DISCUSSION:

The objective of the study which has been under taken to denote and determine the anatomical structure and scientific explanation of concept of Raktadhara Kala as described in Ayurvedic scripts.

*Raktadhara Kala* which is very important topic under the *Kala Shareera* specially attracted the concentration of holder for research study. Because of the fact that vascular system is an essential part of the body which helps regulates several life processes, therefore the final disclosures on the hidden biological values of *Raktadhara Kala* will be elaborated scientifically. The discussion will analyze and evaluate the collected data and information in this account duly to achieve the objectives.

DISCUSSION ON HISTORICAL REVIEW:

After reviewing Historical references from *Vedas, Upanishads, Puranas*, etc we will get a very interesting thing that the word *Kala*, having different meanings in a different context. In *Vedas, Kala* as an eighth and sixteenth part, as a whole they bring together all evil dreams. In *Brihadaranyaka Upanishads, Kala* is used in the context of *Prajapati* is the year and consists of sixteen *Kalas* (digits) is the fixed point.

In *Prashnopenishad* it is stated as a part of wheel i.e. spokes here it gives meaning as a structure of a wheel. In *Mundakopanishad* it has been used as a *Moksha*.

In *Puranas* it is used in the sense of time factor. And in *Ramayana* it is considered as a skill of person i.e. quality.

So, here *Kala* is not in relation to the any structural entity of the body or *Pratyanga* or in a gross manner or in the microscopic way.
DISCUSSION ON WORD KALA

In Ayurvedic Anatomy, the word Kala has been used in the structural entity by our Acharyas like Sushruta, Vagbhata etc to denote only one kind of Pratyanga i.e. tissue. But Acharya Charaka has not used the word Kala in this sense at all; he used to mean guna or qualities.

Acharya Sushruta has opined that, Kalas are the structures in the form of linings for limitation between Dhatu and Ashaya i.e. “धातुश्वश्चान्तर मर्यादा: ”. Here the word meaning of Dhatu is element or primary substance or the essential component of the body. And Ashaya is hallow structure in which some of the material or components will take shelter, in that one in order to carry out their important functions. For ex- Amashaya, Pakwashaya, etc. So in this one, we have to understand that what is in between the Dhatu and Ashaya i.e to know the limitation of Kala. Indu said धातुश्वश्चान्तर means Srotas. In Srotas we can see the function of Kala i.e. formation of Dhatu.

Acharya Sushruta said that anatomy of lining in the body can be seen matching with the form of the wood, when a section is taken in the wooden log, the coverings of inside the structure are exposed, so in the same way we will find Kala after dissecting the Mamsadi dhatus of the body. With the help of above comparison, by giving analogous example Acharya Sushruta has demonstrated the presence of imperceptible Kala in Dhatu. Dalhana commented that different types of Dhatus are perceived or recognized due to Kala itself.

One thing is clear that Kala is a tissue, covering the internal parts of the body, where as skin is the external covering of the body. That is why Sushruta might have kept Twak is in first place and Kala in second place, while mentioning the list of pratyangas.

Acharya Vaghata-I described that the development of Kala is by the Kleda which is present in between Dhatu and Ashaya, gets pakwa by the action of ushnatwa i.e. agni of that particular Dhatu and get converted into Kala.

Both Sushruta and Vagbhata said the structure of Kala is a membranous or covering with Snayu i.e. tendinous sheath, Shleshma i.e. mucus membrane and Jarayu i.e. chorionic membrane and is formed like Sara of plant.
It is not necessary that all these structures should be present in every Kala. Few Kala may be formed by Snayu, few by Jarayu Sadrusha, few by Shleshma, and may be few by mixture of these structures.

Further Vagbhata -1 and Indu said Kala as “Alpatwam” or “Swalpatwam” i.e. very minute structure comparing to other minor organs in the body. Even Haranachandra commentator of Sushruta Samhita, said Kalas are so minute that they are not easily seen by naked eyes i.e. they are microscopic structure. At that time there were no microscopic visual devices than also our Acharys described about the Kala as Alpa, Swalpa and Sukshma, they must have seen or perceived by their Jnanachaksu and Tapaschaksu.

Indu said Kalas are naturally performing specific function. Dalhana has also said Kala can be recognized by their function and also different types of Dhatus are perceived due to Kala itself.

