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Mesenchymal Paradigm: Implications in Morphogenesis

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Abstract

A micro-anatomic study of mesenchyme involvement in the morphogenesis of human biosystem is intended. The research was carried out on 80 sagittal serial sections taken from a 12-week human fetus. Spatial distribution of mesenchyme within the gut tube, urogenital and endocrine systems was analyzed. The results are based on the assumption that there are two forms of mesenchyme if one takes into consideration the embryonic origin: mesenchyme originating from mesoderm (meso-mesenchyme) and mesenchyme originating from ectoderm (ecto-mesenchyme) within the neural crest. We believe that in the morphogenesis of human biosystem, the mesenchyme can be induced byphenotype changes or it can act as an inductor in other structures. The significance of mesenchyme space distribution and of its phenotype changes in pathology is discussed.

Keywords: Meso-mesenchyme; Ecto-mesenchyme; Visceral stroma; Perivisceral fibrous structures

Introduction

Mesenchyma or mesenchyme, (Gr. mes=middle, Gr. enkyma=to infuse) is an embryonic tissue of mesodermal (Gr. meso-mesenchyma) or ectodermal (Gr. ecto-mesenchyma) origin. It plays a very important role in the structural genesis and evolution of the human bio-system. In the history of research the diversity of these mesenchyme-dependent structures raised numerous issues regarding the nomination of the embryonic conjunctive tissue, its morphogenesis and morpho-diferentiation and last, but not least, its regenerating capacity under normal and pathological conditions.

This is not a chance study. Since the introduction of the term mesenchyme by Hertwig et al. [1], the research regarding the mesemchyme has undergone two paradigmatic changes. The first model of paradigm was dominated by micro anatomic research methods; they enabled the evaluation of the mesenchymal role in the genesis and evolution of human biosystem structures [2]. Based on the criteria of its own genesis, two types of mesenchyme were identified: the mesenchyme derived from the mesoblast (meso-mesenchyme) and the mesenchyme derived from the ectoblast (ecto-mesenchyme).

Katschenko [3] observed that the mesenchyme from the cephalic region comes from the neural crest. Platt [4] proved that the mesenchyme within the bronchial arches is of ectodermal origin and her finding was confirmed by Landacre [5]. Along with the preoccupations for the identification of the ectodermal or mesodermal origin of the mesenchyme, numerous studies suggested the role of the interactions between epithelium and mesenchyme during the formation of bio-structures [6]. Cairns and Saunders [7] observed that the mesoderm possesses stimuli that induce the interaction between mesoderm and epithelium. Kollar and Baird [8,9] studied the epithelium-mesenchyme tissue interactions in the morphogenesis of teeth, attesting the influence of dental papillae on their growth.

The change of paradigm was imposed by the appearance of new research methods in the fields of developmental and cell biology; they enabled the discovery of "mesenchymal stem cells" by Friedenstein et al. [10], with implications in the regenesis of tissue and of the developmental genes involved in controlling cell proliferation, migration and differentiation.

Today we think it necessary to move on to a new paradigm in understanding the variable micro-anatomic involvement of the mesenchyme in morphogenesis and the embryo-fetal location of the structures derived from the mesoblast mesenchyme and/or ectoblast mesenchyme.

Our study is focused on the micro anatomic evaluation of the relations between the structures derived from the mesenchyme and the latter's localization within the abdominal cavity of a 12-week foetus. The following mesenchymal structures were analyzed: of the mesogastrium, mesentery and peri-visceral structures within the digestive and urogenital systems, as well as of the adrenal gland.

We consider might contribute to the enlightenment of the phenotypical transformations triggered by the involvement of the mesenchyme, both directly or as an inductor in the morphogenesis of biostructures in the process of epigenesis.

Materials and Methods

Our study was carried out on a 12-week-old human foetus that was spontaneously aborted, in the absence of any pathology of the mother. At the proximal extremity of umbilical cord, herniated ileal loops were present. The sex of the foetus could not be identified. The cephalic extremity did not present any malformations. The length vertex-coccygis was 72 mm.

After washing it with saline solution, the fetus was introduced in 5% formaldehyde solution buffered at 7.5 pH. After dehydration with ethanol and clarification with toluene, the fetus was embedded in paraffin.

We made 80 serial sections, 5 microns thick, following the sagital planes from lateral to medial. The sections were stained with Hematoxiline-Eosine. The microanatomic examination was performed with x20, x40 and x60 objectives of a Nikon Eclipse 80i microscope. The images were captured on Nikon Sight DS-Fi1 High Definition Color Camera Head and were processed by using Nis Element Advanced Research software.

