



Review Article

Explication on tissue nutrition in prenatal and postnatal life: An Ayurveda perspective

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ABSTRACT

Tissue nutrition is the continuous process which is established just after the conception and persists throughout the life. Ayurveda scholars have mentioned that the manner of tissue nutrition is not same in all phases of life. In prenatal life embryo gets nutrition by *Upasneha* (filtration) and *Upasweda* (percolation/secretion) and fetus by *Garbhanabhinadi* (umbilical cord) which is attached with the heart of mother via *Rasavahanadi* (blood vessels). Thus in intrauterine life the nutrition of embryo is histotrophic, whereas just after the formation of placenta nutrition becomes haemotrophic. In post-natal life nutrition is enteral means nutrients are taken in the form of food via mouth called *Aahar*. Ayurveda scholars have postulated theories to understand the mechanism of tissue nutrition are *Ksheera Dadhi Nyaya* (transformation of nutrients), *Khale Kapota Nyaya* (selective uptake of nutrients), *Kedari Kulya Nyaya* (transportation of nutrients via channels), *Ek Kala Dhatu Poshan Nyaya* (simultaneous supply of nutrients to whole body). The theories of tissue nutrition discussed in Ayurveda suggest that although tissues are nourished and replenished continuously at different rate as per the functional state of *Agni* by circulating nutrients obtained from *Ahara*, but tissues are also dependent on each other for their proper nourishment and metabolism. This concept has great implication in management of malnourishment and various other disorders. This manuscript is an attempt to explore the Ayurveda's view on tissue nutrition along with physiological and clinical significance of theories of tissue nutrition in a scientific manner.

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1. Introduction

Ayurveda has recognized the importance of diet and nutrition in health and disease and it has been advocated that both human body and diseases are the product of nutrition [1, Ch. Su. 28/45]. Human body is composed of *Dosha* (biological entity that regulates all the bodily functions), *Dhatu* (structural component includes seven tissues) and *Mala* (waste products), which are in dynamic state and continuously nourished by *Aahar* (food). Circulating *Aahar Rasa* nourishes the body, provides strength, *Oja* (~immunity), complexion (*Varna*) and replenishes the waning *Dhatu*, thus sustains the *Dhatu* in their normal state [1, Ch. Chi.15/5, Ch.Su 28/3].

Ayurveda scholars have mentioned that the manner of tissue nutrition is not same during all the phases of life [2, Su.Su. 14/3]. During prenatal life embryo gets nutrition through the process of

Upasneha (filtration) and *Upasweda* (percolation/secretion) while fetus by *Garbhanabhinadi* (umbilical cord). The whole mechanism of tissue nutrition and transformation of tissue nutrient into bodily element has been discussed in a comprehensive manner through *Dhatu Poshana Nyaya* (theory of nourishment of tissue). These *Nyaya* are *Ksheera Dadhi Nyaya* (transformation of nutrients), *Khale Kapota Nyaya* (selective uptake), *Kedari Kulya Nyaya* (transportation of nutrients), *Ek Kala Dhatu Poshan Nyaya* (simultaneous supply of nutrients to whole body). All the theories are relevant and conjointly represent whole process of tissue nourishment at different levels of the metabolism [3]. Although *Dhatu Poshana Nyaya* have been discussed by many authors [4,5] in different ways but still it needs more appropriate interpretation in light of recent advances in contemporary sciences.

The present article is aimed to describe the mechanism of tissue nutrition and the relevance of *Dhatu Poshana Nyaya* in context with contemporary science, to explore its clinical and physiological significance, which can be useful to explain possible pathway for targeted (tissue specific) drug delivery, malnutrition, under and over nutrition of specific *Dhatu* etc.

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2. Source of information

Literature related to *Dhatu Poshana* (tissue nutrition and replenishment) were collected from various *Ayurvedic* Compendia, contemporary literature and recent research articles were also searched online from scientific sites viz. PubMed, Google scholar, Medline plus through different keywords like *Dhatu Poshana*, *Nyaya*, nutrition, metabolism, nourishment etc. The obtained descriptions were analyzed to understand the relevance and applied aspect of *Dhatu Poshana*. The articles related with metabolism and manner of distribution of nutrients, nourishment and replenishment of tissue were included in this review while other aspects of nutrition like calorie value, nutrients daily requirements, clinical studies pertaining to malnutrition etc. were excluded.

3. Review and discussion

3.1. Tissue nutrition during intrauterine life

Nourishment of body gets established just after the conception, which causes the gradual development of fetus. The fetus is entirely dependent upon mother for its nourishment and is lacking the urge of thirst and hunger. *Aahar Rasa* of mother gets divided into three parts, one part nourishes mother, one to *Stanya* (breast milk) while one part nourishes to the fetus [1, Ch.Sha. 6/23]. It is also evident that during pregnancy the nutritional demand of mother increases with the growth of fetus and maximum nutrition is required during lactation period. This explanation is also concurrent with the *Ayurveda* description of mother's increased demand of nutrition in pregnancy and lactation [6].

During organogenesis, manifested and non-manifested organs get nourishment by the process of *Upasneha* (filtration) and *Upasveda* (Percolation/secretion) [1, Ch. Sha 6/23]. *Sushrut* has also opined that as soon as the process of fecundation gets completed, the vessels (*Dhamani*) of maternal body which carry the nutrients (*Rasa*), run laterally and longitudinally in all directions (*Triyaga Dhamani*) through it, tend to foster the fetus with their own *Upasneha* (Filtration) all through its perpetuation in the womb. After the completion of organogenesis, it gets nourishment by the process of perfusion, sometimes through the hair follicles and sometimes through the umbilical cord. The *Garbhanabhinadi* (Fetal umbilical vessels) is attached to the umbilicus of fetus on one end and the placenta on the other end. The placenta in turn is connected with the heart (circulatory system) of the mother. The placenta gets huge blood supply and nourishment by the heart of mother through the *Rasavaha Nadi* (blood vessels) [2, Su. Sha3/31].