So by above references, we can say that the function of Kala is protection i.e. by holding the dhatu, and formation of Dhatus. And also can say that Kala helps in transformation of Dhaturasa to other dhatu i.e. it perform the function of transformation.

According to Modern science:

We can compare Kala are formed by microscopic bodies i.e. cells. The function of Cells and Tissues described in the modern science is resembled to Karya and Swaroopa of Kala. Functions of Cells and Tissues are Formation, Protection, Absorption, Transformation, Secretion, Selection etc. These functions of cells one can see in the body, performed by Kala.
Discussion On Chronology Of Kala Based On Kriya Shareera

In the order of Dhatu, first Dhatu is Rasa than Rakta and than Mamsa and so on. But in the order of Kala, Rasadhara Kala is not described at all. Instead of describing Raktadhara Kala at first Acharyas described Mamsadhara Kala as first.

Dalhana raised the question and gives the answer that the sequence of Dhatu, is according to its Poshana karma i.e. Rasa Dhatu is nourished by Ahara rasa, then Rakta dhatu, then Mamsa and so on. But sequence of Kala is according to its Dharana Karma. Here Dharana Karma indicates the function of Kala, i.e. giving physical support as well as controlling of physiological action of Dosha, Dhatus, and Mala.

Mamsadhara Kala is first and then Raktadhara Kala is responsible for giving physical support to almost all Dhatus in the body.

Discussion On Chronology Of Kala Based On Rachana Shareera

Acharya Susruta has observed the findings on the level of dissection of cadaver in which he had seen the membranes appearing one by one during the steps followed in dissection under which first is Mamsadhara Kala. Then while dissection of muscle was conducted the membrane related with blood vessels were seen named as Raktadhara Kala and also we find that after discovering the structures into the depth of the deep fascia we find muscular and vascular levels. Since the muscles are integral structures with their continuity in attachment with the deep fascia therefore it falls as first and blood vessels falls as second.

The Medodhara Kala was considered thirdly because we find the fat collected everywhere in the space between the muscles and around the blood vessels and connective tissues. Since joints are the parts of locomotor system and they almost represent to the extremities on to the body wall therefore under the process of dissection the joints are next to be observed and Shleshmadhara Kala was given fourth number. After that the abdomen was to be dissected and since intestines are separated from the abdomen prior to the process of preservation of the body therefore the Purishadhara kala represents to the intestine particularly to the large intestine, was next to be given place. As such Purishadhara kala got fifth number in this order.

Further, dissection was proceed and the membrane lining the stomach and duodenum and related organ were seen on dissection therefore the next Kala was said as Pittadhara on sixth number.
None of the organ and the system attracted during dissection to be specified for the consideration of the Kala.

Lastly he found *Shukradhara kala* in the genito-urinary tract. But he emphasized systemic status of *Shukra dhatu* in concealed form. This was a form which can be seen under this heading to signify the enumeration of seven Kala.

**Discussion On Types Of Kala:**

The general discussion of all the Kala is been done in a concise form and as we have taken *Raktadhara Kala* for our scientific study, where we have tried our level best to explain the Raktadhara Kala.

In *Mamsadhara Kala*, the literal meaning is which holds the Mamsa Dhatu, and inside the Mamsa we can see the branches of Sira, Dhamanis, Snayu, Srotas are spread. Here explaining that Veins, Arteries, and Ligaments are spreading inside this Mamsdhara Kala i.e. we can compare it as Deep fascia and Intermuscular septa.

Since the *Raktadhara Kala* has been taken as a specific area of the study under this thesis, therefore the detail discussions will be presented later on after the completion of this part of the discussion based on the analysis of seven types of Kala in general.

*Medodhara Kala, Meda* is present in the *Udara, Anu* and *Sthulasthi* of all the living beings. In the *Udara* it is called as *Meda*, and in the *Sthulasthi* is called as *Majja*. Whereas the remaining *Anu Asthi* and etc. containing the *Meda* is called as *Sarakta Meda*. The sneha which is present in the *shuddha Mamsa* is known as *Vasa*. We can compare it as omentum, deep fascia and the membrane which holds the medas i.e. adipose tissue.

