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A NARRATIVE REVIEW ON AYURVEDIC ORGANOGENESIS AND ITS MODERN CO-RELATION AS PER SUSHRUTA SAMHITA AND ASTANGA SAMGRAHA

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Abstract:

Ayurveda, a flourishing traditional medical system renowned for its extensive knowledge, includes *Rachana Sharir* as a fundamental subject. *Rachana Sharir Vigyan* explores the anatomical aspects (*Rachna*) of the human body. The immense knowledge of the ancient wisdom of *Ayurveda* is not comprehensively described yet. The *Samhitas* and *Vedas* of Indian literature by different *acharyas* elaborate on how the human body evolved from a combination of *Pancha Mahabhutas* and *Atma* (*Chetana*). This review aims to elucidate the classical aspects of *Anga Avayav Utpatti* from *Ayurvedic* texts and establish correlations with contemporary scientific knowledge. The description about *Anga Avayava Utpatti* is carried out from the classical text books of Ayurveda, previous research articles related to topic, the embryological study are carried out from various modern text books and from internet bases such as Scopus, Google scholar, PubMed, Research gate, etc.

Key Words: *Anga Avayava Utpatti*, Organogenesis

INTRODUCTION

In ancient literature of *Ayurveda "Garbhavkranti Shariram"* is the science which deals with all the embryological phenomena. *Veda, Purana, Brihatrayi, Laghutrayi*, commentators of *Samhitas* especially Dalhan, Chakrapani, Arundatta, etc also has illustrated *Garbhavkranti-Shariram*. It can be divided into three parts so that the gradual development and formation can be studied easily: *Garbha Avataran* (Inception), *Garbha Nirman* (Formation) and *Garbha Poshana* (Nourishment). In this particular study, *Garbha Nirmana* and formation of different *Avyava*, according to Acharya Sushruta and its modern correlation would throw light on the knowledge of sages in ancient era. How different *Mahabhutas, Dhatus*, etc plays significant role in the *Anga Avyava* formation is also stated.

According to Acharya Sushruta there are 6 factors (*Shadbhava*) which are responsible for foetal development; out of these two factors that are mainly taking part in *Avyava* formation are *Matraja* and *Pitraja Bhava*.[1]

- *Matraja Bhava* gives origin to the following organs (*Avyava*): *Twacha, Rakta, Mamsa, Meda, Hridaya, Vrikka, Basti, Yakrit, Kloma, Nabhi, Pleeha, Uttara Guda, Adhara Guda, Purishadhar, Amashaya, Vapavahan, Kshudrantra, Pakvashaya* and *Sthulantra.*

[1] Dr Bhaskar govind Ghanekar vth edition, Sushrut samhita, Sharira Sthana. Publication-motital Banarasi Das, 1962; 3-31.

- *Pitraja Bhava* gives origin to following organs (*Avyava*): *Kesha, Loma, Shamashru, Nakha, Danta, Asthi, Sira, Snayu, Dhamni* and *Virya*.

Acharya Sushruta also mentioned that *Anga Pratayanga* develops by *Swabhava* and whatever *Guna/Aguna* takes part in the development of these *Anga/Pratyanga* they all depends on the *Poorvajanmkrita Dharma* and *Adharma*.[2] According to the Samhita *Pitta Yukta Vayu* by repeated infiltration causes the *Utapatti* of *Srotas*. In the same manner *Pitta Yukta Vayu* enters the *Mamsa Dhatu* and divides it into *Peshis*. *Vayu* also separates *Snehansha of Meda Dhatu* and forms *Sira* and *Snayu*. *Vayu* also causes spaces inside the body and causes the formation of *Aashaya*.[3]

Acharya Vagbhatta has mentioned that *Indriyas* are derived from the *Sarabhaga* of *Kapha* and *Rakta Vaha Srotas* with *Mahabhuta Sanghata*[4].

According to different Acharyas development of first organ in *Garbha*:

Sl No.	First born body part	Acharya Charak (Ch. Sha. 6/21)	Acharya Sushrut (Su. Sha. 3/32) (B. P. Pur. 3/309-315)	Acharya Bhela (Bhela. Sha. 4/3)
1.	Avicharaniya Visaya	Maricha Kashyap	-	-
2.	Shira	Kumarshira Bharadwaj	Shounak	Bharadwaj
3.	Hrudaya	Kankayan	Kritavirya	Parashara
4.	Nabhi	Bhadrakapya	Parashara	Khandakapya
5.	Pakvashaya and Guda	Bhadrashounak	-	Shounaka
6.	Indriya	Vaideha Janaka	--	---
7.	Madhya Sharira	--	Goutam	---
8.	Chakshyu	--	---	Kashyap
9.	Sarvanga Pratyanga	Dhanwantri and Atreya Punarvasu	Dhanwantri	Atreya Punarvasu
10.	Panipada	Badisha	Markendeya	Badisha

