Morphologic synergisms in the ortotaxy and heterotaxy of the subdiaphragmatic digestive system viscera. Consequences in pathology and forensic medicine

Gheorghe S. Dragoi¹²,*, Ileana Marinescu⁴, Ileana Dinca⁴, Elena Patrascu⁴, Petru Razvan Melinte⁴

Abstract: Spatial location of the subdiaphragmatic digestive system viscera fascinates through the manner in which the 9-10 meters of tubular structures (gastroduodenal= approximate 50 cm; jejunal-ileal= approximate 7-8 meters; colorectal= approximate 1.5 meters) wreathe together within the relatively narrow space of abdominal cavity. Authors proposed themselves to perform an anatomic study regarding determinant factors of the combinatorial occupancy of abdominal-pelvic space by these viscera, during the dynamic of their epigenesis. The study was conducted on human biologic material: 8 embryos aged between 6-8 weeks and 15 fetuses, aged between 12-28 weeks. Analysis of relations between digestive system primordia and mesenteric mesenchyme derivates was achieved through macro- and microanatomic methods. Authors consider that the assessment of ortotaxy and heterotaxy of subdiaphragmatic digestive system viscera, as effects of intestinal rotation and malrotation created multiples confusions. The results of our observations, correlated with anatomic literature data, demonstrate that the location of viscera from peritoneal cavity is determined by morphologic synergisms synchronization between ectoblastic and mesenteric mesenchyme derivates. Intestinal rotations described by Fredet (1898), for the achievement of subdiaphragmatic digestive system viscera ortotaxy and heterotaxy appear as effects of tubular digestive structures growth and elongation and not as causes of these phenomenon. The asynchrony of morphologic synergisms generates heterotaxy, atresia, stenosis and abnormal peritoneal recesses which may become sites for congenital internal hernias, highly important in surgical pathology and forensic examination of peritoneal cavity.

Key Words: visceral ortotaxy, digestive system primordia, congenital internal hernia, intestinal rotation.

The issue of subdiaphragmatic digestive system viscera location, in time and space, determined the occurrence, in knowledge history, of various researches and controversies, regarding relations and reciprocal interactions between endoderm-derivate and mesoderm-derivate structures, during their morphologic differentiation dynamics. The assessment of these variable relations represents a study hypothesis, within the contradictions paradigm existing between surgeons, anatomists and embryologists, regarding the determinant factors of antepartum ortotaxy of intraperitoneal and/or secondary retroperitoneal viscera. The purpose of this paper is to analyze the anatomic determinant factors for the abdominal location of subdiaphragmatic digestive system viscera, in embryo and fetus. The objectives of the study were imposed by numerous theoretical and practical issues regarding the epigenesis of subdiaphragmatic digestive system viscera.

We mention:
1) The so-called "rotations of ansa umbilicalis", invoked by Fredet (1901) [1], during epigenesis of subdiaphragmatic digestive system viscera may represent

1) Romanian Academy of Medical Sciences, Bucharest, Romania
2) University of Medicine and Pharmacy of Craiova, Doctoral School, Craiova, Romania
* Corresponding author: MD, PhD, Email: dragoigs@gmail.com
3) University of Medicine and Pharmacy of Craiova, 5th Department, Craiova, Romania
4) University of medicine and Pharmacy of Craiova, Department of anatomy, Craiova, Romania
causes or effects of biostatics and biocinematics of digestive system primordia? 2) In which way does the abdominal cavity volume influence the biodynamics of these primordia evolution? 3) Which are the anatomic factors that allow the occurrence of intestinal ansa hernia, their return into peritoneal cavity and their fixation onto the posterior wall of abdominal cavity, in adult ortotaxy? 4) Which is the contention value of common dorsal meso in the morphogenesis dynamics of subdiaphragmatic digestive system? 5) Which are “the growth factors” for the elongation of subdiaphragmatic digestive system viscera primordia? 6) Which is the contribution of vascular mesenchyme in angiogenesis, formation and differentiation of subdiaphragmatic digestive system viscera?

**MATERIALS AND METHODS**

The study was conducted on human biologic material: 8 embryos aged between 6 and 8 weeks, 6 fetuses aged between 12 and 16 weeks and 9 fetuses aged between 20 and 28 weeks. Embryos were fixed in 6% formaldehyde solution, at pH=7.4. After paraffin inclusion of embryos, seriate sections were performed, in transversal (4 embryos), sagittal (2 embryos), and frontal (2 embryos) planes. Examination of seriate sections stained with Hematoxylin-Eosin was performed with the help of Nikon Eclipse 80i microscope, in order to assess the relations between digestive system primordia and mesenterial mesenchyme.