The developing fetus gets its nutrition from the secretions of the endometrium or from yolk sac before the formation of placenta and thereafter from the umbilical vessels attached to placenta. Now various researchers have suggested that in all mammalian species, nutrition of the conceptus is initially histiotrophic, with the trophoectoderm phagocytosing first oviductal and then uterine secretions called uterine milk. The uterine milk contains glycoprotein and amino acid that nourishes the embryo. Research has shown that the uterine glands are important source of nutrients during organogenesis, when metabolism is essentially anaerobic [8,9]. Yolk sac transfers the nutrients originating from uterine glandular secretion or maternal blood. But still the mechanism of transportation of nutrients to embryo and placenta, required for fetal growth and development is not fully understood [10,11]. Following implantation and establishment of the chorioallantoic placenta, there is a transition to haemotrophic nutrition, with exchange between the maternal and fetal circulations. Recent studies suggest that uterine glands secretions are released into the

intervillous space until at least 8 weeks of pregnancy, and are taken up by the syncytiotrophoblast. During the sensitive period of organogenesis (first trimester) histiotrophic nutrition under a low oxygen concentration reduces the risk of free radical mediated damage. Later on when fetal requirement of oxygen rises, transition to haemotrophic nutrition occurs on complete establishment of maternal placental circulation, at the starting of the second trimester [12].

Thus the recent research studies on transfer of nutrients from mother to embryo have suggested that initial mechanism of nutrient transfer is histiotrophic via uterine tissue secretion that involves perfusion and filtration which is similar as suggested by *Ayurveda* scholars i.e. *Upasneha* and *Upasveda* the mode of nutrient transfer from mother to embryo before the organogenesis. However after organogenesis i.e. after 12 weeks, the fetoplacental circulation gets established and nutrition becomes haemotrophic, is similar to description of nutrition of fetus via *Garbhanabhinadi* (umbilical cord) and *Rasavaha Dhamani* (blood vessels). *Indu*, has conceived *Upasneha* and *Upasveda* as *Snigdhatva* and *Utkleda* (becoming wet or moist) respectively [13, A.S. Sha 2/17]. Further the unctuous part of amniotic fluid such as lipid or glycogen contents which causes growth and development of the body have been regarded as *Upasneha* (unctuousness similar to *Sneha*) while water and electrolyte content of the amniotic fluid as *Upasveda* [14]. It has been also correlated with process of selective and simple osmosis respectively [15]. *Vagbhatta* opined that fetus gets nourished in manner of channels (*Kulya*) irrigating small field (*Kedari*) [7, A.H. Sha 1/56]. The arrangement of vessels in placenta has structured simile with that of *Kedari Kulya*. However after the development of cardiovascular system in fetus the tissues of fetus get their nutrients via blood vessels in same manner as in postnatal life. Thus the nutrient supply via blood vessels could be explained by *Kedari Kulya Nyaya*. The other tissue nutrition theories like *Ksheera Dadhi Nyaya*, *Khale Kapota Nyaya*, *Ek Kala Dhatu Poshan Nyaya* can be applied to understand the various mechanisms and steps of tissue nourishment in intrauterine life similar to post natal life which will be discussed in detail under the nourishment of body tissues (*Dhatu*) in post-natal life.

3.2. Nourishment of body tissues (Dhatu) in post-natal life

In post natal life nutrition is enteral means nutrients are taken in the form of food (*Aahar*) via mouth. Just after birth baby gets nutrition from mother milk (*Stanya*) which is *Upadhatu* of *Rasa Dhatu*, so its quality and quantity depends on *Rasa Dhatu* of mother. The purest form of *Stanya* (breast milk) nourishes the baby, provides strength and reduces the morbidity [1, Ch. Sha. 8/54] while the vitiated form increases the chance of recurrent infection. The ingested food digested in gastrointestinal tract by the action of *Pachakagni* and *Bhutagni*, gets absorbed into blood vessels with the help of *Saman Vata* [16, Sha.Pu. 6/9] and further the nutrients are supplied to whole body by the action of *Vyana Vata* [1, Ch. Chi 15/36]. When nutrients reach into tissues through their respective *Srotas*, are taken up by the tissues thereafter by the action of *Dhatvagni*, get converted into tissue form or utilized for cellular functions. *Sushruta* has described that the continuously circulating *Aahar Rasa* (-nutrient pool) nourishes (*Tarpayati*) the body in a different manner in different phases of life such as *Vardhana* (Growth and development) at *Balyawastha* (Childhood), *Dharana* (Sustenance) at *Madhyawastha* (Middle age) and *Yapana* (Maintenance) at *Vridhdhawastha* (Old age) [2, Su. Su.14/3]. IGF (insulin like growth factor), increases the growth rate of skeleton and skeletal muscle during childhood, in adults helps to maintain the mass of bone and muscles, promotes healing and tissue repair. IGF is secreted from liver and serves as endocrine hormone mediating the

action of GH in peripheral tissues like skeletal muscle, bone, cartilage, nerve, skin, lungs, and liver itself causes cells to grow and multiply by increasing the uptake of amino acid and decreasing its use for ATP production [17].

3.3. Nourishment of Dosha and Mala

Proper nourishment of *Dosha* is important as *Dosha* get vitiated due to faulty dietary habits and life style leading to hyper or hypo functional state of *Dosha*.

Dosha are formed during the phases of both, digestion and metabolism i.e. *Avasthapaka* and *Vipaka*. The *Dosha* produced at the time of *Avasthapaka* are *Malarupi* [1, Ch. Chi 15/9-11], while produced during the *Vipaka* can be considered as *Dhaturupi*. The *Malarupi Dosha*, *Aahar Mala* and *Dhatu Mala* get nurtured by the *Kitta* (metabolic waste products) portion of *Aahar Rasa* [1, Ch. Su. 28/4 & Ch. Chi. 15/18].