*Shleshmadhara Kala* is present in all the joints. And supporting the life of all *Sandhis*. We can compare it as Synovial membrane present in the joints.

*Pureeshadhara Kala* is present inside the *Koshtha*, which separates the *Mala* from the *Saara Bhaga* i.e. in *Pakvashaya*. This Kala is commencing from *Yakrit* and the *Antra*, which separates from the essence part *Mala* at the *Unduka*. This Kala is also called as *Maladhara Kala*. We can compare it as Mucus membrane of colon and rectum.
Pittadhara Kala supports the four kinds of food, pushed out from the Amashaya and staying in the Pakwashaya. All kinds of foods which are eaten, swallowed, chewed and drunk, are reaching to the Kostha is digested there in due course of time and gets observed by the Tejas or the effect of pachaka pitta. We can compare it as Mucus membrane of Small Intestine.

Shukradhara Kala pervades in the entire body in all living beings. Shukra comes out through the urinary passage of man, from a distance of two angula (approx 4cm) beneath the orifice of urinary bladder on the right side. Shukra present in the entire body comes when man indulges in copulation with the woman, in a happy mind. We can compare it as Mucus membrane of the Seminal Vesicles, Vas deferentia, etc.

**Discussion On Rakta:**

Rakta is one among the seven Dhatus, usually participate in governing or supporting the body and is extremely important for sustenance of life. It is therefore needed to protect this Dhatu by every possible measure. Raktadhatu takes part in origin, sustaining and are responsible for jeeva. So this Raktadhatu is holed or supported by Raktadhara Kala.

Raktadhatu is originating from Rasadhatu, due to circulation along with Rasadhatu, Raktadhatu cannot be physically separated from Rasadhatu and therefore must be perceived by its functions in the body. May be that’s why our Acharyas not mentioned about the Rasadhara Kala.

Rakta is present in large quantity in some places and may be functioning specifically in some organs. Raktadhatu is produced in his own srotas i.e. Raktavaha srotas. Yakrit and Pleeha are the principal organ plays an important role in production of Raktadhatu i.e. Blood. After consuming the Ahara, it is converted into Ahara Rasa is called as Rasadhatu. This Ahara Rasa after being subjected to Paaka by Teja or Ranjaka Pitta brings the red color to the Rasa i.e. understood as a Rakta.

Rakta is moving in its own sira (Raktavaha sira) performs functions such as supplying nutrition to the tissues, brings color to the skin responsible for sensation of touch. When aggravated, Rakta accumulates in their own sira, and then many diseases caused by blood develop in the body. Prana circulates along with Rakta as it is considered one of the pranayatana by our Acharyas. Hence utmost care should be given for Rakta.
For understanding of *Rakta*, the *Guna of Rakta* is given like this, it appears like heated gold, like insect *indragopa*, or *Gunja* etc. So we can understand red liquid component of the body. Its quantity is measured about 8 *anjali*.

**Discussion On Blood:**

Exact comparative component of the *Raktadhatu* can be understood as Blood. Blood is a connective tissue, in fluid form even considered as the fluid of life and also known as fluid of growth because it carries nutritive substances from the digestive system to all the tissues. Blood is red in color. It is about 5 liters in normal adult. There are three types of cells present in blood. Among these three cells the red color of RBC is due to the presence of the coloring matter-hemoglobin. The red blood cells has the mechanical advantage that, while passing through minute capillaries, these cells can squeeze through the capillaries very easily. The diameter of capillaries is less or equal to that of RBC. The destruction of RBC occurs mostly in the capillaries of *spleen* because; the splenic capillaries have a thin lumen. So the spleen is usually called graveyard of RBC.

The site of erythropoiesis in embryonic life is during the first two months of IUL, the primitive RBC’S are produced from mesenchyma of yolk sac and from third month of IUL, liver is the main organ that produces RBC’S. Some erythrocytes are also produced from *spleen*. During the last three months of IUL the RBC’s are produced from red bone marrow and liver.

**Discussion On Raktadhara Kala:**

**Definition of Raktadhara Kala:**

Based on the function of *Kala* - *Raktadhara Kala* can be defined as, a thin membrane which holds or which gives support to the *Rakta*.