Fetuses were fixed in 10% formaldehyde solution, at pH=7.4, by catheterization of umbilical vein. Fetuses’ dissection included, after exposing abdominal and peritoneal cavities, the visualization and analysis of relations between medium intestine primordia derivates and afferent mesos.

Microphotographs were taken with Nikon Sight DS-Fi1 High Definition Color Camera Head and processed by Software NIS-Elements Advanced Research. Microphotographs were taken with Canon EOS-1ds Mark II Digital Camera with Macro Ultrasonic Lens, 100mm, f/2,8.

**RESULTS**

**A. Microanatomic analysis of relations between subdiaphragmatic digestive system primordia and mesenterial mesenchyme, in embryo**

From the analysis of transversal seriate sections through 7 and 8 weeks embryos, it was easily noticed the presence of small intestine secondary loops, herniated through umbilical ring (Anulus umbilicalis) (Fig. 1 A-D). Common mesenteric pedicle (Truncus mesentericus communis) is formed by the fusion of ansa umbilicalis meso (common mesentery) to the duodenal meso. After this merging, common mesentery divides into a superior portion, where the colon is attached and will become mesocolon and an inferior portion, where the small intestine is attached and will become the definitive mesentery (mesojejunum and mesoileum) (Fig. 1 C). Intestinal loops, on seriate sections, have the shape of U, V or A letters, their branches being reinforced by jejunoileal mesentery (Fig. 1 B, C, D). Examination of supraumbilical seriate sections reveals glandular derivates of duodenal ansa: liver and pancreas, establishing contiguity relations between them (Fig. 1A). Dorsal mesogastrum is longitudinally sectioned and contains glandular elements of pancreas and lymphoid spleen structures; between them, relations are established through gastro-pancreatic and pancreatic-spleen folds (Fig. 1B). Ventrally to these structures, retrogastric space of omental bursa is visible (Fig. 1 A, B); dorsally, relations of dorsal mesogastrum derivates with suprarenal gland and genital crest are easily identifiable (Fig. 1 A, B). Ventrally, gastric-spleen fold becomes visible. The examination of infraumbilical seriate sections allowed the visualization of mesonephros, metanephros, terminal intestine (hindgut), connected to the dorsal wall of celiac cavity through common dorsal mesentery (mesocolon) (Fig. 1D).

**B. Macroanatomic analysis of relations between digestive system primordia derivates and mesenterial mesenchyme in human fetus**

Macroscopic examination of 10 weeks fetus’s frontal and lateral parts of anterior abdominal wall, allowed visualization of secondary intestinal ansa, herniated through anulus umbilicalis (Fig. 2 A-C). It is easily noticeable the spiral trajectory of intestinal ansa (Fig. 2D). In 16 weeks fetus, after exposing abdominal and peritoneal cavities, we identified, within the superior level, a clew of tertiary jejunal-ileal intestinal loops, which continues, caudally, with the primordial colon (Fig. 2F). Intestinal ansa trajectory is determined by helicoids spatial orientation of jejunal-ileal meso, the loops describing curves with great curvatures, giving the impression of merging during macroscopic examination of these intestinal loops clew (Fig. 2 E, F, H). Primordial colon is visible near the median plane, continuing directly the jejunal-ileal loops clew, describing, within its first portion, three curvatures, in a spiral trajectory (Fig. 2 F, G). Jejunal-ileal loops clew tilting to the right of medial-sagittal plane allows the visualization of two major junctions: gastro-duodenal and duodenal-jejunal (Fig. 2H). Examination of peritoneal cavity in 4 and 6 months old fetuses, allowed the visualization, within supramesocolic space, of stomach and duodenum, till the superior half of the descendent portion, and, within inframesocolic space, the jejunal-ileal intestinal loops, covered by greater omentum, attached by the greater curvature of stomach and which, in its pathway, covers the transverse colon (Fig. 2I). Jejunal-ileal loops have a spiral trajectory and appear as suspended by the

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mesentery, which present subperitoneal, lymphatic-nodular conglomerates (Fig. 2 J, K). At the level of ileal-caecal junction, it is easily highlighted the ileal-caecal meso, containing branches of superior mesenteric artery (Fig. 2L). Caecum and ascendant colon are attached to the posterior wall of abdominal cavity (Fig. 2L). Examination of transverse mesocolon, after cranial tilting of transverse colon, allowed the visualization, within the meso thickness, of an arterial vascular network, formed by inferior and superior mesenteric arteries branches (Fig. 2M). Spatial distribution of inferior mesenteric artery branches was visible after the excavation of left mesenteric-celiac space. Sigmoid colon is easy to mobilize through its meso (Fig. 2N).