Results

Microanatomic analysis of mid gut mesenchyme structure in 12-week human foetus

On examining these sagittal serial sections, with the objective x4, we identified the derivates of the primordium foregut caudal part (supra-ampular duodenum=Pars praeenteronica duodeni) and of the proximal limb of the midgut loop (infra-ampular duodenum=Pars mesenteronica duodeni, jejunum, ileum). Supra-ampular duodenum appears, on the sagittal sections, as having a semicircular shape, with dorsally oriented concavity. The dorsal part of the pancreas head is included in the duodenal concavity (Figure 1).

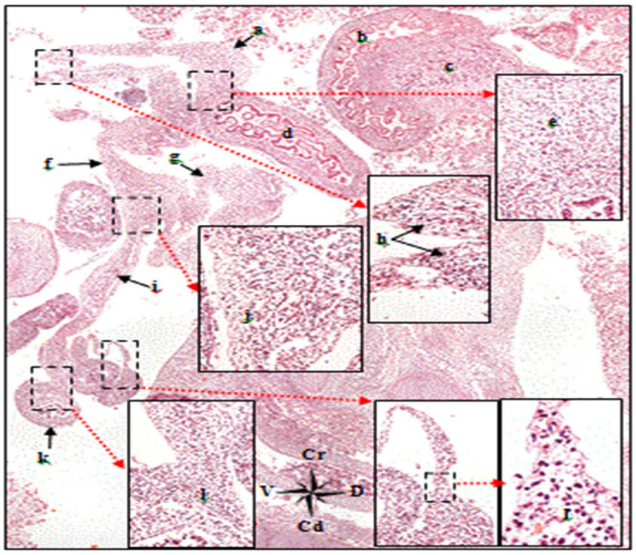

Figure 1: Microanatomic topography of mesenchyme inside the meso of midgut in 12 weeks human fetus; a: Mesoduodenum dorsale; b: Pars preenteronica duodeni; c: Pars dorsalis capitis pancreatis; d: Pars mezenteronica duodeni; e: Mesenchyme inside dorsal meso duodenum in relation to external layer of pars mesenteronica duodeni; f: Mesenterium dorsale commune; g: Mesojejunum; h: Vascular connective tissue inside dorsal mesoduodenum; i: Mesoileum; j: Mesenchyme inside mesenterium dorsale commune; k: Herniated ileal loops through umbilical orifice; l: Mesenchyme inside mesoileum. Cr: Cranialis; Cd: Caudalis; V: Ventralis; D: Dorsalis. Paraffin section. Hematoxylin – Eosine stain. Microphotographs taken with Nikon Sight DS-Fi1 High Definition Color Camera Head. Large image x4; Magnifier: x10; x20.

Infra-ampular duodenum appears, on the sagittal sections, as having an ovoid shape. Its external tunic continues with the mesenchyme of the mesoduodenum dorsale (Figure 1). When examining this mesenchyme, with the objective x40, the presence of numerous blood vessels surrounded by lax connective tissue is detected (Figure 1d). The mesoduodenal mesenchyme preserves a structure similar to the one of common dorsal mesentery: mesojejunum and mesoileum (Figure 1f, 1g and 1i). On examination with the objectives x10, x20 and x40, we identified, within meso-jejunum and meso-ileum, the same conjunctive-vascular structure as the one found at mesoduodenum level (Figure 1h, 1j and 1k).

Microanatomic analysis of location, in structures derived from dorsal mesogastrium mesenchyme, in 12-week human foetus

On examining the sagittal serial sections, with the objective x4, omental bursa appears as located retro-gastrically and delineated by mesenchymal structures, as follows: the external tunic of the gastric wall, the gastro-pancreatic ligament, the pancreatic-lienal ligament and gastro-lienal ligament. Ventral expansion of omental bursa is bordered by the gastro-pancreatic ligament (Figure 2). Dorsal mesogastrum mesenchyme contains the pancreatic bud, towards the ventral extremity of the pancreatico-lienal ligament (Figure 2d).