Embryology is the branch of medical science which deals with the study of the formation of the human embryo and its development inside the utero till birth of a foetus. Modern embryology gives very minute and meticulous description of the formation of embryo at molecular and genetic level. With the advents in embryological studies one can now observe the formation of different organs in embryo while Organogenesis process takes place during the first trimester of the pregnancy. Acharya Sushruta also explained the *Avayava Utpatti* in the first four months of the pregnancy. Modern day organogenesis studies also shows very close resemblance with that of the Ayurveda *Avayava Utpatti* descriptions.

REVIEW OF LITERATURE

Organogenesis of different organs as per Ayurvedic concept and its modern narration:

1. YAKRUT

[2] Acharya YT. Susruta Samhita of Susruta with the Nibandhasangraha commentary of Sri Dalhanacharya. Shaareera Sthana; Garbhaavakraanti Shaareera: Chapter 3, Verse 36. Varanasi: Chaukhamba Surabharati Prakashan; reprint 2017:354.

[3] Acharya YT. Susruta Samhita of Susruta with the Nibandhasangraha commentary of Sri Dalhanacharya. Shaareera Sthana; Garbhaavakraanti Shaareera: Chapter 4, Verse 26-31. Varanasi: Chaukhamba Surabharati Prakashan; reprint 2017

[4] Vagbhata, Ashtanga Samgraha, Sharira Sthana, Angavibhaga Sharira, 5/50[1], commentary by Arunadatta, Sarvangasundar, Hemadri, Ayurveda Rasayana, edited by Dr. Anna Kunte, Krushna Shasri Navare, reprint ed., Chaukhamba Sanskrut Sansthan, Varanasi, 2005;

As the liver is a site for haematopoiesis/ *Rakta Dhatu* formation in intrauterine life and stores blood in adults, Ayurveda considers it as *Rakta Adhara* or *Raktashaya*.[5] According to Acharya Sushruta *Yakrut* originated from *Rakta*.[6] According to Astanga Hriday, *Yakrut* derived from essence part of *Rakta* due to action of body heat influenced by the force of *Samana Vayu*. According to Acharya Arundatta the three *Bhavapadarthas* i.e., *Samana Vayu*, *Dehoshma*, and *Rakta Dhatu*, are involved in the formation of the liver, spleen and *Kloma*.[7] From these descriptions, it is clear that all Acharyas emphasized the significant role of Rakta Dhatu in liver development.

The liver starts developing as a hollow endodermal bud from the foregut around the 3rd week of gestation. This bud divides into two parts: hepatic and biliary. The hepatic portion contains bipotential progenitor cells, which differentiate into hepatocytes or ductal cells that form the early primitive bile duct. These rapidly growing cells invade the surrounding mesodermal tissue (septum transversum) and connect with an ingrowing capillary plexus from the vitelline and umbilical veins, which eventually develop into sinusoids. The biliary portion of the endodermal bud gives rise to the gallbladder and the extrahepatic bile duct. Because of the connection between these growing cell masses and the foregut, bile enters the gastrointestinal tract, beginning to flow around the 12th week of intrauterine life. Hemopoietic cells, Kupffer's cells, and connective tissue cells are derived from the mesoderm of the septum transversum. The fetal liver performs a significant hemopoietic function during the first and second trimesters. This function diminishes in the final two months of intrauterine life, leaving only a few hemopoietic cells at birth.

2. PLEEHA

Acharya Sushruta[8] and Astanga Samgraha[9] both have opined about the genesis of *Pleeha* (spleen) from *Rakta Dhatu* (blood tissue).

It develops from mesoderm in the dorsal mesogastrium, close to the developing stomach during 5th week of intrauterine life (IUL). Anatomically spleen is made up of the reticular activating system and the dense network of blood as well as lymphatic vessel, and hence like liver it is also looked like to be composed of the blood. Embryological origin of spleen is from mesenchyme and mesoderm which are again suggesting the origin of spleen from blood.[10]

Therefore, the *Utpatti* of *Yakrut* and *Pleeha*, which is said to be from *Rakta Dhatu* (blood) in Ayurveda, is scientifically rational and evidence based.

