Review Article

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A VALUABLE EXPLANATION OF THE CARDIOVASCULAR SYSTEM BY ANCIENT AYURVEDIC SCIENCE PIONEERS

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Received on:28/03/14 Revised on: 02/05/14 Accepted on: 20/05/14

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DOI: 10.7897/2277-4343.05379

ABSTRACT

Cardiovascular System is an essential life supporting and tissue nourishing system of the human being. Now-a-days modern science scholars accurately explained the entire cardiovascular system, but dating from the Vedic era the Ancient Indian science's explanation also makes substantial contribution to understanding the organization and functions of the Cardiovascular System, which is closely correlates with the Modern cardiologist explained Cardiovascular Systems organization and function. Considering the fact in the recent past one of the studies validate that Ayurveda masters have also played a important role in explanation about the blood circulation before the Hippocrates, William Harvey etc, we conducted the present study by focusing the all the aspects of the cardiovascular system in term of their embryological, anatomical and physiological aspects explained in Ancient Indian Science texts and correlated it with modern science to evaluate that Ancient Indian Science pioneers also accurately known all the aspects of the cardiovascular system in scientific view. In our present study we have gone through the different Ancient Indian Science texts and after that selected the Literatures and Sanskrit Slokas which were relevant to present day modern Cardiology and then translated and explained it and after that compared it with modern Cardiology. Ancient Indian Science pioneers also have a deep accurate Knowledge about the Cardiovascular System.

Keywords: Ancient Indian Science, Cardiovascular System, Sanskrit Sloka.

INTRODUCTION

The main aim of the cardiovascular system is to maintain the adequate tissue perfusion.[1] it is an essential life supporting and tissue nourishing system of the human being. It is consist of the heart and blood vessels. Ancient Indian science pioneers have accepted the importance of Hridaya (heart) and have considered it to be the site of Cetana Dhatu (the soul) (Su. Sha. 4/33).[2] Also, Hridaya has been described to be a site where Prana (vital force) resides (Ca. Su. 29/3; Ca.Sha.7/9).[3]

Methods

Description of Cardiovascular system in Ancient Indian Science

Cardiovascular system has been very elaborately described in Brihatrayi and in their commentaries with a highly considerable amount of precision. Treatises not only are comprised of the description related to the structural entities of C.V.S., but also imbibe its embryological aspects, genetic aspects, anatomical physiological aspects and pathological aspects. Basically the descriptions about cardiovascular system in Ancient Indian Science can be found in the contexts of Hridaya, Sira, Dhamani, Rasa dhatu, Rakta dhatu, Vyana Vayu etc.

Embryological Aspect

According to Caraka Samhita, Hridaya is produced in third month of embryonic life as all Indriyas, all body organs and components are developed in the third month (Ca. Sha.4/11).[3] Susruta and Vagbhata consider the origin of Hridaya is in the fourth month of embryonic life (Su. Sha. 3/5, 10).[2] According to Kritavirya, Hridaya is the organ that is produced first in embryonic life and it is the organ that is also the site for the intellect and mind (Su. Sa. 3/30).[2] Kankayana also accepts the origin of Hridaya to be the first during embryonic life (Ca. Sha. 6/21).[3] According to the present day knowledge, most cells and organs in an embryo do very little except grow and differentiate—the brain, lungs, liver, digestive system, gonads, and kidneys - all fall in this category. But the cardiovascular system has to do the real work early on. The reason is that once the embryo has become thicker than 200 to 400 microns, the diffusion of nutrients, oxygen, and carbon dioxide are inadequate to service an inner mass of very metabolically active cells. A circulatory system is needed to keep these cells from dying, and it needs to do it by the middle of the fourth week of gestation. Therefore, the views expressed by Kritavirya and Kankayana seem to be highly logical. Hridaya is produced from the essence of Rakta and Kapha (Su.Sha. 4/30).[2] According to Caraka and Susruta, Sira and Dhamani are the parts that are of paternal origin while Sonita and Hridaya are of maternal origin (Su. Sha. 3/31, Ca. Sha. 3/6.3/14).[2,3] Caraka also describes that Rasa and Rakta have more Apya content (Ca. Sha. 7/16).[3] Hridaya measures two Angula (Ca. Vi.8/117)[3] while Rakta measures eight anjalis, and Rasa dhatu nine Anjalis (Ca. Sha 7/15).[3] The total number of Siras is seven hundred while Dhamani are two hundred in number according to Caraka. Susruta considers the number of Siras to be seven hundred and that of Dhamani to be twenty four (Su. Sha. 5/6).[2]