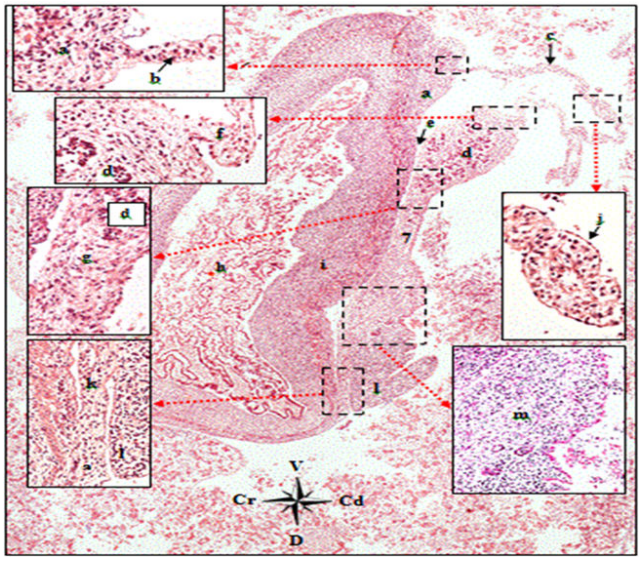

Figure 2: Differentation abilities of mesenchyme inside dorsal mesogastrum into pancreas stroma and lymphoid structures of spleen in 12 weeks human fetus. a: External tunic of gastric wall; b: Gastric insertion of gastropancreatic ligament;c. Gastropancreatic ligament; c: Dorsal pancreatic bud; d: Bursa omentalis; e: Pancreatic insertion of gastropancreatic ligament; f: Pancreaticosplenic ligament; g: Mucous tunic of stomach; h: Muscular tunic of stomach; i: Blood vessel forming mesenchyme; j: Gastrosplenic ligament; k: Lymphoid tissue primordia of spleen; l: Splenic insertion of pancreaticosplenic ligament. Cr: Cranialis; Cd: Caudalis; V: Ventralis; D: Dorsalis. Paraffin section. Hematoxylin – Eosine stain. m: Microphotographs taken with Nikon Sight DS-Fi1 High Definition Color Camera Head. Large image x4; Magnifier : x10 x20.

Within the dorsal mesogastrium extremity, we identified lymphoid structures belonging to spleen primordia. At this level, we visualized, with objectives x20 and x40, the primordia of spleen capsule, spleen reticular stroma and the origin of the gastro-lienal ligament (Figure 2k-2m). The connection between pancreatic and spleen primordia is made by a strong pancreatico-lienal ligament (Figures 2b, 2f, 2j and 2m). On examining the dorsal mesogastrium mesenchyme, with objectives x20 and x40, a rich vascular network, containing haematic-formator elements is visualized (Figures 2b, 2f, 2j and 2m).