3. PHUPHUSA

It develops from the laryngotracheal groove on 22nd day of intrauterine life. It is endodermal in origin. Anatomically lungs are composed of the large number of thin capillaries separated with thin lungs parenchyma and alveolar spaces with surfactant (mucilaginous substance), which gives the appearance

[5] Sushruta, Sushruta Samhita, Sharira Sthana, Sharirsankhya Prakarana Adhyaya, 5/7, edited by Bhaskar Ghanekar, reprint ed. Meharchand Lakhamandas Publication, New Delhi, 2007; 150.

[6] Acharya YT. Susruta Samhita of Susruta with the Nibandhasangraha commentary of Sri Dalhanacharya. Shaareera Sthana; Garbhaavakraanti Shaareera: Chapter 4, Verse 26-31. Varanasi: Chaukhamba Surabharati Prakashan; reprint 2017

[7] Vagbhata, Ashtanga Hrudaya, Sharira Sthana, Angavibhaga Sharira, 3/12, commentary by Arunadatta, Sarvangasundar, Hemadri, Ayurveda Rasayana, edited by Dr. Anna Kunte, Krushna Shasri Navare, reprint ed., Chaukhamba Sanskrut Sansthan, Varanasi, 2005; 387

[8] Acharya YT. Susruta Samhita of Susruta with the Nibandhasangraha commentary of Sri Dalhanacharya. Shaareera Sthana; Garbhaavakraanti Shaareera: Chapter 4, Verse 26-31. Varanasi: Chaukhamba Surabharati Prakashan; reprint 2017

[9] Vagbhata, Ashtanga Hrudaya, Sharira Sthana, Angavibhaga Sharira, 3/12, commentary by Arunadatta, Sarvangasundar, Hemadri, Ayurveda Rasayana, edited by Dr. Anna Kunte, Krushna Shasri Navare, reprint ed., Chaukhamba Sanskrut Sansthan, Varanasi, 2005; 387

[10] Dr. Akashdeep Meshram, Embryonic Development of Organs – AN Ayurvedic review, European Journal of Molecular & Clinical Medicine; ISSN 2515-8260 Volume 7, Issue 11, 2020

of air bubbles in the blood to the lungs. Embryological origin of lungs is mesodermal as well as mesenchymal, which again suggest its origin from blood.

Therefore, the *Utpatti* of *Phuphusa* is said to be *Shonita Phena Prabhava* in Ayurveda, which goes hand in hand with the modern organogenesis.[11]

4. *HRIDAY*

Embryologically *Hriday* is produced from the essence of *Rakta* and *Kapha*. The *Dhamanis* carrying *Prana* to the body part are attached to *Hriday*[12]. Charaka believes that complete development of *Hriday* takes place at the end of third month[13], whereas Sushruta believes that it develops in the beginning of fourth month.[14] According to Sushruta, *Hriday* is derivative of *Matraja Bhava* (maternal factor)[15].

Anatomically heart is composed of the cardiac muscles with blood filled four chambers and connected to major or great vessels. Heart is encircled with the pericardial fluid and lymphatic glands.

Therefore, the *Utpatti* of *Hriday* is said to be *Shonita Kapha Prasadaja*, i.e., blood filled chambers (*Shonitaja*), with the pericardial and lymphatic fluid around the heart (*Kaphaja*).[16]

5. *UNDUKA*

According to Acharya Sushruta and Astanga Samgraha *Unduk*a develops from *'Shonit Kitta'*[17] i.e., from the waste product of *Rakta*.[18]

As *Unduka* is a controversial organ these days it is not further elaborated in the study.

6. *ANTRA, GUDA* AND *BASTI*

According to Acharya Sushruta, the *Sarabhaga* of *Rakta* and *Kapha* getting metabolised by *Vata* and *Pitta*, forms *Antra*, *Guda* and *Basti*.[19] According to Astanga Samgraha, *Antra* is developed from the essence part of *Rakta* and *Mamsa*.[20]

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[11] Dr. Akashdeep Meshram, Embryonic Development of Organs – AN Ayurvedic review, European Journal of Molecular & Clinical Medicine; ISSN 2515-8260 Volume 7, Issue 11, 2020

[12] Sushruta, Sushruta samhita, Sharira sthana, English translation by Prof. Srikantha Murti KR, Chaukhambha Orientalia Publishers, Volume-I, 3rd edition, Varanasi, 2007; 4/31: 60.

[13] Agnivesha, Charak samhita, Sharira sthana, Sharma RK and Dash B English translation and critical exposition based on Chakrapani datta‟s Ayurveda dipika, Chowkhambha Sanskrita Series, Volume- II, 6th edition, Varanasi, 2007; 4/11: 391.

[14] Sushruta, Sushruta samhita, Sharira sthana, English translation by Prof. Srikantha Murti KR, Chaukhambha Orientalia Publishers, Volume-I, 3rd edition, Varanasi, 2007; 3/18: 38.