Anatomical considerations of Hridaya

Caraka considers Hridaya to be one among the ten sites of Prana (Ca. Sha. 7/9).[3] He considers Hridaya among Marmatraya also (Ca. Su. 29/3).[3] He quotes that out of

one hundred and seven Marmas, Sira, Hridaya and Basti are considered as major ones (Ca. Ci. 26/3).[3] Acarya Vagbhata also considers Hridaya as one of the ten special sites of life (Prana) i.e. Sira, Rasana, Kantha, Sira, Guda, Basti, Nabhi, Sukra, Ojas and Hridaya (A.H. Sha. 3/13).[4] Caraka considers Hridaya among one of the fifteen Koshthangas. (Ca. Sha. 7/10).[3] Vagbhata also considers Hridaya among one of the Koshthangas i.e. Hridaya, Kloma, Phuphphusa, Yakrit, Pliha, Unduka, Vrukkau, Nabhi, Dimbhas, Antra and Basti (A.H. Sha.3/12).[4] Hridaya is present or located in between the two breasts near the opening of Amasaya and is considered as the site of Satva, Raja, Tama and injury to this area causes immediate death (Su. Sha. 6/26).[2] Vagbhata follows the view of Susruta and considers Hridaya to be situated in between the two breasts and mid position of Koshtha and sharp injury to this area causes immediate death (A.H. Sha. 4/14).[4] Susruta further elaborates the position of Hridaya as follows: Pliha and Phuphphusa are found below and to the left side of Hridaya; while Yakrit and Kloma are found on the right side of Hridaya. (Su Sha. 4/30).[2] Ashtanga Hridaya quotes that Hridaya is the opening of Amasaya and through the same opening the liquid and solid food passes into Amasaya. (A.H. Sha. 4/13).[4] Susruta has described that shape of Hridaya in the body is like that of an inverted bud of lotus and there occur the cycles of Sankoca and Vikasa continuously i.e. it contracts and relaxes alternatively (Su. Sha. 4/31).[2] Sankoca and Vikasa should be considered as contraction and relaxation respectively. Srikanthmurthy, in his commentary on Susruta considers that the terms Jagrataha and Svapataha should be considered as the stages of life and death respectively. During one's lifetime, it contracts and relaxes continuously while after death it permanently stops functioning (Srikantha Murthy commentary on Su. Sha. 4/31).[5] In days time when person is awake Hridaya is like a bloomed lotus and in night it is like closed lotus (Su. Su. 46/537-538).[2] Arunadatta in his commentry on Ashtanga Hridaya states that; Hridaya is formed from the essence of Kapha and Rakta and it is the site of Ojas; it is made up of different types of Pesis and is having the shape of red inverted bud of lotus. To the right side of Hridaya, Kloma, Yakrit and Phuphphusa are present (Arunadatta in his commentry Sarvanggsundari on A. H. Sha. 3/12).[6] In Astanga Hridaya, Hridaya has been considered as the opening of Amasaya as it is in centre of Uras; Stana and Kostha (A.H. Sha. 4/13).[4] Dalhan in his commentary Nibandha Sangraha describes Hridaya as "Inverted Bud of Lotus". "Mahat" and "Artha" are considered to be the synonyms of Hridaya (Ca. Su .30/3).[3] Cakrapani explains Hridaya to be Mahamula because it is the root of great vessels and these vessels are dependent on it i.e. Samasakta (Cakrapani in commentary on Ca. Su. 30/3).[7] Hridaya is the root of ten major vessels that's why these ten vessels are known as Mahamula and these Mahamula are responsible for circulation of Ojas throughout the body (Ca. Su. 3/8).[3] Hridaya is given utmost importance in treatises as its functioning not only forms the basis of life but it is the main site where components supporting life reside. As per the description available in Caraka Samhita, six Angas, intellect, five types of sensory perceptions, soul and mind with its subjects resides in Hridaya (Ca. Su. 30/4).[3] Caraka further adds Hridaya as the site of Rasa, Satva, Intellect, Indriyas, Ojas, soul, and also considers it to be the pathway for movement of Dosha (Ca. Ci.24/35).[3] As the fine spokes are arranged in a wheel around a centre, in same fashion vessels, Pranvayu, Apanvayu, Manas, Buddhi, Atma and Mahabhutas are arranged around Hridaya (*Ca*. Si. 9/4).[3] Hridaya is the site of Cetana Dhatu so when it is surrounded by Tamogunasa, results in sleep (Su. Sha. 4/33)[2], Dalhana quotes that although the whole body is the place of Cetana Dhatu; Hridaya is considered to be the special site. Mana also resides in Hridaya that's why when Hridaya is surrounded by Tamoguna person sleeps (Dalhan in Nibandh Sangraha on Su.Sha.4/33).[8] Hridaya itself gets importance as it is the root of Pranvaha Srotas and Rasavaha Srotas (Ca. Vi. 5/8).[3]