Based on the Structure of *Kala* - *Raktadhara Kala* can be defined as, a border line or lining of *Ashaya* apart from *Dhatu*. Or *Kala* is a structure which separates two *Dhatus* or *Dhatus* and *Ashaya* from each other. In *Raktadhara Kala*, “धात्वाशयान्तर मर्यादाः” as, *Dhatu* is *Rakta*, *Ashaya* is *Raktashaya* and *Maryada* is *Kala*. 
Sthana of Raktadhara Kala:

For understanding of Raktadhara Kala as we are in the most advance medical field, here it becomes very necessity to fix the exact limitation of the Raktadhara Kala. Acharya Sushruta has said that it is a structure holding the Rakta, present inside the Mamsa in general and specially present in Sira, Yakrit, and Pleeha.

Acharya Vagbhata also quotes the similar to that of Acharya Sushruta, Raktadhara Kala is a structure which is present in the Mamsa abhyantara in general and specially present in Yakrit, Pleeha and Sira. So here we have to understand that, what is the structure present in the Sira, Yakrit and Pleeha, which is going to hold the Rakta.

Discussion On Structure Of Raktadhara Kala In Sira:

As we come across few examples, such as Rakta is flows through tubular structures i.e. Sira and Dhamani. Acharya Sushruta has said Sira and Dhamani are different structures But Acharya Charaka said Sira means to understand both artery and vein i.e. blood vessels. Sira is the channel where the function of sarana (continuous motion) takes place. Chakrapani states that siras communicate to various (peripheral) parts of the body. Siras are found all over the body in the form of a network that travels to the various parts of the body which carries the blood and responsible for proper functioning of the body.

Here we have to understand Sira as a Blood vessel. The structures involved or the structural components present in the formation of Sira and in this the membranous structures doing the dharana of Rakta, should be considered as Raktadhara Kala.

While comparing with modern science, in Sira i.e. Blood Vessels there are three membranous structures. From outside to inside they are- Tunica Externa, Tunica Media, and Tunica Intima

1. Tunica Externa:

   - It mainly composed of collagen fibers.
   - The collagen serves as to anchor the blood vessel to nearby organs, giving it stability.
2. **Tunica Media:**

- In Arteries- it is made up of smooth muscle and elastic tissue.
- In small arteries – plain muscle fibers arranged in the lamellae.
- In smallest arteries- thickness is mainly due to this wall of artery.
- In larger arteries- elastic fibers unite to form lamellae which alternate with the layers of muscular fibers.
- In still larger arteries – amount of elastic tissue is very considerable.
- In vein – composed of thick layer of connective tissue with elastic fibers, in some veins with transverse layer of muscular tissue.

3. **Tunica Intima:**

- It is the innermost layer of the blood vessel.
- It is made up of one layer of endothelial cells and is supported by an internal elastic lamina.
- Because of its friability, this layer cannot be separated as a complete membrane.
- It is a fine transparent colorless structure which is highly elastic.
Microscopic structures that can be compared with Raktadhara Kala in Sira:

The innermost layer, Tunica intima is in direct contact with blood and it consists of membranous structures they are, an elastic or fenestrated layer, Sub endothelial layer, Basal lamina and a layer of Endothelium.

1. An internal elastic or fenestrated layer:
   - It is the outermost layer in the Tunica intima.
   - Containing a network of elastic fibers
   - This membrane forms the chief thickness of the inner coat, can be separated into several layers.

2. Sub Endothelial layer:
   - Consisting of delicate connective tissue with branched cells lying in the interspaces of the tissues

3. Basal Lamina:
   - A thin layer of glycoprotein which lines the external aspect of the endothelium and is called the basal lamina.

4. A layer of Endothelium:
   - It is a thin layer of simple squamous cells that lines the interior surface of the blood vessel. It is a Mesodermal in origin. It lines entire vascular tree.
   - It is a thin layer of flattened cells that lines the inner surface of blood vessels.
• The endothelium is the cellular interface between the circulating blood and underlying tissue. As the medium between these two sets of tissues. Basement membrane (lamina) is second component, deep to the endothelium. It is absent in the capillaries and sinusoids.

• Endothelium is formed by endothelial cells, these are thin and laminar.

• Endothelial cells are in direct contact with blood are called Vascular endothelial cells.

• Vascular endothelial cells line the entire circulatory system from the heart to the smallest capillaries. These have unique function in the vascular biology.