**DISCUSSION**

Morphogenesis of subdiaphragmatic digestive system viscera is multifactor dependent and yet widely debated by anatomists, embryologists, surgeons and pediatric doctors. Viscera primordia belong to those three parts derivated from vitelin sack: foregut (Praenteroni), midgut (Mesenteron) and hindgut (Metenteron). Epigenesis of medium intestine led to intense researches and controversies.

Two particular features were nominated within midgut (mesenteron) evolution: hernia and rotation of intestinal loops (Meckel 1817 [2]; Mall 1898 [3]; Fredet 1901 [1]). Intestinal organogenesis in the first development weeks of embryo is presented in classical works by the scheme of the surgeon Fredet (1901)[1], in the work of human anatomy of Poirier-Charpi (1901)[1]. It is known as “intestinal rotation”.

The assessment of ortotaxy and heterotaxy of subdiaphragmatic digestive system viscera, as effects of intestinal rotation or malrotation, created many confusions. Frazer and Robbins (1915)[5] remarked that small intestine development occurs between two landmarks of *ansa umbilicalis*: a proximal one, at the level of duodenal-jejunal junction and another one, distally, at the level of umbilical ansa colic angle. Later, Snyder and Chaffin (1954)[6] considered that these landmarks are more likely growth and differentiation areas of *ansa umbilicalis* derivates.

Soffer *et al.* (2015)[7], resuming the idea of Meckel (1817)[2], demonstrated that rapid longitudinal growth process of midgut coincides with the one of mesentery. Intestinal rotation process is classically divided into three stages (Frazer and Robbins, 1915)[5]: 1) Temporal, physiologic, extracelomic hernia of intestine through *anulus umbilicalis*; 2) Intracelomic return of the herniated intestine and 3) Intestinal portions attachment.

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**Diagram 1.** International embryological terminology for the primordium of digestive system (*Primordia systematis digestorii*). (Federative International Programme on Anatomical Terminologies, 2013).
to the abdominal posterior wall through mesentery, into the adult position. During these stages, *ansa umbilicalis* would suffer rotations up to 270 degrees (Fredet, 1901) [1].

There are, still, contradictory data regarding major events synchronization: time of physiological umbilical hernia onset (Frazer and Robbins, 1915[5]; Estrada, 1958[8]; Skandalakis and Eray, 1994[9]), hernia reduction speed (Mall, 1898[3]; Snyder and Chaffin, 1952[6]; Cyr et al. 1986[10]); caecum location immediately after hernia reduction (Frazer and Robbins, 1915[5]; Dott, 1923[11]); Snyder and Chaffin, 1954; Fitzgerald et al. 1971[12]) and not least, the temporal duration of rotation (Frazer and Robbins, 1915[5]; Estrada, 1958[8]).

Repciuc (1964[13], 1971[14]), anatomist and embryologist, observed that in the intervals between *ansa umbilicalis* rotations, the intestine still grows and folds, and thus, shadows the successive rotations effects. Already in 1920 and 1926, Pernkopf [15;16], anatomist and embryologist, noticed the inconsistence of a certain part of Fredet's rotations description (1901)[1]. It is considered that, after umbilical ansa rotation, colon is situated above and the small intestine, below. The root of common *meso* is located inside “duodenal horseshoes”, so that mesocolon is situated upper and the mesentery lower, continuing to the right through common *meso* root, being parallel and inside duodenal ansa. This situation is impossible to explain by Fredet's proposed rotation theory. This fact led to a new series of researches. Repciuc et al. (1964, 1971)[13, 14] contributed to the discrediting of rotation theory, demonstrating that reality is different.