Structural Components of Cardiovascular System

Sira and Dhamani along with Hridaya form the basis of cardiovascular system. In fact, the term 'vascular' in CVS comprises of Sira and Dhamai i.e. hollow and tubular structures. Hridaya is also a modified, specialized tubular hollow structure. Contemporary authors use the terms Sira and Dhamani to designate the veins and arteries respectively. But as per Ayurvedic literature, it is difficult to draw such one-to-one correlation. Vessels in which there is *'Adhmana'* i.e. pulsation are called Dhamani and one in which there is transudation / secretion are called as Srotas and vessels where 'Sarana' i.e. transportation of substance from one place to other takes place are called as 'Sira' (Ca. Su. 30/12).[3] 'Sira' are different from Dhamani and Srotas because their features (shape, morphology, and characters), roots and functions are different (Su. Sha 9/3).[2] Although different in number, Sira and Dhamani both have common origin from Nabhi and both of them spread in upward, downward and oblique directions (Su. Sha. 7/3, Su. Sha. 7/4-5, Su. Sha. /9/4).[2] basically, though the term Nabhi has been used in Ayurveda to indicate the umbilicus, in a wider perspective, it means a 'centre'. Susruta describes that all the Siras present in the body are attached to Nabhi and from Nabhi, they spread in all directions. He further adds that Prana resides in the Nabhi and they are homologous to the center of a wheel and it's radiating spokes (Su. Sha 7/4-5).[2] Dhamanis also have their root in Nabhi and from Nabhi they spread in upward, downward, and oblique directions (Su. Sha. 9/5, A. H. Sha. 3/38-40).[2, 4] In the opinion of this investigator, by the term "Nabhi" heart should be considered here. It has been explained by Acaryas that life resides in Nabhi. Caraka explains the ten sites of Prana two times in Caraka Samhita. Once he has considered Hridaya and Nabhi both among ten Prana (Ca. Sha 7/9)[3] and on second occasion, he has not considered Nabhi among the ten sites of Prana along with Hridaya (Ca. Su. 29/3).[3] In Cikitsa Sthana he has explained that out of one hundred and seven Marmas, Sira, Hridaya and Basti are of special importance because these three are special sites of life. Further to emphasize he has termed these three as "Marmatraya" (Ca. Ci. 26/3, Ca. Su. 29/3).[3] In Siddhi Sthana, Caraka has clearly mentioned that as the Aras (radiating spokes) are arranged around Nabhi (centre point), in the same fashion, ten Dhamais, Prana Vayu, Apana Vayu, Mana, Buddhi and

