic surface of the peritoneum. It is known that mesothelial cells produce anti-inflammatory cytokines that help reduce inflammatory processes in the abdominal cavity organs [35, 36].

The exchange of peritoneal fluid and the transport of immunocompetent cells through the walls of the greater omentum are critically important processes that facilitate the adaptation of the immune response. This is supported by European research on real-world data regarding the treatment of allergic conditions, emphasizing the significance of behavioral therapy models [37].

The greater omentum is characterized by a high intensity of blood flow. For instance, the blood flow rate in the omentum surpasses that of the skin, mesentery and parietal peritoneum [1]. Visualizing the vascularization of the human omentum is challenging due to the abundance of adipose tissue surrounding the vessels. However, limited studies have revealed that the blood supply to the omentum is provided by the right and left gastroepiploic arteries, which branch off the celiac trunk. . These arteries follow the contour of the greater curvature of the stomach and decrease in caliber as they give off branches to the stomach and omentum The right gastroepiploic artery typically has a larger diameter and significantly greater length. Small-diameter anastomoses often exist between the left and right gastroepiploic arteries. Throughout the omentum, numerous capillaries are densely distributed, with their highest concentration at the lower edge of the omentum. Venous drainage occurs parallel to the arterial pathway through the corresponding veins, with each omental artery typically accompanied by a vein.Typically, each gastroepiploic artery is accompanied by a corresponding vein. In most cases, the gastroepiploic vein anastomoses with the superior mesenteric vein before its entry into the portal vein. Occasionally, it drains into the initial segment of the splenic vein [38, 39].

The greater omentum also exhibits a well-developed system of lymphatic vessels. Certain areas of the serous membrane of the omentum are specialized for enhanced lymph transport, which some researchers refer to as “lymphatic windows” [40, 41, 42].

Lymphoid structures of the greater omentum have drawn scientific interest since the late 19th century. For the first time, in 1863, Recklinghausen associated the greater omentum with lymphoid tissue. He studied the omentum of rats and identified white spots later named “milky spots.” Similarly, Ranvier, in 1874, while examining the omentum of rabbits, discovered opaque spots located at vascular branches. He described their cellular composition and structure, which resembled a lymph node, suggesting that the greater omentum functioned as a “giant lymph node” that contributes not only to local immune balance but also to systemic immune defense. This hypothesis aligns with contemporary research highlighting the intricate immunological pathways involved in combating allergic reactions [43]. This perspective was widely accepted for a long time. However, an alternative view questioned the presence of lymphatic vessels in the omentum [44, 45, 46]. Subsequent studies advanced the understanding of milky spots, identifying phagocytic cells within them. Milky spots were first differentiated from lymph nodes in 1920. According to Seifert, the distinction lies in the absence of a capsule, sinuses, and germinal centers in milky spots, which are present in lymph nodes. Milky spots, however, possess their own capillary network, a unique cellular composition, and are covered by specialized mesothelium. Their stroma consists of mesothelial and reticular cells that can easily differentiate. Based on their structural characteristics, milky spots were classified as part of the reticuloendothelial system [47, 48, 49].

Milky spots are small, opaque areas of the omentum with an ovoid, rounded or irregular shape, covering an area of 0.5–3.5 μm². These structures appear in the omentum starting from mid-embryogenesis and persist throughout life [50]. They are found on both surfaces of the omentum, with their quantity varying based on individual and age-related factors. Milky spots are well-visualized in newborns and infants, but their number decreases with age. In adults, they are less apparent due to the higher adipose tissue content in the omentum. In elderly individuals, the number of milky spots further declines, accompanied by reduced capillary network density and the occurrence of fibrosis and calcification [51, 52, 53].

The blood capillaries in the area of the milky spots are characterized by endothelial cells with multiple fenestrations, facilitating intensive fluid exchange with the peritoneal cavity. In the region of the milky spots, the peritoneal leaf is thinner.