• These functions include fluid filtration, blood vessel tone, hemostasis, neutrophil recruitment and hormone trafficking.

• Endothelium of the interior surface of heart chambers is called Endocardium.

As our Acharyas mentioned that structure of Kala is like Jarayu Santata i.e. it is a continuous membrane which covers the whole body of fetus similarly the Endothelium is a membranous structure which spread in the body.

In modern literature it is said that the fetal membrane i.e. amnion, chorion and Endothelium both are originating from Mesodermal germ layer. So by above reference we can interpret that structure of Raktadhara Kala i.e. Endothelium is like Jarayu Santata.

Functions of Endothelium:

• The endothelium is an important barrier to the free passage of molecules and cells from the blood to the underlying interstitium and cells.

• The endothelium produces a number of vasodilator and vasoconstrictor substances which regulate vasomotor tone and the recruitment and activity of inflammatory cells, and
regulate thrombosis. **Nitric oxide** – as a vasodilator and **Endothelin** – as a vasoconstrictor.

- Endothelial cells are in a unique strategic position as key players in host defense and inflammation.

- Endothelial and smooth muscle cells express a variety of proteins directly participating in haemostasis.

- Vascular endothelial growth factor (VEGF) is an angiogenic factor produced by a variety of cells, including endothelial cells.

**Discussion On Structure Of Raktadhra Kala In Yakrit And Pleeha:**

Our Acharyas mentioned two important organs i.e. *Yakrit* and *Pleeha* within which *Raktadhara Kala* is spreads. So it becomes necessary that what is the structural component in the *Yakrit* and *Pleeha* which is forming the *Raktadhara Kala*. So as we know there is no controversy or there is enough literary evidence present in *Ayurveda* to consider *Yakrit* as a liver and *Pleeha* as a spleen. Taking this as a main base we now try to understand the structural component or the membranous structure either in the gross manner or in the minute form can be understood as *Raktadhara Kala*.

**Structure of Raktadhara Kala in Yakrit:**

As our Acharyas said that *Kala* can be seen only after taking the section i.e. काण्येषु छिद्रमानेषु दृष्नि, so when we look into the transverse section of the liver, the membranous structure present in the liver which holding the blood can be correlated with the sinusoids.
Sinusoidal membrane in liver:

- Liver contain vessel structures called sinusoids instead of capillaries.

- Similar to capillaries sinusoids are composed of endothelium.

- The individual endothelial cells however do not overlap as in capillaries and are spread out.

- Endothelial cells may have unusually large fenestrations.

- Hepatocytes are separated from Sinusoids by the Space of Disse.

- Oxygen, carbon dioxide, nutrients, proteins and wastes are exchanged through the thin walls of the sinusoids.

- Kupffer cells are located inside the sinusoids and can take up and destroy foreign material such as bacteria etc.

Discussion On Yakrit For The Presence Of Raktadhara Kala:

By reviewing Ayurvedic literature we can interpret,

1. Yakrit as a Moolastana of Raktavaha Srotas.

2. Yakrit as a Rakta upatti sthana.

3. Yakrit as a Raktashaya

4. Yakrit as a sthana of Ranjaka Pitta as well as Shonita.

5. Yakrit is formed from Shonita.
After reviewing modern literature following reasons can be taken,

1. **Liver Has High Blood Flow:**

   About 1050 milliliters of blood flows from the portal vein into the liver sinusoids each minute, and additional 300 milliliters flows into the sinusoids from the hepatic artery, the total averaging about 1350 ml/min. This amounts to 27 percent of the resting cardiac output.

2. **Liver Functions as a Blood Reservoir:**

   Because the liver is an expandable organ, large quantities of blood can be stored in its blood vessels. Its normal blood volume, including both that in the hepatic veins and that in the hepatic sinuses, is about 450 milliliters, or almost 10 percent of the body's total blood volume.

3. **Hemopoietic function of liver:**

   During the middle trimester of gestation, the liver is the main organ for production of red blood cells but reasonable numbers are also produced in the spleen. Liver stores vitamin B12 necessary for erythropoiesis and iron necessary for synthesis of hemoglobin. Liver produces thrombopoietin that promotes production of thrombocytes.