Mahabhutas are arranged around Hridaya (Ca. Si. 9/4).[3] This concept is further strengthened as Vagbhata has described that ten basic Siras have their root in Hridaya and from Hridaya they spread to all over body and circulate the Rasatmaka Ojas. Siras are wider at base and becomes thinner and thinner as they divide and count hundreds to thousands in number (A.H. Sha. 3/18-20).[4] Sira's count seven hundred (Ca. Sha 7/14, Su. Sha. 7/3)[3] and Dhamani count is hundred (Ca. Sha. 7/14).[3] As Arama (garden) or Kedari (a small piece of land) is irrigated by Jalharini or Kulya (small channels) in the same fashion body is nourished by Sira. Siras are arranged in body like venations on the leaves i.e. thicker at centre and become thinner and thinner as they divide and move away from the centre (Su. Sha.7/3).[2] Basic Sira's are forty in number including Vatvaha, Pittavaha, Kaphavaha and Raktavaha (ten each) and each of these divide ultimately into one hundred and seventy five counting totally as seven hundred Siras (Su. Sha. 7/6).[2] Although divisions are done on the basis of conduction of Vata, Pitta, Kapha and Rakta but all Sira conduct all four entities i.e. Vata, Pitta, Kapha and Rakta (Su. Sha. 7/7)[2] that's why Sira are known as Sarvavaha (Su. Sha 7/18).[2] Siras that conduct mainly Vata are reddish in colour, filled with Vata maintain normal functioning of body and mind. Siras that conduct Pitta mainly are bluish in colour and somewhat hot. They are responsible for maintenance of normal skin complexion, hunger, Agni and good health (Su. Sha. 7/19, Su. Sha 7/9, 7/ 11, A.H. Sha. 3/36-38).[2,4] Arunadatta in his commentary on Astanga Hridaya quotes that Vatavah Sira become alternatively filled and emptied with blood due to Cala guna of Vata and that's why Vatavaha Siras have the property of Spandana (Arundatta commentry on A.H. Sha. 3/36-38).[6] Sira that conduct Kapha are whitish in colour and cold on sensation. These are responsible for stability of joints and promotion of body strength. Siras that conduct Rakta are bright red in colour, neither too hot nor too cold and form the basis of nourishment of Dhatu, maintenance of normal skin complexion and absolute sensory knowledge (Su. Sha. 7/13, 15, 19, A. H. Sha 3/36-38).[2,4] The number of Dhamanis originating from Nabhi is twenty four. Out of them ten Sira's go upwards, ten downwards, and four go obliquely (Su. Sha. 9/4, A. H. Sha 3/38-40).[2,4] Functions of Dhamani's are well enumerated in literature. Dhamanis that go upwards from Nabhi, carry the sensory modalities i.e. Sabda, Spara, Rupa, Rasa, Gandha and they also mediate inspiration, expiration, yawning, sneezing laughing, speech, weeping and after getting into the heart they divide into thirty branches (Su. Sha. 9/5).[2] Dhamanis going downward carry Vata, Mutra, Purisha, Sukra, Artava and after reaching Pittasaya they causes nourishment of body by Annarasa that is produced owing to Ahara paka. These Dhamanis are responsible for the fulfilment of Hridaya with Rasa and for nourishing the Dhamanis that are going upwards and obliquely. These causes the separation of Mutra, Purisha, Sveda from each other and after reaching the site situated in between Amasaya and Pakvasaya they get divided into thirty branches (Su. Sha. 9/7).[2] Dhamani's that are obliquely directed are four in number and each of them is divided in hundreds to thousands of branches and these minute branches further divide into more and more branches becoming infinite in number. That is why body looks like a reticulum or network of Dhaman i.e. "Gavaksita". The minute branches of oblique Dhamanis are attached to the Romakupa and are responsible for sweating as well as absorption of the drugs applied in the form of Abhyanga (external massage) Pariseka (fluid Irrigation), Avagaha (tub bath) and also are responsible for perceptions of pleasant / non pleasant tactile sensations (Su. Sha 9/9).[2]

Dynamic contents of the Cardiovascular Compartment

Dynamicity is a basic feature of CVS and it ensures that the nourishment and oxygen are delivered to each and every cell of the body. As per the descriptions available in Ayurveda it is Rasa and Rakta that move in this closed circuit along with Ojas. Rasa and Rakta are the first two Dhatus in the sequence of seven Dhatus and Raktadhatu is produced from the nutrient portion of Rasadhatu. The term Rasa is derived from "Gatyarthak Rasadhatu" depicting its meaning that it moves throughout day and night (Su. Su 14/13)[2] Production of Rasa takes place from digestion of food material that is made up of Pancmahabhutas, having six types of Rasa, two or eight types of Virya and having many qualities. Rasa is the minutest and essential fraction of properly digested food formed after the action of Agni on it (Su. Su. 14/3).[2] Caraka describes that owing to Adankarma of Pranavayu, ingested food material is propelled to Kostha where it is softened by liquid content of surroundings and after getting support from Vayu, Agni causes digestion of food that ultimately supports life. As fire cooks rice with help of water present in pot, Agni causes digestion of food present in lower part of Amasaya resulting in Rasa and Mala (Ca. Ci. 15/6-8).[3] Process of formation of Rakta takes place from Rasa itself in a sequential fashion (Ca. Ci. 15/16, Su. Su. 14/10, A. H. Sha. 3/62).[3,2,4] Process of conversion of Rasa to Rakta takes place with the help of Rannjaka Pitta. Anatomical locations of Ranjaka Pitta are yakrit and Pliha (Su. Su. 21/10, Su. Su. 14/4-5, Ca. Ci. 15/28).[2,3] Vagbhata considers the location of Rannjaka Pitta to be "Amasaya" (A. H. Su. 12/13).[4] The colour of Rakta is like red hot gold, Indragopa and Gunjaphala (Ca. Su. 24/22).[78] It is neither too thick nor too dilute (Su. Su. 14/12).[2] It is having Madhura, Lavana Rasa, somewhat Sita and Ushna and having a colour of red lotus and resembles the blood of sheep or rabbit (A.H. Su. 27/1-2).[4] Cakrapani considers that individuals have different colours of Rakta due to different Doshaja Prakriti (Cakrapani on Ca. Su. 24/22).[7] Rakta is having Pancabhautika characters i.e. Vistrata owing to Prithvi, Dravata due to Jala, Raga due to Agni, Spandana due to Vata, and Laghuta due to Akasa (Su. Su. 14/9).[82] The total amount Rakta is eight Anjalis (Ca. Sha. 7/15)[3] and main anatomical site is Yakrita and Pliha (Su. Sha. 21/16).[2] Mula of Raktavaha Srotas are Yakrita and Pliha (Ca. Vi. 5/7)[3] along with Raktavaha Dhamani (Su. Sha. 9/12).[2] The volume of Rasa is nine Anjalis (Ca. Sha. 9/15).[3] Rasavaha srotas has its Mula in Hridaya and ten major vessels (Ca. Vi. 5/8)[3] and Hridaya and Rasavaha Dhamani (Su.Sha. 9/12).[2] This Rasa causes satisfaction, nourishment of body and production of Rakta Dhatu (Su.