Three types of milky spots are distinguished: 1) primary milky spots, which are found in fetuses, newborns, and children under 5 years old; 2) passive milky spots, consisting mainly of adipose cells; 3) active or secondary milky spots, which contain a high number of leukocytes, especially plasma cells. Active spots are normally present in the greater omentum, and in response to any irritation of the peritoneum, their number increases significantly. This transformation involves the remodeling of passive milky spots into active ones. In this state, the spots enlarge, the number of adipocytes decreases, and the content of immune cells increases [8, 54].

Milky spots also play a role in specific immunological responses. These structures are characterized by numerous macrophages, lymphocytes, plasma cells and mast cells, which together ensure the phagocytosis of foreign structures, such as bacteria, micro-particles, and various dyes. They also synthesize antibodies and serve as a source of emergency release of free macrophages and plasma cells into the peritoneal cavity, where they perform phagocytosis and produce immune antibodies [4, 55]. Due to these properties, the greater omentum plays an important role in cleaning the peritoneal cavity.

Many authors associate milky spots with lymphoid tissue. Several studies highlight the involvement of milky spots in specific immunological reactions, particularly their important role in T-cell responses [10]. In the absence of a spleen and Peyer's patches (groups of lymphoid follicles), some studies have shown that mesothelial cells migrate to the milky spots of the greater omentum, where the production of IgG and IgM occurs, as well as the formation of germinal centers for B-cells and T-cell immune responses [56]. The greater omentum also serves as a site for the lymphopoiesis of B1 cells and immune responses to T-independent antigens. The number of B-cells in the milky spots ranges from 10% to 30% [57]. Antigen presentation occurs in the milky spots, which is crucial for both T-cell and B-cell immune responses, despite the absence of follicular dendritic cell networks. Dendritic cells appear in the milky spots only after bacterial immunization, whereas they can be observed in the intact state within the peritoneal cavity, with their numbers increasing after bacterial immunization. These findings suggest that other cells, distinct from macrophages and dendritic cells, might have antigen-presenting functions.

A review of the literature shows that the anatomical and physiological properties of the greater omentum have long attracted the attention of physicians and scientists from various specialties, including surgeons, transplantologists, mammologists, cardiothoracic surgeons, oncologists, immunologists and morphologists. The greater omentum is an essential functional organ that provides protection to the abdominal organs from mechanical damage, helps maintain homeostasis in the abdominal cavity, participates in immune reactions, produces biologically active substances and possesses unique plastic properties that allow it to be widely used in reconstructive surgical interventions.

Factors that activate the protective properties of the greater omentum tissue include mechanical damage to the serosal surface, infectious processes, foreign material, ischemia of the omental tissue and abdominal organs, and disturbances in the peristalsis of the small and large intestines. It becomes quite clear that the greater omentum is inevitably involved in the processes of peritonitis development. In this regard, it should be considered that the immunological reactions of its milky spots must be selective with respect to the etiological factors, which act as antigens of corresponding origin.

CONCLUSIONS

Thus, a clear understanding emerges regarding the fundamental anatomical structure of the human greater omentum. In our view, it results from the invagination of two layers of the visceral peritoneum, which fuse at a certain depth within the peritoneal cavity, one of them connected to the greater curvature of the stomach and the other to the transverse part of the colon. This fusion allows the greater omentum a certain degree of mobility within the peritoneal cavity. It is important to note that this feature distinguishes the greater omentum from other derivatives of the peritoneum. In other words, there are no other similar structures in humans.

Aside from some anatomical peculiarities, it can be observed that the connective tissue stroma of the greater omentum contains blood vessels along which significant deposits of adipose tissue are distributed, as well as unique lymphoid formations known as milky spots. However, milky spots cannot be considered specific to the greater omentum alone, as they are also present in other serous membranes. These structures are part of the peripheral immune system, serving the function of immune surveillance over the antigenic composition of the respective serous cavities.

PROSPECTS FOR FUTURE RESEARCH

It is planned to study the microscopic structure of the greater omentum with the differentiation of the cellular composition of the peripheral organs of the immune system, the so-called milk spots, using immunohistochemical methods and scanning electron microscopy.

AUTHOR CONTRIBUTIONS

All authors substantively contributed to the drafting of the initial and revised versions of this paper. They take full responsibility for the integrity of all aspects of the work.

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None.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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