[15] Sushruta, Sushruta samhita, Sharira sthana, English translation by Prof. Srikantha Murti KR, Chaukhambha Orientalia Publishers, Volume-I, 3rd edition, Varanasi, 2007; 4/33: 47

[16] Dr. Akashdeep Meshram, Embryonic Development of Organs – AN Ayurvedic review, European Journal of Molecular & Clinical Medicine; ISSN 2515-8260 Volume 7, Issue 11, 2020

[17] Acharya YT. Susruta Samhita of Susruta with the Nibandhasangraha commentary of Sri Dalhanacharya. Shaareera Sthana; Garbhaavakraanti Shaareera: Chapter 4, Verse 25. Varanasi: Chaukhamba Surabharati Prakashan; reprint 2017

[18] Vagbhata, Ashtanga Samgraha, Sharira Sthana, Angavibhaga Sharira, 5/48-58, commentary by Arunadatta, Sarvangasundar, Hemadri, Ayurveda Rasayana, edited by Dr. Anna Kunte, Krushna Shasri Navare, reprint ed., Chaukhamba Sanskrut Sansthan, Varanasi, 2005;

[19] Acharya YT. Susruta Samhita of Susruta with the Nibandhasangraha commentary of Sri Dalhanacharya. Shaareera Sthana; Garbhaavakraanti Shaareera: Chapter 4, Verse 26-31. Varanasi: Chaukhamba Surabharati Prakashan; reprint 2017

[20] Vagbhata, Ashtanga Samgraha, Sharira Sthana, Angavibhaga Sharira, 5/48-58, commentary by Arunadatta, Sarvangasundar, Hemadri, Ayurveda Rasayana, edited by Dr. Anna Kunte, Krushna Shasri Navare, reprint ed., Chaukhamba Sanskrut Sansthan, Varanasi, 2005;

Early in the formation of the primitive gut tube, the endodermal layer recruits the splanchnopleure mesoderm which goes on to become the bowel mesentery, connecting the gut tube posteriorly in the embryo.[21] By week four of development, the division of the gastrointestinal tract into the foregut, midgut, and hindgut occurs.[22] The small and large intestines undergo rapid growth during weeks four and five of development. Embryological science believes that the enlarging intestines quickly outgrow the space available in the abdominal cavity causing the entire midgut to herniate into the umbilical cord forming a loop. The superior limb of the intestinal loop forms the ileum while the inferior limb forms the colon. Between the two limbs is the vitelline duct which connects the intestine to the yolk sac. From here, the bowel continues to grow and rotate for the next five weeks as follows:

- The herniated intestine rotates ninety degrees counter clockwise around the mesentery causing the proximal portion of the loop to migrate from the superior position to the right side and the distal portion of the loop to migrate from the inferior position to the left.
- At week ten, the bowel retracts back into the abdominal cavity where it rotates one hundred and eighty degrees more counter clockwise. The cecum is now in the right upper quadrant of the abdominal cavity.
- Enlargement of the large intestine pushes the cecum down into its final position in the right lower quadrant.[23]

During the time of midgut growth and rotation, other developmental changes are occurring simultaneously, including:

- Week 4: Neural crest cells enter the foregut.
- Week 7: Neural crest cells reach the hindgut.
- Week 9: The cloaca becomes patent, and villus formation begins.
- Weeks 11: Mature smooth muscle layers are present along the gastrointestinal tract.

Rectum Formation[24]

Mucous membrane:
(a) Above the Houston's third valve (middle rectal valve), the mucous membrane is developed from the pre-allantoic part of the hind gut.
(b) Below the third valve, it is developed from the dorsal part of the endodermal cloaca, which is separated from the ventral part of the cloaca (primitive urogenital sinus) by a coronally oriented urorectal septum.
Musculature and the other coats:
These are derived from the splanchnic mesoderm which surrounds the hind gut.

Anal canal Formation[25]

• Above the pectinate line: the anal canal is developed from the dorsal part of the endodermal cloaca.
• Below the pectinate line: it is derived from the ectodermal proctodeum. The pectinate line represents the primitive position of the anal membrane.