Su. 15/7).[2] Rasa is responsible for obesity as well as emaciation (Su. Su.15/37).[91] It's deficiency results in palpitation, non endurance of loud sound, feeling of black hollows, and pain in cardiac region (Ca. Su. 17/64),[3] along with weakness, tremors and excessive thirst (Su. Su. 15/13) [2] and emaciation, and dryness of skin (A. H. Su 11/17)[4] while Rasa Vriddhi produces the same features as of kapha Vriddhi i.e. anorexia, disguisea, loss of taste sensation, nausea, heaviness in body, drowsiness, mild body ache, fever, black hollows, anaemia, impotency, weakness, emaciation, greying and loss of hairs (Ca. Su. 28/9-10,Su. Su 24/10, 15/19)[3,2] along with Svasa, Kasa, and excessive sleep (A. H. Su. 11/7-8).[4] This Rasa is responsible for lactation and menstrual blood flow (Ca. Ci. 15/17)[3] having its Mala as Kapha. Rasa is main reason for origin of Purusha itself (Su.S 14/12).[2] Pure Rakta is responsible for healthy complexion, satisfaction, pleasure, well nourished body and physical strength (Ca. Su 24/24).[3] Owing to Rakta; ears, eyes, mouth, tongue, lips, hand, nails, forehead etc of individuals appear reddish, glowing and attractive (Ca. Vi. 8/104, Su. Su 38/18).[2,3] It is responsible for the glow of complexion, production and nourishment of Mamsadhatu (Su. Su. 15/7, A.H. Su 11/4)[2,4] and is responsible for growth and loss of other Dhatus. Pitta is Mala of Rakta (Ca. Ci. 15/18, A.H. Sha 3/63-64)[2,4] and Kandara, Sira are Updhatu of Rakta (Ca. Ci. 15/17).[3] It's deficiency manifests as desire to eat acidic and cold things, looseness of vessels, and dryness of body (A.H. Su 11/17, Su .Su 15/13, Ca Su 17/65) [4,2,3] and its increase manifests as redness of eyes, overfilled vessels with blood (Su. Su. 15/19).[2] Bodies cannot exist without Vata, Pitta and Kapha but cannot exist without Rakta also that's why Rakta is considered as fourth Dosha (Su. Su. 21/4)[2]

Physiology of Cardiovascular System

Physiological processes related to the cardiovascular system comprises of ejection of Rasa from Hridaya, movement of Rasa in channels that ultimately result in nourishment of Dhatus, movement of waste products from Dhatu and factors that regulate all these processes.

Unique Feature of C.V.S. as a Closed Circuit

Rasa is ejected from Hridaya and circulates throughout body and from there it ultimately returns to Hridaya i.e. as a closed circuit (Bhel. Sa. Su .20/3).[9] This depicts the feature of CVS as a closed circuit.