3.4. Nourishment of Dhatu

*Dhatu*s are nourished by specific *Dhatuvaha Srotas* and *Dhatvagni*. When *Aahar Rasa* reaches to the *Dhatu* through their specific *Srotas*, *Dhatvagni* transforms and assimilates the required nutrients for the nourishment of *Dhatu*. The role of *Dhatuvaha Srotas* and *Dhatvagni* in tissue nutrition has been explained by various *Dhatu Poshana Nyaya* i.e. *Ksheer Dadhi Nyaya*, *Kedari Kulya Nyaya*, *Khale Kapota Nyaya*, *Ek Kala Dhatu Poshana Nyaya*.

3.5. Theory of total transformation (Ksheera Dadhi Nyaya)

This theory postulates that the preceding *Dhatu* transforms completely into the succeeding *Dhatu* in the [1, Ch.Chi. 15/16] similar fashion of complete transformation of milk into curd, curd into butter, butter into ghee, ghee into *Ghrutamanda* [1, Ch.Chi. 15/17]. Some scholars on this verse of tissue nutrition “*Rasatraktam Tato Mansam Mansaanmedastatoasthi cha. Asthano Majja Tatah Shukram Shukratgarbha Prasadjah*” [1, Ch. Chi. 15/16] have postulated that the tissues are produced and nourished in a sequential manner from first *Dhatu* i.e. *Rasa* to the last *Shukra Dhatu* by their own specific *Agni* and are converted into respective *Dhatu*. For example *Rasa* after being digested by *Raktagni*, gets converted to *Rakta*, similarly *Rakta* becomes *Mamsa*, *Mamsa* into *Meda*, *Meda* into *Asthi*, *Asthi* into *Majja*, and *Majja* into *Shukra* [1, Ch.Chi.15/16; 2, Su.Su.14/10]. Chakrapani has rejected the above theory. He argues that if total transformation of *Dhatu* occurs, then a person who is starving for one month (in this duration *Shukra* and *Aartava* are formed from *Rasa*) will be having only one *Dhatu* i.e. *Shukra*, which seems unlikely. He further elucidated that the term *Prasadaja* denotes the nourishment and not the production of succeeding *Dhatu* [1, Ch.Chi. 15/17]. He has explained the word ‘*Prasadajah*’ means ‘*Poshan*’ (nourishment) not the production of succeeding *Dhatu* from previous *Dhatu* “*Prasadjah ityatra Jatasabdah Poshan eva Vartate napoorvotpade, Raktadayo Hi Garbhatprabhrityevotpanna Rasadibhih Poshyanta, Raktadayo Hi Garbhprabhritae Poshyante*” [1, Ch.Chi. 15] Thus it is clearly mentioned by Chakrapani that the tissues which are formed during embryonic life are only nourished and replenished by *Aahar Rasa* during later phases of life. However the description of successive transformation of *Rasa Dhatu* to *Shukra Dhatu* may be understood as the sequential tissue differentiation during embryonic life as the totipotent cells of embryo get differentiated into different types of tissue specific cells. At a very early stage of human development, all the cells of embryo are identical, but unlike adult cells are very flexible and carry within them the potential to become any tissue type, whether it be muscle, skin, liver or brain. Cell differentiation process during development

is a largely (spontaneously) irreversible process: the zygote robustly reaches other cell types in a predetermined order. The extracellular environment play a great role in the signalling mechanism required for cell differentiation [18]. Thus it may be inferred that this theory explains the sequential differentiation of totipotent embryonic cell into specific type of cell forming different tissues during the embryogenesis and their nourishment thereafter.

Acharya Chakrapani has clarified that each *Dhatu* has two parts i.e. *Sthayi Poshya* (permanent) and *Asthayi Poshak* (nutrient part). The *Asthayi Poshaka* (nutrient part) undergoes transformation in *Srotas* with the action of respective *Agni* and nourishes the next tissue. The clinical condition of manifestation of *Asthi Kshaya* in case of *Medo Vriddhi* was not much understood through theory of total transformation which has been clarified by Acharya Chakrapani [1, Ch. Vi 5/3 & Ch. Su. 28/4]. This shows that each tissue is nourished as per their requirement by action of their own specific *Agni*, taking nutrient from nutrient pool i.e. *Ras-Rakta Dhatu*.

Dalhana has conceived it in more scientific manner and justified that *Rasadi Dhatu* are not completely transformed into succeeding ones, instead only a fractions of the nutrient part of these *Dhatu* get converted into next one. Each metabolizing *Dhatu* gets divided into to three parts i.e. *Sthula*, *Sukshma* and *Mala* part [2, Su. Su. 14/10]. From *Sthula* part respective *Dhatu* gets nourished while from *Sukshma* part succeeding *Dhatu* is nourished and from the *Mala* part the *Mala* of respective *Dhatu* is produced. In this process *Upadhatus* are also produced just like the subsidiary products produced from the metabolites [1, Ch. Chi. 15/17]. Dalhana has elaborated that specific nourishment i.e. *Upadhatus* are formed from *Rasa*, *Rakta*, *Mamsa* and *Meda Dhatu* and not formed from *Asthi* and *Majja Dhatu* [2, Su. Su. 14/10]. Thus it can be opined that the simile of transformation of one substance into another shows the action of specific *Agni* which might be either at the level of digestion or at the level of metabolism. At cellular level, metabolisms like gluconeogenesis, glycolysis, beta oxidation pathway etc. one metabolite is converted into next metabolite completely with the help of specific enzymes [19]. During this process at some stages subsidiary products and waste products are also formed.