Bladder Formation[26]

The mucous membrane of the bladder is developed from the following sources;

[21] Davis NM, Kurpios NA, Sun X, Gros J, Martin JF, Tabin CJ. The chirality of gut rotation derives from left-right asymmetric changes in the architecture of the dorsal mesentery. Dev Cell. 2008 Jul;15(1):134-45. [PMC free article] [PubMed]
[22] Kluth D, Jaeschke-Melli S, Fiegel H. The embryology of gut rotation. Semin Pediatr Surg. 2003 Nov;12(4):275[PubMed]
[23] Davis NM, Kurpios NA, Sun X, Gros J, Martin JF, Tabin CJ. The chirality of gut rotation derives from left-right asymmetric changes in the architecture of the dorsal mesentery. Dev Cell. 2008 Jul;15(1):134-45. [PMC free article] [PubMed]

[24] A.K Datta, Essential of Human Embryology, 7th edition, Current books International 60, Lenin Saranee, Kolkata,2017;147.
[25] A.K Datta, Essential of Human Embryology, 7th edition, Current books International 60, Lenin Saranee, Kolkata,2017; 148.
[26] A.K Datta, Essential of Human Embryology, 7th edition, Current books International 60, Lenin Saranee, Kolkata,2017; 219,220

(a) The entire mucosa of the bladder except the internal trigone is developed from endoderm of the vesicourethral part of the cloaca. More recently it is believed that the entire mucosa is endodermal in origin.
(b) The apex of the bladder is derived from absorption of the proximal part of the allantoic diverticulum. The distal part of the diverticulum is obliterated and the fibrosed persists as the urachus which extends from the apex of the bladder to the umbilicus. The fibrous cord of urachus is derived from the splanchnic mesoderm around the allantoic canal.

The internal trigone of the bladder is developed from mesoderm by the incorporation of caudal parts of the mesonephric ducts. The mesonephric ducts open into the pelvic part of the urogenital sinus, and the common excretory ducts (the part of mesonephric duct between the ureteric bud and the cloaca) are blended with the dorsal wall of vesicourethral part of the cloaca after forming an S-shaped loop. Eventually the ureteric buds open directly into the bladder. Thereafter, the ureteric openings migrate head wards and laterally, probably due to the growth of the bladder wall; this increases the surface area of the internal trigone. The mesodermal contribution of the trigone is not only confined to the bladder, but extends along the dorsal wall of the proximal part of the urethra. Currently it is thought that the mesodermal tissue of the trigone is over grown by the endoderm from the surrounding bladder wall, and the mesodermal components of the mesonephric ducts persist as the trigonal muscle of ureters. This accounts for smooth and glistening mucosa of the internal trigone. The musculature and other structure of the bladder are developed from the splanchnic layer of lateral plate mesoderm which surrounds the cloaca.

Antra, *Guda* and *Basti* are derived not only from the endoderm but from mesoderm as well, which is the origin of connective tissues including blood (*Rakta)* and muscles (*Mamsa*). Muscles and its vasculature are an integrated part in the formation of gut tube. During the development it is also seen that there is extensive bowel movements and metabolic processes involved which are the *Karma* of *Vata* and *Pitta.* These afore-mentioned facts explain the descriptions given in Ayurveda about their origin.

7. JIHWA

According to Acharya Sushruta[27] and Astanga Samgraha[28] from the *Sarabhaga* of *Rakta*, *Mamsa* and *Kapha*, *Jihwa* is formed.

The tongue develops in relation to the pharyngeal arches (1st to 4th) in the floor of the developing mouth. It develops during 4th to 8th weeks of intrauterine life (IUL).[29] The development begins with the growth of a medial swelling from the first pharyngeal arch, known as tuberculum impar. Gradually, two lateral lingual swellings start to grow in the 5th week from the same arch. As the lateral swellings increase in size, they eventually merge and overlap tuberculum impar. This merging leads to the formation of the anterior two-thirds of the tongue. Meanwhile, from the mesoderm of the second, third, and fourth pharyngeal arches, another median swelling, known as hypobranchial eminence, begins to develop and form the posterior third of the tongue. The posterior-most part of the tongue develops from a third median swelling, arising from the fourth pharyngeal arch. The muscles of the tongue predominantly derive from the myoblasts which originate in the occipital somites. The cells which form the tongue are hybrid in nature. The connective tissue component, as well as vasculature of the tongue, is derived from cranial neural crest cells (CNCC). These cells initiate the formation of the tongue bud and the interstitial connective tissue. The myoblasts which are responsible for the formation

[27] Acharya YT. Susruta Samhita of Susruta with the Nibandhasangraha commentary of Sri Dalhanacharya. Shaareera Sthana; Garbhaavakraanti Shaareera: Chapter 4, Verse 26-31. Varanasi: Chaukhamba Surabharati Prakashan; reprint 2017

[28] Vagbhata, Ashtanga Samgraha, Sharira Sthana, Angavibhaga Sharira, 5/48-58, commentary by Arunadatta, Sarvangasundar, Hemadri, Ayurveda Rasayana, edited by Dr. Anna Kunte, Krushna Shasri Navare, reprint ed., Chaukhamba Sanskrut Sansthan, Varanasi, 2005;