Nature and Main Depot of Rasa being ejected

Rasa that is ejected from Hridaya is the most minute and essential form of properly digested Ahara formed after proper action of Agni (Su.Su.14/3).[2] This minutest and essential fraction of properly digested food is called 'Sara' in this context. This is 'Rasa'. This 'Sara' includes all completely digested materials absorbed from GIT.[10] Dalhana quotes that "Rasa" is "Paramasukshma" means Rasa can follow very minute channels (Dalhana on Su. Su.14/3).[115] According to Caraka, Rasa is produced due to action of Agni in lower part of Amasaya to produce Rasa and Mala (Ca.Ci.15/6-80).[3] Rasa is having its main depot (Sthana) as Hridaya (Su. Su.14/3).[2] Dalhana in his commentary on same verse states that although the whole body is place of Rasa, Hridaya is considered to be the special site of Rasa. Cakrapani states that term Rasa includes all circulating fluids along with Rakta (Cakrapani on Ca.Ci. 15/38).[7] Cakrapani has further quoted that Rasa along with Rakta circulates in ten main Dhamani that are attached to Hriadya ."Raktadi" i.e. Rasa along with Rakta circulates in whole body having its main Sthana as Hridaya.(Cakrapani on Ca. Ci. 24/36).[7] Vijayraksita in his commentary on Madhava Nidana 33/4 has used the term Raktarasa to indicate the extract of properly digested food due to Agni.[11] Vagbhata has further clarified the issue that it is not only the Rasa but also "Rasatmak Ojas" that circulates in whole body via ten great vessels that directly emerge from Hridaya. (A. H. Sha. 3/18).[4] In Ayurvda Sutra, (a work of 15th century) Yogendra Nath states that Rasa itself is Rakta and Rakta itself is Rasa and Rakta is both Rasa and Rakta (Dwarakanath C).[12] So, ultimately we come to the conclusion that fluid that circulates in the CVS is a combination of Rasa, Rakta and Ojas.

Driving Force that Ejects Rasa from Hridaya

As the main depot of Rasa is Hridaya, there must be some force that ultimately causes the ejection of Rasa from Hridaya and also the movement of Rasa to the whole circuit and finally resulting in re-entry of Rasa into Hridaya. The two main driving forces are-

1. Contractility and auto rhythmicity of Hridaya itself
2. Vyana Vayu

Susruta has described that Hridaya is the organ that has activity of Sankoca and Vikasa in jagrata and Swapata states (Su. Sha. 4/32).[2] Srikanthmurthy in his commentary to Susruta has quoted that from term Jagrata and Swapata, states of life and death should be taken respectively (Srikanthmurthy on Su. Sha .4/32).[5] In Nadi Jnana terms "Sukha" and "Duhkha" are elaborated as the state of wellbeing or non-wellbeing. Auto- rhythm city in Hridaya in the form of Sankoca and Vikasa, takes place repeatedly and automatically[10] i.e. Hridaya contracts and relaxes itself repeatedly. Rasa dhatu being ejected from Hridaya is being further propelled in circulatory channels of whole body by "Vyana Vayu". Caraka states that "Viksepana" is the normal function of Vyana Vayu i.e. Vyana Vayu is responsible for movement of Rasa Dhatu in the whole body simultaneously all the time (Ca.Ci.15/36-37).[3] Cakrapani states that Rasa i.e. Dravadhatu is being circulated in whole body by Vyana Vayu. He further adds that Viksepa is the Prakrita Karma of Vyana Vayu (Cakrapani on Ca. Ci. 15/36-37).[7] Susruta and Vagbhata both find agreement with this concept of Caraka (Su. Ni.1/17-18, A. H. Sha 36/68-69).[2,4] Susruta further adds that Sara is the extract part of digested Ahara and undigested part is known as Mala. This Sara i.e. Rasa being propelled by Vyana Vayu causes nourishment of the body (Su. Su. 46/536).[2] Dalhana accepts the importance of Vyana Vayu. He uses the term Vyapti in reference of Vyana Vayu i.e. it is present in every part of body and is responsible for movement of Rasa in the whole body (Dalhana on Su. Su. 46/536).[8] In the context of production of Dhatu, Arunadatta raises a question that as Rasa Dhatu nourishes each Dhatu in a "Yugpat"

fashion i.e. if Rasa reaches each Dhatu simultaneously, then how can one Dhatu be produced from its previous one? i.e. each Dhatu should be produced simultaneously. So, he explains the term Yugpat to be 'in a very quick fashion'. He further explains that as in the case of a bunch of lotus petals being pierced by a needle, where, it appears that the needle has pierced all the petals simultaneously, actually it is not so. The needle pierces all the petals one by one. In the same fashion, Rasa nourishes Dhatus one by one but in a very quick manner (Arunadatta on A. H. Sha. 3/62).[6]