Thus the theory of total transformation (*Ksheera Dadhi Nyaya*) is still relevant and elucidates possibly the following mechanism: 1. The transformation and differentiation of tissues taking place during embryogenesis. 2. All the tissues that are formed during intrauterine life only get nourished and replenished in post-natal life by the nutrients obtained from diet, but the complete conversion of one tissue into another does not take place. 3. Digestion and metabolism taking place at cellular level like gluconeogenesis, glycolysis, beta oxidation pathway etc. 4. Digestion in GIT: During the intestinal digestion too, the complex molecules are converted completely in to simple molecule with the help of specific enzymes.

3.6. Theory of circulation and transportation (Kedari Kulya Nyaya)

In this *Nyaya* analogy of water channels (*Kulya*) irrigating to the plots of paddy or wheat (*Kedari*) has been given to explain the mode of nourishment and pattern of distribution of nutrients to the *Dhatu*s. This theory explains the process of nourishment of *Dhatu* in the similar fashion of irrigation of different field by water from the main canal which branches and re-branches into smaller channels. Thus the nearby fields are irrigated first and thereafter distant fields are irrigated. In this way *Rakta Dhatu* gets nourished first by its homologous nutrient fraction present in *Rasa Dhatu* and thereafter other *Dhatu* in succeeding manner get nourished. This theory suggests the following things related to tissue nutrition: Individual blood supply to tissue or organs, Pressure gradient for blood flow or

transportation of different nutrient substances, Time lag in nourishment of different tissue and Target drug delivery.

3.6.1. Specific channel of circulation for each tissue or organs

Each *Dhatu* gets nourished through their specific *Srotas* [1, Ch. Chi. 8/38]. The microcirculation of each organ is organized in such a way that it fulfills that organ's need. Each nutrient artery on entering the corresponding organ branches and re-branches six to eight times to become arterioles (diameter 10–15 μm) which further re-branched two to five times to become capillaries (diameter 9 μm). Similar fashion of branching and re-branching of water channels irrigating to the field is observed in circulatory system too i.e. aorta emerging from the heart, gets branched and re-branched into artery, meta-arterioles, capillaries, which supply nutrition to tissues. This individual circulation of tissue signifies two mechanisms i.e. end artery circulation and transportation of substances across the capillary membrane of tissue [20].

3.6.2. Pressure gradient for blood flow or transportation of different substances

This analogy of irrigation of *Kedari* via *Kulya* might be indicating passive mode of transport i.e. flow of fluid in accordance to pressure gradient [19]. As pressure difference between two points is one of the influencing factors for rate of blood flow/gaseous exchange. For example, during the cardiac cycle, ventricles eject the blood in aorta and pulmonary arteries when ventricular pressure exceeds than that of aorta (80 mmHg) and pulmonary artery (8 mmHg). In addition with transportation due to pressure gradient, this analogy also explains the pressure of blood flow. Blood flow to tissue also depends on the pressure in its artery. Greater the pressure more will be the perfusion. Three zones of pulmonary blood flow is the best example to explain it. At standing position pulmonary blood pressure is 15 mmHg lesser in apex and 8 mmHg greater at base of lungs than pulmonary blood pressure at the heart level. This difference in blood pressure is because of difference in hydrostatic pressure that results in regional blood flow in lungs, in accordance with cardiac cycle. When pulmonary capillary pressure exceeds the alveolar pressure, blood flows but when alveolar pressure exceeds blood flow stops. Thus the blood flow in all part of lung is not uniform in standing position [20].

3.6.3. Targeted drug delivery

The specific action of drug in particular tissue can be understood by this analogy of irrigation through specific *Kulyas* (channels). This theory suggests the specificity of channels for each tissue. Drug administered through different routes reaches to targeted tissue via its specific *Srotas* (channels) only. For example *Shatavari* (*Asparagus racemosus*) as *Shukrala* (enhances sperm and ova formation), *Shukti* (pearl oyster) and *Sikta Varga* as *Ashtiposhaka* (enhances bone nourishment), *Gokshura* (*Tribulus terrestris*) and *Ashwagandha* (*Withania somnifera*) as *Mamsabalya* (enhances muscle growth, physical and mental strength) etc. [21].

3.7. The law of selectivity (*Khale Kapota Nyaya*)

The *Aahar Rasa* nourishes to each *Dhatu* (tissue elements) by their specific channels. In this context, analogy of pigeons selecting the choicest grain has been given. Pigeons coming from different places to field, choose the grain as per their need and choice i.e. type of grain and quantity of grain are selected by them from the field. This analogy explains the following things related to nutrient

supply and uptake: Selectivity, Receptor mechanism, Active mode of transport, Autoregulation and Time lag in distribution of nutrients in distant and nearby tissue.

3.7.1. Selectivity

The *Khale Kapota Nyaya* refers to selectivity of cells for uptake of nutrients and other chemical compounds. Plasma membrane is selectively permeable and does not allow all the nutrients to pass through it. Plasma or blood constitutes i.e. all the organic and inorganic substances required for growth and development are supplied to whole body and the specific nutrients are taken up by the tissues as per their requirement through specific channels. For example nutrients like Ca, Fe, O₂, amino acids circulate by binding with specific plasma protein, taken up by bones, muscles as per their requirement [20].

3.7.2. Active mode of transport

Energy utilized by the pigeon for travelling through and from the field is suggestive of active transport. Na⁺ K⁺ ATPase pump, absorption of glucose, fructose, amino acids across the apical membrane of absorptive epithelial cell of villi, are common examples of active transport [20].