[29] T.W Swadler, Langman's medical embryology; Chptaer 6, Third to eighth week: The embryonic period; 11th edition, South Asian edition; Wolter Kluwer health, Gurgaon: Third Indian Reprint 2011: p no. 67 to 87.

of the muscle components of the tongue derive from the occipital somite. Cells from this somite migrate into the primordium of the tongue, thus, forming the muscle cells in the tongue.[30]

As per the aforesaid description *Jihwa* or tongue develops from a medial and two lateral swellings (which shows its *Kaphaja* origin), which later is consolidated by muscles and vasculatures. These details explain the Ayurvedic origin of tongue from *Rakta*, *Mamsa* and *Kapha*.

8. *VRIKKA*

According to Acharya Sushruta[31] and Astanga Samgraha[32] from the *Sarabhaga* of *Rakta* and *Meda*, *Vrikka* are formed.

The definitive human kidney arises from two distinct sources. The secretory part, i.e. excretory tubules (or nephrons) are derived from the lowest part of the nephrogenic cord. This part is the metanephros, the cells of which form the metanephric blastema[33]. The collecting part of the kidney is derived from a diverticulum called the ureteric bud which arises from the lower part of the mesonephric duct, it develops during the 5th week of intrauterine life (IUL).[34] The development of the kidneys occurs in three consecutive phases. It starts with the formation of the pronephros from the intermediate mesoderm. The pronephros is composed of a very primitive tubular system that ends in the nephric duct. Subsequently, the mesonephros forms more caudally, while the pronephros degenerates. This newly formed organ already shows proximal tubular-like structures and glomeruli. At the final stage of kidney development, the metanephros forms even more caudally from the mesonephros. It represents the permanent kidney in mammals. wo distinct structures are required to form the metanephros, the ureteric bud (UB) and the metanephric mesoderm (MM). The UB appears as an outgrowth of the nephric duct induced by secretion of glial cell line-derived neurotrophic factor (GDNF) from the adjacent MM (20). GDNF binds and activates RET and its coreceptor GFRA1, which are expressed along the nephric duct (20). This leads to branching of the UB and subsequently gives rise to the collecting system of the kidney, including the collecting ducts, the calyces, the renal pelvis, and the ureter.[35] The embryonic kidney hosts at least three types of lineage-specific stem cells that give rise to (a) a ureter and collecting duct system, (b) nephrons, and (c) mesangial cells together with connective tissue of the stroma. Renal stroma is a part of the mesenchymal population that caps the nephron-forming mesenchyme.[36] The adult kidneys produce a hormone called erythropoietin that signals the bone marrow to make red blood cells.

The development of the kidney from the mesonephric duct which has the appearance of *Meda* and its further extensive budding for the establishment interfaces in b/w nephron and blood shows its origin from *Rakta* and *Meda*.

9. *VRUSHANA*

According to Acharya Sushruta and Astanga Samgraha from the *Sarabhaga of Rakta*, *Kapha*, *Mamsa* and *Meda*, *Vrushana* is developed.

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[30] Jain P, Rathee M. Embryology, Tongue. In: StatPearls. StatPearls Publishing, Treasure Island (FL); 2023. PMID: 31613477.

[31] Acharya YT. Susruta Samhita of Susruta with the Nibandhasangraha commentary of Sri Dalhanacharya. Shaareera Sthana; Garbhaavakraanti Shaareera: Chapter 4, Verse 26-31. Varanasi: Chaukhamba Surabharati Prakashan; reprint 2017

[32] Vagbhata, Ashtanga Samgraha, Sharira Sthana, Angavibhaga Sharira, 5/48-58, commentary by Arunadatta, Sarvangasundar, Hemadri, Ayurveda Rasayana, edited by Dr. Anna Kunte, Krushna Shasri Navare, reprint ed., Chaukhamba Sanskrut Sansthan, Varanasi, 2005;

[33] T.W Swadler, Langman's medical embryology; Chptaer 6, Third to eighth week: The embryonic period; 11th edition, South Asian edition; Wolter Kluwer health, Gurgaon: Third Indian Reprint 2011: p no. 67 to 87.

[34] T.W Swadler, Langman's medical embryology; Chptaer 6, Third to eighth week: The embryonic period; 11th edition, South Asian edition; Wolter Kluwer health, Gurgaon: Third Indian Reprint 2011: p no. 67 to 87.

[35] Röck R, Rizzo L, Lienkamp SS. Kidney development: recent insights from technological advances. Physiology. 2022 Jul 1;37(4):207-15.