Vessels into which Rasa is being Propelled

Rasa being ejected from its main depot or Sthana i.e. Hridaya, enters the Dhamanis. Susruta clearly states that Hridaya is a place of Rasa and this Rasa after being ejected enters into the twenty four Dhamani i.e. ten going upwards, ten going downwards and four going obliquely. This fact provides a clear indication that vessels that emerge from Hridaya and carry Rasa to nourish the Dhatu are none other than the Dhamani (Su. Su.14/1-4).[2] Caraka mentions the feature of Dhamani as vessels in which 'Adhmana' i.e. pulsation takes place (Ca. Su. 30/12).[3] Cakrapani in his commentary states that Dhamana i.e. pulsation is produced in Dhamani (Cakrapani on Ca. Su.30/12).[7] Cakrapani writes that ten Dhamani that originates from Hridaya are known as Rasavatadivahanama i.e. they transport Rasa and Vatadi Dosha (Cakrapani on Ca. Ci. 24/35).[7] All these descriptions dictate the fact that vessels in which Rasa is being propelled from Hridaya are Dhamanis.

Propagation of Rasa in a Downhill Journey

Rasa propagates in the body in a fashion that is similar to the movement of Sabda, Arci and Jala (Su. Su.14/16).[2] Dalhana quotes that Rasa moves in body in oblique direction like Sabd, in upwards direction like Arci and in downward direction like Jala. Dalhana further adds that these three types of movements of Rasa are directly related to the status of Agni i.e. Tikshna, Sama and Manda and ultimately to the duration of production of Dhatu. If there is Tikshnagni then it takes one week for production of Sukra from Rasa and if there is Mandagni then it takes more than one month (Dalhana on Su. Su. 14/6).[8] This concept of Susruta of Rasa movement can be explained on the basis of mean flow velocity. As per the view of different commentators, velocity with which sound moves is greater than that of fire, whereas, the velocity of fire is greater than that of water. The fact is supported by the scientific explanations. The velocity of sound is 340 meter/sec. that of fire (wildfire) is 40-50 meter/sec. (The velocity of fire is dependent on the wind velocity, humidity, temperature and the type of fuel.) The velocity of water is 4-5 meter/sec (average velocity of rivers in plains). Mean Flow Velocity (MFW in cm/sec) can be calculated by the following formula:

$$MFW = \text{Volume Flow } (cm^3/\text{Second}) / \text{Cross Sectional Area } (m^2)$$

By using this formula it can be said that the mean flow velocity of blood is maximum in aorta, as aorta is the smallest cross sectional area which receives the entire output of the blood from the heart. This mean flow velocity decreases as the blood moves down the CVS into the arterioles and is lowest in capillaries. So, movement of Rasa is similar to the movement of Sabda, Arci and Jala.[10] Vagbhata describes Siradi are Mahamula i.e. they are having more cross sectional area at base and become narrower and divided as they moves away (A. H. Sha.3/18-19).[4] Susruta also agrees with the view of Vagbhata in Sarira Sthana that as Dhamani propagates becomes narrower and divided in hundreds to thousands of branches so that body looks like Gavaksita i.e. network like.

Events of Exchange at Minute Level

As vessels become very minute and thin, they become porous. Acarya Susruta has described that like the stalk of lotus, Srotas are having abundant fine pores and these Srotas are spread throughout the body (Su. Sha. 9/13).[2] Vagbhata has further elaborated that as the stalk of lotus has fine and innumerate pores, Srotamsi are also having pores. Rasa oozes from these pores and nourishes the body (A. H. S. 3/46).[4] Susruta has further enumerated that Dhamani are having small perforations for Rasa movement (Su. Sha. 9/10).[2] So, Susruta and Vagbhata both have clearly mentioned the presence of pores. Describing Srotas, Caraka has described that Srotas serves as 'Ayanmukhani' to both Prasadakhya and Malakhya Dhatus (Ca. Su. 28/5).[3] The term Ayana has been defined in Amarkosa Ka II Bhumi Varga as "Ayate Iyate Va Anena Iti Ayanama"(Dwarakanath C).[12] While describing the Srotamsi, Caraka has mentioned the feature of Srotasa as "Sravanat Srotamsi" i.e. channels in which oozing takes place (Ca. Su. 30/12).[3] Cakrapani in his commentary states "Srotamsi ayanmukhani" i.e. Srotamsi are those that carry or bear innumerate Mukhas. Rasa oozes from these Mukhas to nourish the Prasadakhya Dhatu i.e. Sthayi or Poshya Dhatu and these Mukhas are responsible for exit of Malakhya Dhatu from Sthayi Dhatu to nourish mala. It means that Ayana or Mukha are pores that cause exit and entry of substances. Cakrapani describes Ayanani as pathway or channels which carry Prasada and Mala both. Ayanani or Srotamsi are very specific to their respective Dhatus as they cause exit or entry of substance from and in to their respective Dhatus only (Cakrapani on Ca. Su. 28/5).[7] So it is significant from descriptions that Mukha (pores) as well as Srotsas (ayana)