3.7.3. Autoregulation

Khale Kapota Nyaya also indicates the diverse requirements of different pigeon in terms of quantity. It is obvious that tissue requirement and nourishment differ individual to individual according to their metabolic state of tissue or *Dhatu* measurement. Tissue nourishment varies according to age, body type i.e. obese, emaciated, short stature and tall person [1, Ch.Su 28/4]. Again caloric requirement depends upon the age, life style i.e. sedentary or active, physiological conditions like pregnancy, diseased condition, habitat etc. This confers the mechanism of autoregulation too as the tissues or *Dhatu* are regulating the amount of nutrient required by them. Decreased status of *Dosha*, *Dhatu*, *Mala* and even *Bala* (strength) develops desire for the food articles which will make them to increase, and after having them the imbalance state is corrected [2, Su. Su. 15/29–30]. For instance, in case of *Rakta Dhatu Kshaya* (decreased blood) desire of intake of sour and cold substances (Su.Su.15/9) [2].

3.7.4. Receptor mechanism

The pigeons are selective in picking up the grains from the field and choose the one which is compatible to them. This also happens in case of receptor mechanism i.e. the receptor allows the substances to bind with them which are compatible. For example ion channels, the hormone receptor, all are substrate specific [20].

3.7.5. Time lag in blood flow in distant and nearby tissue

The pigeon whose shelter is nearer to the field will reach to the field earlier while whose shelters are far will reach later. Although *Vyana Vata* circulates *Rasa Dhatu* at a time to all over the body but still there is difference in fraction of time (in millisecond) for blood flow to nearer and distant tissues.

3.8. Simultaneous supply of nutrient to all the tissues (*Ek Kaal Dhatu Poshana Nyaya*)

The food after being digested gets absorbed and circulated through the *Dhamnis* (ten great vessels attached to heart) by the action of *Vyana Vata* at a time to the whole body [1, Ch. Vi 2/18, Ch.

Chi 15/36 & 7, A. H. Sha 3/62]. This analogy refers to the haemodynamics and circulation of fluids in body (Fig. 1).

3.9. Time duration of replenishment of Dhatu

The process of transformation of tissue elements is a continuous phenomenon and it depends on the state of Agni [1, Ch. Chi 15/21]. Ayurveda scholars have difference of opinion regarding the time duration required in replenishment of Dhatu, as the mentioned time duration required for the formation of Shukra Dhatu from Aahara Rasa is one day and night, six days and night or one month according to functional state of Agni [7, A. H. Sha 3/65]. Sushruta has explained that Rasa Dhatu resides in one Dhatu for 5 days and nights (3015 Kalas), thus formation of Shukra Dhatu takes one month [2, Su.Su. 14/14]. This portrayal justifies that formation of Dhatu will depend upon the strength of Jatharagni and Dhatvagni of the subject. To explain the role of strength of Jatharagni and Dhatvagni the analogy of moving wheel [1, Ch. Chi 15/21 & 7, A. H. Sha 3/66] and speed of movement of molecules of water, sound and light have been given [2, Su. Su. 14/16].

The continuous process of transformation of Dhatu is like a moving wheel used for drawing water from well. The amount of water withdrawn will depend upon the physical strength and the

speed of movement of wheel i.e. faster the wheel quicker the water will be drawn and vice versa. In the same way more the strength of Jatharagni, faster will be transformation [1, Ch. Chi 15/21]. The analogy of circulation of Rasa Dhatu in body is given with the movement of Shabda (sound), Archi (light) and Jala (water) refers to the manner of Rasa circulation and the strength of Agni i.e. Teekshnagni, Madhyamagni and Mandagni [2, Su. Su. 14/66].

These analogies of Shabda, Archi and Jala in context to Rasa-Rakta (blood) circulation and functional status of Agni explicate the following: Difference in time duration required for transformation of tissues, Time difference in action and effect of hormones, other chemical substances and Direction and velocity of blood flow.

3.9.1. Difference in time duration required for transformation of tissues

Formation of different cells of the tissues takes different time on the accountability of their Agnibala. Thus rate of metabolism will be affected by its Agnibala. Speed of water is slow, on this account Dhatvagni will be weak and transformation will occur in one month. The speed of sound is faster than water but slower than light thus Dhatvagni will be moderate and transformation will be neither slow nor too fast. Speed of light is very fast and thus