First, authors observed that digestive tract, mostly *ansa umbilicalis*, were not located in the mediol-sagittal plane. Descendent portion is deviated to the right, meanwhile, the ascendant part is situated in an almost perfect transversal (horizontal) plane, directed from right to left, crossing medial-sagittal plane and returning again to the right till the median line, from where it continues with terminal intestine, which descends vertically down. Neither the following stage of development involves rotations. *Ansa umbilicalis meso*, with the shape of a cone, sectioned after its generator, is opened to the right and merges with duodenal *meso* (mesoduodenum) which, in this development stage, is almost horizontal. Still, mesoduodenum already contains pancreas sketch and has, consequently, a considerable thickness (Fig. 1B). When common mesentery (*ansa umbilicalis meso*) merges with mesoduodenum, they constitute an assembly which Pernkopf (1922)[15] nominated as "common mesenteric pedicle" (*Truncus mesentericus communis*).

After merging, common mesentery divides into two mesos: a superior one, where colon is attached (mesocolon) and an inferior one, where small intestine is suspended (mesenter) (Fig. 1C). Because the two mesos derive from common mesentery, they must continue one to each other. If we take into account the geometrical shape of common mesentery, then the continuity line is located to the right. Authors mention that mesocolon remains short, while mesentery elongates considerably, mostly because intestinal ansa grow vigorously and leave the abdominal cavity through umbilical ring (*Anulus Umbilicalis*), achieving the physiological umbilical hernia. In this development stage, mesos remain for a long period of time inside "duodenal horseshoe".

During the last development stage, small intestine mesentery merges with abdominal cavity posterior wall, in the same time with mesoduodenum. In this manner, the coalescence fascias appear: Treitz fascia, behind mesoduodenum and Told fascia, behind mesentery. Still, mesentery coalescence is only partial. It occupies the triangular area situated between transverse colon meso, ascendant colon and an oblique line that units duodenal-jejunum flexure with the point where ileum makes the junction with ascendant colon. To the left of this line, called also tertiary mesentery root (Radix mesenterii), the free, unattached mesentery portion is found.

Common mesenteric pedicle merges through its right face (mainly superior in certain development stages) to the trunk's posterior wall and through its left face (mainly inferior in certain development stages) to the common mesentery (namely to the *ansa umbilicalis meso*). So, we understand that common mesenteric pedicle is a veritable structural plate in abdominal viscera evolution.

Equally, the theory of stomach rotations was discredited by researches of Meffert (1970; 2000)[17;18]. She demonstrated that stomach modifies its shape, but does not pivot in its axis; the greater epiplon (Omentum majus) is just a mesenchyme proliferation in the region of stomach's greater curvature and does not have any connection with dorsal mesogastrum. All the beautiful theories regarding the six layers of dorsal mesogastrum, which the student must learn, in a shameful way, are legends (Repciuc, 1971)[14].

The results of our observations, correlated with anatomic literature data, demonstrate that ortotaxy of subdiaphragmatic digestive system viscera is determined by morphogenesis synergisms synchronism between ectoblastic and mesenteric mesenchyme derivates. Asynchronies of reciprocal interactions between digestive system and mesenteric mesenchyme primordials generate, on one side, heterotaxy, atresia and stenosis and on the other side, through peritoneal relations, the formation of abnormal peritoneal recesses. It is known the fact that peritoneum achieves, frequently, in duodenal, caecal and sigmoid portions, semilunar folds, under which, more or less deeper depressions are found, nominated as recesses (synonym with fossette in French Nomina). In pathology, these recesses may become sites for hernia (congenital internal): paraduodenal, pericaecal and intersigmoid, widely explored in peritoneal cavity forensic examination. It is regrettably the fact that International Embryology
Terminology (2013) includes within the group of small intestine malformations also the malrotations, although the absence of rotations during subdiaphragmatic digestive system viscera morphogenesis was demonstrated. Moreover, types of malrotations are nominated: incomplete rotations, hyperrotations, non-rotations and reverse rotations.

**CONCLUSIONS**

1. Ortotaxy of subdiaphragmatic digestive system viscera is determined by synergic and synchronic interactions, in time and space, between ectoblastic and mesenteric mesenchyme derivates.

2. Morphologic differentiation synchronism of digestive system primordia, offers anatomic arguments against rotation and malrotation concepts, in order to explain the location and spatial relations of subdiaphragmatic digestive system in normal and pathological conditions.

3. Umbilical ansa rapid growth and fold shadow the effects of its successive rotations.

4. Common mesenteric pedicle, through its location inside “duodenal horseshoes” represents a veritable structural plate in the evolution of subdiaphragmatic digestive system viscera.

5. Peritoneal recesses within duodenal, caecal and sigmoid regions become elective sites for congenital internal hernias.

**References**