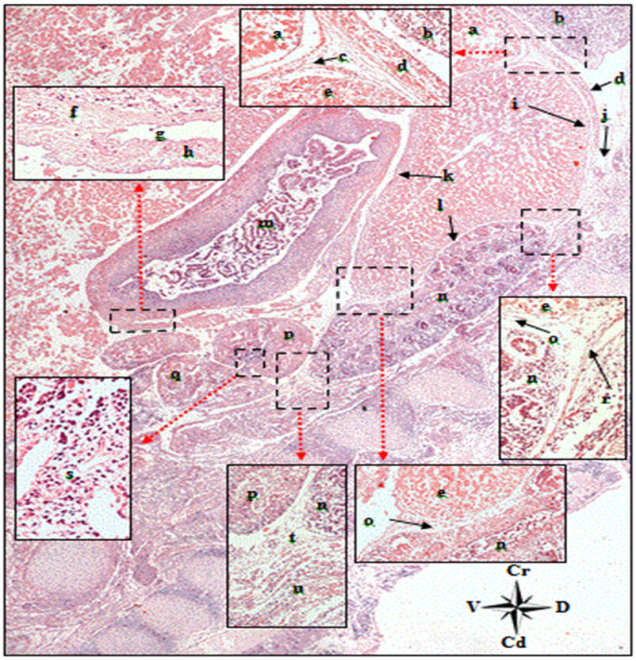

Figure 3: Microanatomic topography of mesenchyme inside suprarenal and urogenital systems in 12 weeks human fetus. a: Hepar – facies diafragmatica, pars superior; b: Basis pulmonis – facies diaphragmatica; c: Subdiaphragmatic mesenchyme expansion between liver and suprarenal gland; d: Diaphragm; e: Glandula suprarenalis; f: External tunic of gastric wall; g: Bursa omentalis – recessus inferior; h: Gastrosplenic ligament; i: Glandula suprarenalis – facies posterior; j: Recessus costodiaphragmatis; k: Glandula suprarenalis – facies anterior; l: Glandula suprarenalis – facies renalis; m: Gaster; n: Metanephros; o: Suprareno-renal mesenchyme expansion of renal capsule; p: Primitive gonad; q: Mesonephros; r: Perirenal fascia; s: Meso for primitive gonad; t: Fascia between primitive gonad, metanephros and psoas muscle. Cr: Cranialis; Cd: Caudalis; V: Ventralis; D: Dorsalis. Paraffin section. Hematoxylin – Eosine stain. u: Microphotographs taken with Nikon Sight DS-Fi1 High Definition Color Camera Head. Large image x4; Magnifier: x10.

Microanatomic analysis of perivisceral mesenchyme structures within the urogenital system, in a 12-week human foetus

The examination of sagittal serial sections, with the objective x4, made visible structures derived from the mesenterium urogenitale mesoblast. Within the space delineated cranially by the diaphragm muscle, dorsally by the spine and ventrally by omental bursa, it is easily noticed the presence of the adrenal gland-of important size-metanephros, the primitive gonad and mesonephros, in involutionary stage (Figure 3). Mesenchymal structures surround these viscera and are organized as capsules and intervisceral fibrous expansions. The adrenal gland is surrounded by a capsule-mesenchyme structure, through which it is in relation with the diaphragm, by facies dorsalis, with metanephros, by facies renalis and with omental bursa, by facies ventralis. In sagittal section, metanephros has an ovoid shape. The mesenchyme contributes to the formation of the renal capsule, through which metanephros is in relation with the adrenal gland through adreno-renal fibrous expansion (Figures 3o), with the primordial gonad, through a gonado-renal fibrous expansion and dorsally with the spine and psoas-iliac muscle, through a dorsal fibrous expansion of the renal capsule (Figures 3e, 3i, 3k, 3l, 3n, 3o and 3t). The primordial gonad maintains a connection with the mesonephros through the "primordial gonad meso" (Figure 3s). The gonad is surrounded by a perigonadal fascia, through which it is in relation with the psoas-iliac muscle (Figure 3q and 3u).

Discussion

The mesenchyme remains a wide field of research due to its involvement in morphogenesis, re-genesis and tissue repair processes under normal or pathological conditions.

We made a micro anatomical analysis of the location of the mesenchyme within structures capable of growing and differentiating in time and space and within structures that limit compartments, such as visceral lodges.

The mesoderm mesnchyme within the mesentery was visualized and analyzed: a) at the insertion site of inter-visceral ligaments: gastric or pancreatic insertions of gastro-pancreatic ligament; pancreatic and splenic insertion of pancretico-splenic ligament; gastric and splenic insertions of gastro-splenic ligament; b) within the structures that fix the sub diaphragmatic digestive tube to the posterior abdominal wall: mesoduodenum dorsal, mesenterum dorsal commune, mesojejunum, mesoileum that are connected to the mesentery lymphatic system; c) within the perivisceral mesenchyme expansions: hepato-suprarenal, suprareno-renal, the fascia between the primitive gonad, metanephros and psoas muscle as well as in the meso of the primitive gonad.

The variability of the mesenchymal structures we analyzed is determined by the expression of tissue interactions such as: a) the mesenchyme originating in the mesoblast induces the morphogenesis of the mesentery of pancreas and gonads, of the perivisceral fibrous expansions, of the visceral stroma and last but not least, of the sub epithelial basal membrane; b) the mesenchyme originating in the ectoblast contributes to the morphogenesis of adrenal medulla together with the mesenchyme that determines the formation of adrenal cortex.

But, what is the significance of the mesenchyme spatial distribution and of its phenotype changes in pathology? Visceral stroma, as a form of mesenchyme distribution, offers information regarding the relations between epithelium and mesenchyme through the anatomic changes undergone by the sub-endothelial basal membrane. Stroma resists to the processes of putrefaction and can be visualized after reduced silver nitrate Gömöri method and/or after van Gieson picrofuxine staining. The presence of perivisceral fibrous expansions makes spaces that can be invaded by puss collections or haemorrhage.

Conclusion

The mesenchyme is an omnipresent and pluripotent embrionary structure that is present in the morphogenesis and evolution of human biosystem structures.Today the change of paradigm is imposed as a need to analyze the variability of the morphogenesis of biostructures as a consequence of mesenchymal contribution in the dynamics of its epigenesis.

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