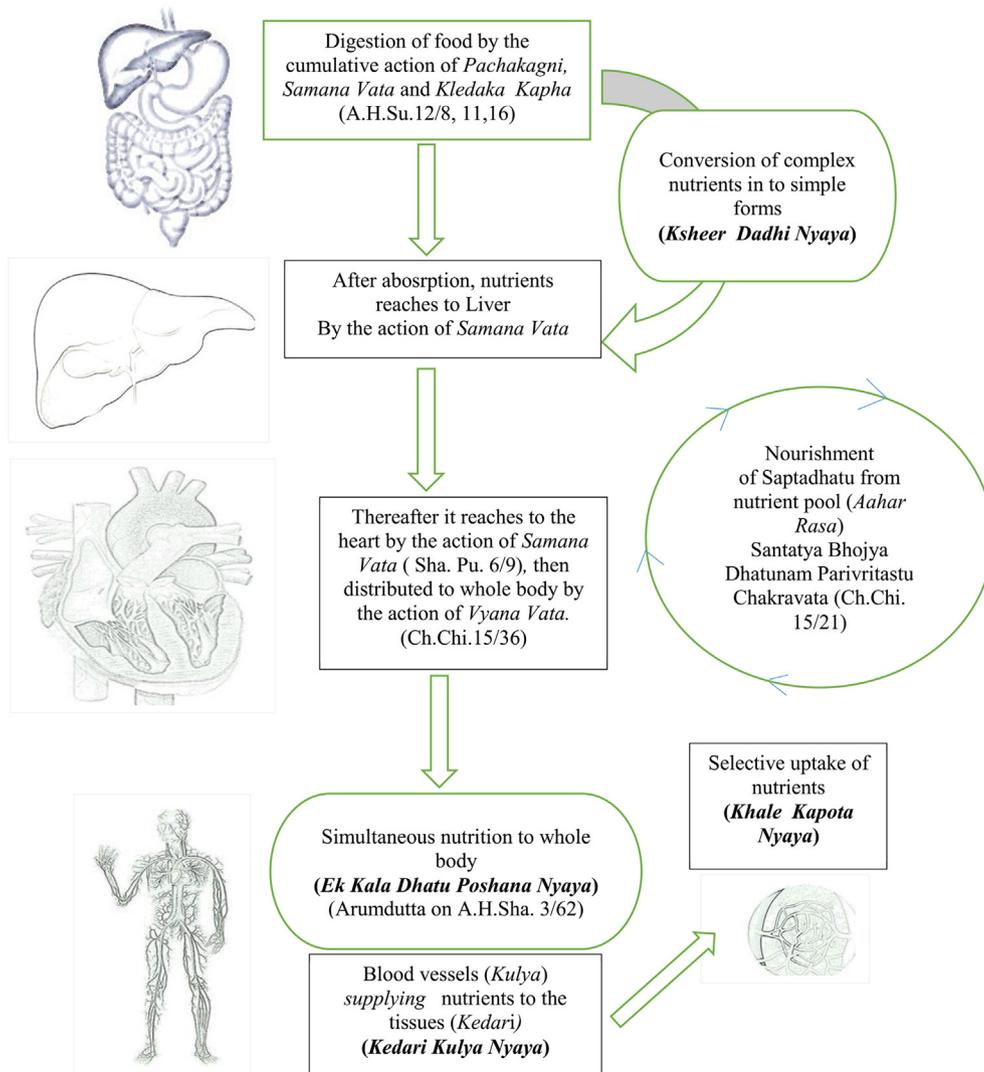


Fig. 1. Theories of tissue nourishment.

transformation will be quickest taking one day and night [22, Su. Su. 14/16] (Table 1). However Dalhana has different opinion regarding the time taken in transformation of tissue i.e. rate of transformation will be fastest, moderate and slowest in analogy of *Shabda*, *Archi* and *Jala* respectively [2, Su. Su. 14/16]. Different body cells have different time of regeneration and life span. For example life cycle of RBCs is 120 days, neutrophils is 5–7 days, platelets 10 days, and sperm in female genital tract is 2–3 days. The process of oogenesis and spermatogenesis is long term phenomenon whereas formation of erythrocytes from reticulocytes takes approximately seven days [20].

3.9.2. Time difference in action of hormones and other chemical substances

Difference in opinion among scholars regarding the time taken in transformation of nutrients may be understood through the time taken by various kind of hormones to elicit their action i.e. some hormones like epinephrine, nor-epinephrine have immediate effect on body while others like thyroid hormone have maximum effect within 2–3 days, aldosterone takes 30 min to synthesize new RNA and 45 min to increase sodium reabsorption after its release [20].

3.9.3. Rate of blood flow

This analogy can also be understood in light of rate of blood flow in accordance with basal metabolic rate. *Mandagni*, *Teekshnagni* will affect the basal metabolic rate and the rate of blood flow. More the basal metabolic rate, more the metabolites like CO₂, hydrogen etc. are produced leading to vasodilatation and thus more will be the rate of blood flow and vice versa (Fig. 2).

3.10. Interdependence among the tissues for nourishment

All tissues are *Panchbhautic* having different proportion of each *Mahabhut* in them and tissues require the nutrient in accordance. If *Aahar Rasa* is deficient in particular nutrient the effect will be reflected in corresponding *Dhatu* only. For example if *Aahar Rasa* is deficient in calcium, the nourishment of *Asthi Dhatu* will be affected while nourishment of other *Dhatu* will not be affected directly. In two types of *Kshaya* described by Acharyas, *Anuloma Kshaya* is due to deficient or reduced quality of *Aahar Rasa* while *Pratiloma Kshaya* is due to *Ativyaya* (excessive indulgence in sexual activity refers to excessive exercise) is due to more utilization of energy in comparison to supply of nutrients. Along with it nourishment and metabolism of one tissue affects the nourishment of another tissue by communicating with them through certain hormones and chemicals. "*Purvah purvaativridhtavaata vardhayedhi param tasmaata atipravridhanam dhatunam hrasanam hitam*" [2, Su. Su. 15/18] refers that nourishment of one tissue is not only dependent on nutrient obtained from diet but they are also affected by the nourishment and metabolism of another tissue. Chemicals or hormones released by one tissue affects the functioning of another tissue, for example leptin is secreted by adipose tissue but it affects nourishment of bones, erythropoietin is released by kidney but it stimulates bone marrow for erythrocytosis [23,24]. Thus the theories of tissue nutrition discussed in Ayurveda suggest that tissues are not only nourished by *Aahar Rasa* rather tissues are dependent

on each other also for their proper nourishment and metabolism. This concept has great implication in management of malnourishment and various other disorders.

4. Factors affecting tissue nourishment

4.1. Functional status of different types of Agni

Functional status of *Jatharagni* (digestive power), *Dhatvagni* (fraction of *Agni* residing in tissues) and *Bhutagni* determines the nourishment of body. *Kshayavridhi* (under or over nourishment) of *Dhatu* depends upon the status of *Agni*. *Bhutagni* transforms consumed *Aahar Dravya* of *Vijatiya* origin (non-homologous to body tissues) to *Sajatiya* nature (homologous to body tissues). *Aahar Rasa* gets separated in to five constituents *Parthiva*, *Aapya*, *Aagneya*, *Vayavya*, and *Aakashiya* which are digested by the respective *Bhutagni* and make it homogenous to the body [1, Ch. Chi. 15/13]. *Dhatvagni* too determines the level of nourishment, *Teekshnagni* (hyper functional state) leads to depletion of *Dhatu* while *Mandagni* (hypo functional state) leads to *Vridhi* of *Dhatu* [7, A. H. Su. 11/34]. The action of *Dhatvagni* forms the basis of action of drug on specific tissue. The drugs like *Shukrala Dravyas* (drugs of spermatogenesis and release of sperm) specifically augment the *Shukragni*, the *Raktavardhaka Dravyas* (haematinics) augment the *Raktagni* and corrects the disturbed respective *Agni*. Induced oogenesis by clomiphene citrate, hormone replacement therapy augments the *Shukragni* and corrects the imbalance.