[36] Li H, Hohenstein P, Kuure S. Embryonic Kidney Development, Stem Cells and the Origin of Wilms Tumor. Genes (Basel). 2021 Feb 23;12(2):318.

Gonads (testis and ovary) are derived from coelomic epithelium covering the nephrogenic cord. Ova and spermatozoa arise from primordial germ cells that arise in the region of the yolk sac. The testis is formed in the lumbar region, and later descends to the scrotum. It develops during 4th to 8th weeks of intrauterine life (IUL).[37] The labioscrotal swellings are the structures that appear during the fourth week of gestations and give origin to the scrotal tissue. These two structures are present lateral to the genital tubercle. The migration of the labioscrotal swellings takes place in the 9th to 11th weeks of gestation and follows in a caudal and medial direction until they fuse at the 12th-week of gestation and form the scrotum.[38] Normal testicular descent is achieved by a residuum of primitive embryonic mesenchyme which is retained through into the fetal period; this is the gubernaculum testis. It forms a medium into which the cremaster muscles and the processus vaginalis can develop in anticipation of testicular descent. At the time of descent the gubernacular mesenchyme dilates, largely due to the uptake of fluid by the interstitial hyaluronic acid. By this means the scrotal sac is dilated and, with concurrent growth of related structures, all under the overall influence of maternal and chorionic gonadotrophic (luteinising) hormones, stimulating the testicular interstitial cells of the fetal testis, testicular descent is permitted.[39] The blood-testis barrier exists in all animals.[12] It is a structural and physiologic compartment created by inter–Sertoli cell tight junctions located on the luminal side of the basally positioned spermatogonia and the earliest germ cells that develop from them, the preleptotene/leptotene primary spermatocytes. And is first formed in the peripubertal period during the initiation of spermatogenesis in response to gonadotropic stimulation and the appearance of zygotene-pachytene primary spermatocytes. In the developing human testis, the junctional specializations between Sertoli cells are absent until about 8 years of age but are assembled in the early phase of puberty (11 to 13 years of age), thus establishing the basal and adluminal compartments of the seminiferous tubule.[40]

The development process of testicles and scrotum shows its *Kaphaja* origin as it is developed from labioscrotal swelling, and later cremaster muscles (*Mamsaja*) alongwith processus vaginalis (resembling *Meda* like structure) incorporates into it. The establishment of the blood-testis barrier shows its close relation to *Rakta.*

OBSERVATIONS

Avayava Utpatti and its modern correlation:

Avayava	Ayurvedic Organogenesis	Modern Organogenesis
Yakrut	*Rakta Dhatu*	The liver starts developing as a hollow endodermal bud from the foregut around the 3rd week of gestation. This bud divides into two parts: hepatic and biliary. The hepatic portion contains bipotential progenitor cells, which differentiate into hepatocytes or ductal cells that form the early primitive bile duct. These rapidly growing cells invade the surrounding mesodermal tissue (septum transversum) and connect with an ingrowing capillary plexus from the vitelline and umbilical veins, which eventually develop into sinusoids. Hemopoietic cells, Kupffer's cells, and connective tissue cells are derived from the mesoderm of the septum transversum. The fetal liver performs a

[37] T.W Swadler, Langman's medical embryology; Chptaer 6, Third to eighth week: The embryonic period; 11th edition, South Asian edition; Wolter Kluwer health, Gurgaon: Third Indian Reprint 2011: p no. 67 to 87.

[38] https://www.ncbi.nlm.nih.gov/books/NBK549893/#:~:text=The%20scrotum%20derives%20from%20the,to%20a%20common%20embryologic%20origin. (Retrieved on 26/12/24)

[39] Backhouse KM. Development and descent of the testis. European Journal of Pediatrics. 1982 Dec;139:249-52.

[40] https://www.sciencedirect.com/topics/immunology-and-microbiology/blood-testis-barrier (Retrieved on 26/12/24)