- Both acts as bidirectional pathways for movement of Prasada and Mala. Such a kind of movement is generally seen at the level of capillaries i.e.it shows the exchange at capillary level.
- Secondly they not only cause input of Rasa to Dhatu but also are responsible for removal of waste product from the Poshya dhatu. Since Srotasas are very specific to their Dhatu this depicts the exchange at Dhatu or tissue level.

To explain these events there are two classical theories of Dhatu Poshana:

1. Kedari- Kulya Nyaya or Theory of Channel and Fields.

2. Khale-Kapota Nyaya or Theory of Grains and Pigeons.

Kedari- Kulya Nyaya or Theory of Channels and Fields

This theory describes that Dhatus are arranged in the body in the same sequence as per sequence of their production. These Dhatus can be considered as different pieces of lands or fields and Kulya as channels. As the different channels carry water from a big reservoir to fields or plots for irrigation, Kulya also carry Rasa to nourish the Dhatus. Plot that is nearer to the reservoir is irrigated first and plots that are distant are irrigated later. In the same fashion Dhatu that is located nearer (or that is produced first) receives Rasa first and only thereafter other Dhatus receive Rasa in a sequential fashion (Cakrapani on Ca. Ci. 15/16-17).[7] This theory probably explains the importance of pressure gradient, which determines the flow into the tissue spaces. This is similar to the movement of water in the direction of gravitational force. This theory can also explain the passive diffusion of particles across the cell membrane, along the concentration gradient as occurs in the case of carbon dioxide, oxygen etc because water in this case passes into different fields passively along the direction of concentration gradient.[10]

Khale- Kapota Nyaya or Theory of Grains and Pigeons

(Cakrapani on Ca.Ci.15/16); this theory explains the auto-regulation of blood flow by tissue factors. Blood flow to each tissue is regulated depending on the metabolic needs of the particular tissue. The example given to explain this theory is that of different pigeons, picking up grains from the same field and then returning to their original places. Here, the choice regarding the amount of grains purely depends upon the need of the individual pigeon. This theory can also explain the transport of different particles across the cell membrane with the expenditure of energy as occurs in case of different molecules like glucose, amino acids and some ions. This is because, the pigeons have to spend energy to procure the grains and this process is active one.[10]

Re-entry of Rasa to Hridaya

As per description "Srotamsi" are responsible for the movement of Malakhya Dhatu from Poshya dhatu. According Sarngdharas Samhita Pu 6/8 Samana Vayu is responsible for re-entry of Rasa into Hridaya.[6] So, Rasa nourishes the Dhatu in a circular fashion as described in Caraka and Astanga Hridaya. (Ca. Ci. 15/21"A. H. Sha.3/66).[3,4]

DISCUSSION

In the recent past one of the researcher focused on blood circulation in Ayurveda and noted that Ayurveda masters have also played a important role in explanation about the blood circulation before the Hippocrates, William Harvey etc.[13] In the present article we focused all aspects of the cardiovascular system in respect to its embryological, anatomical and physiological explanations by varies ancient Indian science pioneers and correlate it with contempory science, however Now-a-days contempory science historians, fully ignore the Ancient Indian science pioneers valuable contribution in cardiovascular system because the language used by the ancient Indian Ayurvedic Science pioneers for documentation of these early textbooks is in Sanskrit, a language that is not in day-to-day use among the general population but this article somehow reveals that Ancient Indian Ayurvedic Pioneers had clear and deep understanding of cardiovascular system.

CONCLUSION

The Ancient Indian Science pioneers had clear and deep understanding of Cardiovascular System as shown by the some classical ancient Slokas and Literature. Hence it is clear that these Ancient Indian Pioneers deserve to be recognized for their contribution in the cardiovascular area.

ACKNOWLEDGEMENT

The authors want to express thanks for the Guidance Received from their guide and support and facilities they received from the IMS Library, Banaras Hindu University, Varanasi, India.

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Cite this article as:

Rapolu Sunil Buchiramulu, Piyush Kumar Tripathi. A valuable explanation of the cardiovascular system by ancient Ayurvedic science pioneers. Int. J. Res. Ayurveda Pharm. 2014;5(3):384-389 http://dx.doi.org/10.7897/2277-4343.05379