4.2. Role of Srotas

Dhatu Poshana occurs through their specific *Srotas* by the action of specific *Dhatvagni* [1, Ch. Vi 5/3]. So nourishment of *Dhatu* will be affected if the particular *Srotas* is obstructed due to any factor. For example in the pathogenesis of *Rajyukshma*, it has been explained that blockage of *Rasavaha Srotas* by predominant *Shleshma* leads to improper nourishment leading to depletion of all *Dhatu* and emaciation of the body [25, M.N. 10/2].

4.3. Factors enhancing tissue growth (shariravridhikarabhav)

Four types of *Shariravridhikara Bhava* are *Kalayoga*, *Svabhava Sansidhi*, *Aharasaushthava* and *Avighata* [1, Ch. Sha. 6/12].

4.3.1. Time factor (Kalayoga)

It refers to the age, up to *Balyaavastha*, *Dhatu*s are not fully developed while on attainment of *Madhyamavstha* gains complete maturity and gradually gets decline in *Vridhdavstha* [1, Ch. Vi. 8/122]. The nourishment of the body is a continuous phenomenon but is not same in all phases of life. It brings about the nutrition (*Tarpana*) in all phases of life, development and growth (*Vardhana*) during childhood, sustainment (*Dharana*) of well-developed tissue during adulthood and maintenance (*Yapana*) of depleting *Dhatu* during old age. It shows that *Rasa Dhatu* provides nutrition, causes tissue growth and development, responsible for tissue repair in case of wear and tear too [2, Su. Su. 14/3]. All vital organs begin to lose some function with the advancing age from

Table 1
Analogy of *Shabda*, *Archi* and *Jala* in context to *Rasa-Rakta* (blood) circulation and functional status of *Agni*.

Analogy for transformation of tissue	<i>Agnibala</i> (power of digestion and metabolism)	Time required for transformation of tissue	Velocity of blood flow	Direction of <i>Rasa-Rakta</i> Circulation
<i>Shabda</i>	Sharp (<i>Teekshnagni</i>)	One day	Fast	Radial (<i>Tirayaga</i>)
<i>Archi</i>	Moderate (<i>Madhyamagni</i>)	One week	Moderate	Upward (<i>Urdhva</i>)
<i>Jala</i>	Weak (<i>Mandagni</i>)	One month	Slow	Downward (<i>Adho</i>)