		significant hemopoietic function during the first and second trimesters.
Pleeha	*Rakta Dhatu*	It develops from mesoderm in the dorsal mesogastrium, close to the developing stomach during 5th week of intrauterine life (IUL). Anatomically spleen is made up of the reticular activating system and the dense network of blood as well as lymphatic vessel.
Phuphusa	*Shonita Phena Prabhava*	It develops from the laryngotracheal groove on 22nd day of intrauterine life. It is endodermal in origin. Anatomically lungs are composed of the large number of thin capillaries separated with thin lungs parenchyma and alveolar spaces with surfactant (mucilaginous substance), which gives the appearance of air bubbles in the blood to the lungs.
Hriday	*Shonita Kapha Prasadaja*	Anatomically heart is composed of the cardiac muscles with blood filled four chambers and connected to major or great vessels. Heart is encircled with the pericardial fluid and lymphatic glands.
Antra, Guda	*Sarabhaga* of *Rakta* and *Kapha* getting metabolised by *Vata* and *Pitta*	Early in the formation of the primitive gut tube, the endodermal layer recruits the splanchnopleure mesoderm which goes on to become the bowel mesentery, connecting the gut tube posteriorly in the embryo.[41] By week four of development, the division of the gastrointestinal tract into the foregut, midgut, and hindgut occurs.[42] The small and large intestines undergo rapid growth during weeks four and five of development. Embryological science believes that the enlarging intestines quickly outgrow the space available in the abdominal cavity causing the entire midgut to herniate into the umbilical cord forming a loop. The superior limb of the intestinal loop forms the ileum while the inferior limb forms the colon. Between the two limbs is the vitelline duct which connects the intestine to the yolk sac.
Basti	*Sarabhaga* of *Rakta* and *Kapha* getting metabolised by *Vata* and *Pitta*	The mucous membrane of the bladder is developed from the following sources; (a) The entire mucosa of the bladder except the internal trigone is developed from endoderm of the vesicourethral part of the cloaca. More recently it is believed that the entire mucosa is endodermal in origin. (b) The apex of the bladder is derived from absorption of the proximal part of the allantoic diverticulum. The distal part of the diverticulum is obliterated and the fibrosed persists as the urachus which extends from the apex of the bladder to the umbilicus. The fibrous cord of urachus is derived from the splanchnic mesoderm around the allantoic canal. The internal trigone of the bladder is developed from mesoderm by the incorporation of caudal parts of the mesonephric ducts. The mesonephric ducts open into the pelvic part of the urogenital sinus, and the

[41] Davis NM, Kurpios NA, Sun X, Gros J, Martin JF, Tabin CJ. The chirality of gut rotation derives from left-right asymmetric changes in the architecture of the dorsal mesentery. Dev Cell. 2008 Jul;15(1):134-45. [PMC free article] [PubMed]

[42] Kluth D, Jaeschke-Melli S, Fiegel H. The embryology of gut rotation. Semin Pediatr Surg. 2003 Nov;12(4):275[PubMed]

		common excretory ducts (the part of mesonephric duct between the ureteric bud and the cloaca) are blended with the dorsal wall of vesicourethral part of the cloaca after forming an S-shaped loop. Eventually the ureteric buds open directly into the bladder.
Jihwa	*Sarabhaga* of *Rakta*, *Mamsa* and *Kapha*	The tongue develops in relation to the pharyngeal arches (1st to 4th) in the floor of the developing mouth. It develops during 4th to 8th weeks of intrauterine life (IUL). The development begins with the growth of a medial swelling from the first pharyngeal arch, known as tuberculum impar. This leads to the formation of the anterior two-thirds of the tongue. Meanwhile, from the mesoderm of the second, third, and fourth pharyngeal arches, another median swelling, known as hypobranchial eminence, begins to develop and form the posterior third of the tongue. The posterior-most part of the tongue develops from a third median swelling, arising from the fourth pharyngeal arch. The muscles of the tongue predominantly derive from the myoblasts which originate in the occipital somites.
Vrikka	*Sarabhaga* of *Rakta* and *Meda*	The definitive human kidney arises from two distinct sources. The secretory part, i.e. excretory tubules (or nephrons) are derived from the lowest part of the nephrogenic cord. This part is the metanephros, the cells of which form the metanephric blastema . The collecting part of the kidney is derived from a diverticulum called the ureteric bud which arises from the lower part of the mesonephric duct, it develops during the 5th week of intrauterine life (IUL).
Vrushana	*Sarabhaga of Rakta, Kapha, Mamsa* and *Meda*	The labioscrotal swellings are the structures that appear during the fourth week of gestations and give origin to the scrotal tissue. These two structures are present lateral to the genital tubercle. The migration of the labioscrotal swellings takes place in the 9th to 11th weeks of gestation and follows in a caudal and medial direction until they fuse at the 12th-week of gestation and form the scrotum.

CONCLUSION

The embryological, anatomical and physiological descriptions given in *Sharira Sthana* of most of the Ayurvedic texts have a spiritual aspect related to it, as they are not seen through eyes but perceived by vision with the help of *Gyana Chakshu* during meditation. So, these descriptions depend on resemblance of structures or metaphor narration for the thorough understanding of the subject. The embryonic organogenesis as per modern science and anatomico-functional co-relations of the organs has a close similitude with the Ayurvedic narrations of *Anga Utpatti* as mentioned in this study.