**Structure of Raktadhara Kala in Pleeha:**

When we look into the transverse section of the Spleen, the membranous structure present in the spleen which holding the blood can be correlated with the sinusoids.

1. **Trabeculae:**
   - It is a fibroelastic coat of the spleen invests the organ and at the hilum is reflected inward upon the vessels in the form of sheaths.
From these sheaths, as well as from the inner surface of the fibroelastic coat, numerous small fibrous bands, the trabeculae of the spleen, emerge from all directions, these uniting, constitute the framework of spleen.

The spleen therefore consists of a number of small spaces or areolae, formed by the trabeculae in these areolae is contained the splenic pulp.

It is a vascular and has parenchyma and lots of vascular sinuses.

2. Sinusoids of spleen:

- Spleenic sinuses of the spleen, also known as sinusoids are wide vessels that drain into trabecular veins.

- Gaps in the endothelium lining the sinusoids mechanically filter blood cells as they enter the spleen. Worn out or abnormal red cells attempting to squeeze through the narrow intercellular spaces become badly damaged and are subsequently devoured by macrophages in red pulp.

- In addition to aged RBC, the sinusoids also filter out particles that could clutter up the blood stream, such as nuclear remnants, platelets or denatured hemoglobin.
Discussion On Pleeha For The Presence Of Raktadhara Kala:

Our Acharyas mentioned that,

1. Pleeha is the principle organ for moola sthana of Raktavaha Srotas.

2. Pleeha as a Raktashaya

3. Pleeha as a Rakta utpatti sthana

4. Pleeha as a Raktadhara.

5. Pleeha is formed from Shonita.

After reviewing modern literature following reasons can be taken,

1. The Spleen as a Reservoir for Storing Red Blood Cells:

   Red pulp of the spleen is a special reservoir that contains large quantities of concentrated red blood cells. As much as 50 milliliters of concentrated red blood cells can be released into the circulation, raising the hematocrit 1 to 2 per cent.

2. Blood-Cleansing Function of the Spleen:

   Reticulo endothelial cells present in venous sinuses act as cleansing system for blood by digesting old RBC and produces new RBC. It remove debris, bacteria, parasites, and so forth.

3. Formation of Blood cells in Spleen:

   Spleen plays an important role i.e. haemopoietic function in embryo. During the hepatic stage, spleen produces blood cells along with liver. In myeloid stage it produces the blood cells along with liver and bone marrow. Spleen produces red cells before birth and is believed to produces afterbirth only in extreme and hemolytic anemia.
4. In case of severe hemorrhage:

If the body suffers from severe hemorrhage the spleen can contract and increase the blood volume from 350ml to 550 ml in less than 60 seconds.

Table showing comparison to conclude:

Table No – 16.

<table>
<thead>
<tr>
<th>Structure of Raktadhara Kala</th>
<th>Endothelium</th>
</tr>
</thead>
<tbody>
<tr>
<td>One kind of Pratyanga.</td>
<td>One kind of tissue.</td>
</tr>
<tr>
<td>Present between Dhatu and Ashaya.</td>
<td>Cellular interface between the circulating blood and underlying tissue.</td>
</tr>
<tr>
<td>Derived from Jarayur ulbaka.</td>
<td>Originating from Mesodermal germ layer.</td>
</tr>
<tr>
<td>Kahsteshu chiddamaneshu drushyate.</td>
<td>Endothelium can be seen after the transverse section.</td>
</tr>
<tr>
<td>Thickness – alpatwam.</td>
<td>Endothelial cell is thinner and laminar: measure as little as 0.2 μm in thickness.</td>
</tr>
<tr>
<td>Present in imperceptible form in Dhatu.</td>
<td>Endothelium is a microscopic structure.</td>
</tr>
<tr>
<td>Perform specific function.</td>
<td>Vasomotor tone, blood vessel permeability, hemostasis.</td>
</tr>
<tr>
<td>Protection of Dhatus.</td>
<td>Phagocytic activity and are able to extract substances from the blood.</td>
</tr>
<tr>
<td>Secretion.</td>
<td>Secrete vasoconstrictive (thromboxane) and vasodilator (prostacyclin) prostaglandins, nitric oxide (NO, relaxing factor) and endothelin.</td>
</tr>
</tbody>
</table>