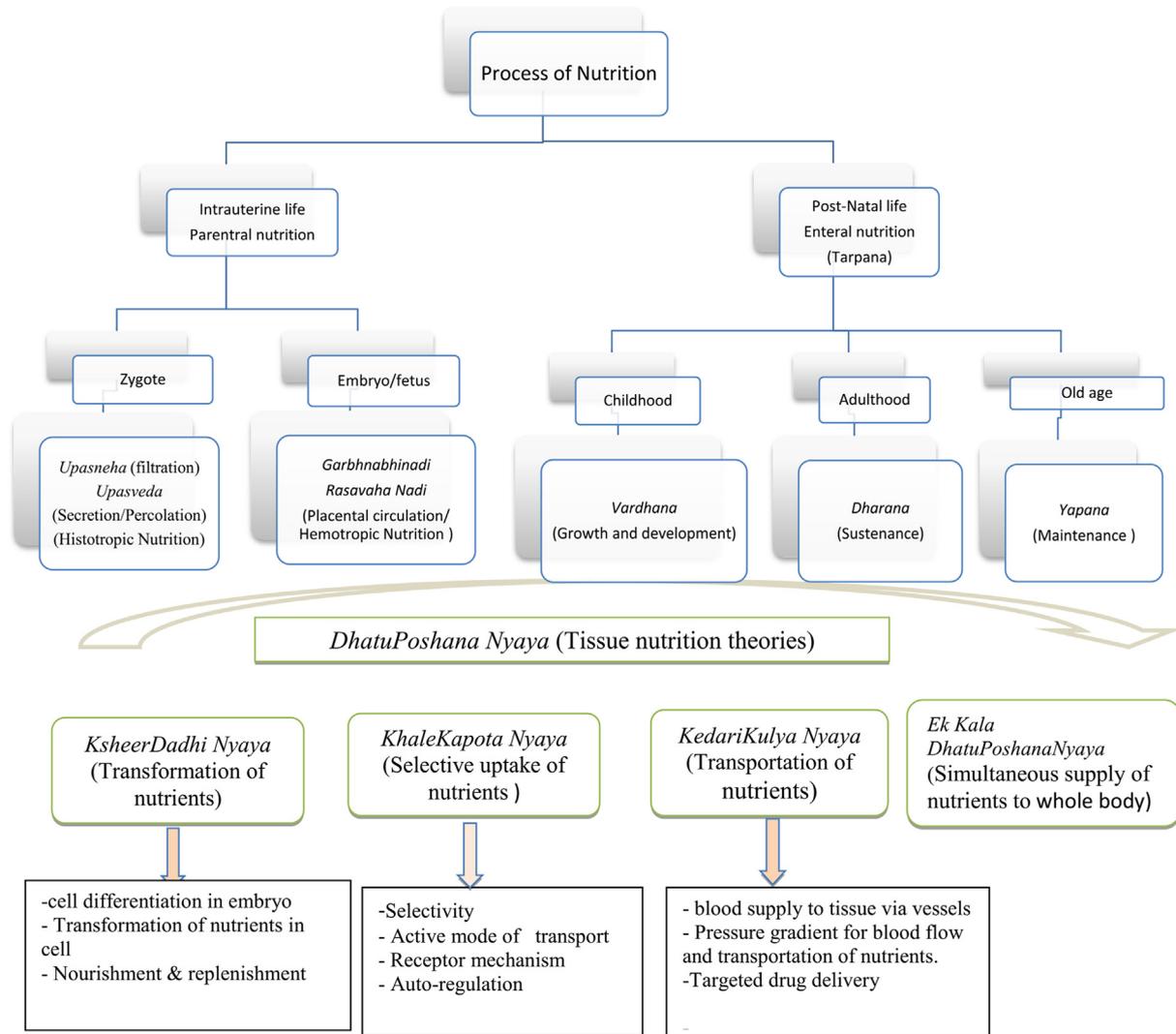


Fig. 2. Schematic representation of tissue nourishment.

adulthood to old age due to aging. The basal metabolic rate also decreases almost linearly with age. Skeletal musculature is a fundamental organ that consumes the largest part of energy in the normal human body. It is shown that the decrease in muscle mass relative to total body may be wholly responsible for the age-related decrease in basal metabolic rate. The volume of skeletal musculature decreases and the percentage of fat tissue increases with age. Studies have suggested that both the FFM and FM is significant contributor to BMR [26,27].

4.3.2. Diet

The body is outcome of type of *Aahar* taken by an individual. Both quality and quantity of *Aahar* determines the proper nourishment of body. Quantity should be in accordance to *Agnibala*, type of diet and stomach capacity. Intake of food in reduced quantity causes emaciation of the body [1, Ch. Su 25/40]. Similarly the *Gurvadi Guna* (20 physical attributes) found in various food substances, when administered causes nourishment of the similar properties and depletion of opposite one. Intake of heavy (*Guru*), unctuous (*Snigdha*) *Aahar* causes proper nourishment (*Santarpana*) while light (*Laghu*) and nonunctuous (*Ruksha*) *Aahar* cause depletion (*Aptarpana*) of the body. *Rasayana* therapy administered either in form of food supplement or drug brings

about improved tissue nutrition and replenishment by respective *Dhatwagni* [28].

4.4. Psychosomatic constitution

The nourishment of body occurs as per its requirement in accordance with age, body type viz. heavy (*Sthula*), thin (*Krisha*), long (*Deergha*), short (*Harshva*) etc. and state of body [1, Ch. Su. 28/4]. Tissue nutrition differs in accordance with psychosomatic constitution (*Prakriti*) of an individual due to difference in functional state of *Agni*. In recent studies it is reported that *Pitta Prakriti* are fast metabolizers than other two *Prakriti* [29]. *Kapha Prakriti* individuals have well-formed and fully developed organs and muscles [1, Ch. Vi. 8/96] while *Vata Prakriti* individuals are having short (*Alpa*) and emaciated (*Apachita*) body [1, Ch. Su. 8/98] [Fig. 3].

5. Clinical implication of *Dhatu Poshana* theories and future perspective

The different *Dhatu Poshana* theories are associated with the manner of nutrient distribution, replenishment of tissues and the different level of tissue metabolism. *Kedari Kulya Nyaya* and *Khale Kapota Nyaya* suggest that different tissues have different level of

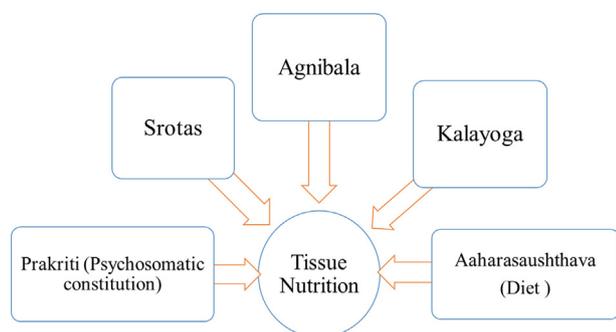


Fig. 3. Factors affecting tissue nutrition.

metabolism through their specific channels and Agni as well as different time span for their replenishment. Different drugs (e.g. *Shukrala*, *Mamsala* etc.) acting on particular tissue may be acting through their specific channels and need to administered for different time interval for obtaining desirable outcomes, for example course of treatment for reproductive tissues will be more than for the *Rakta Dhātu*. However evidence based researches are required to evaluate the time required for action of drug on different tissues for obtaining the desirable outcomes. Along with this interdependence of tissue for their nourishment should also be considered for the intervention of drug. *Ksheer Dadhi Nyaya* which has been previously mistaken as formation of succeeding *Dhātu* from previous *Dhātu* should be understood as conversion of Pluripotent embryonic cell or adult stem cell into different tissue type cell as well as nourishment and replenishment of different tissues by taking nutrients from the circulating nutrient pool.

6. Conclusion

On the basis of above discussion it is summarized that Ayurveda has given a depth of scientific insight on tissue nutrition. The theories of tissue nutrition discussed in Ayurveda are pertinent in present scenario and suggest that although tissues are nourished and replenished continuously by nutrients obtained from circulating *Aahar* in accordance with functional state of *Agni*, but tissues are also dependent on each other for their proper nourishment and metabolism. This concept has great implication in management of malnourishment and various metabolic disorders. It has been also reported by various contemporary researches that hormones or chemicals (which can be considered as a form of *Agni*) released by one tissue affects the functioning of other tissue. Thus, all the *Dhātu Poshan* theories are in relevance with current scientific knowledge referring to haemodynamics, mode of nourishment, nutrient supply and replenishment of tissues at different levels of metabolism.

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Conflict of Interest

None.

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