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Historical Article

Abu-Sahl al-Masihi (960-1010 AD) and His Description of the Heart

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Abstract

Since the Old Testament era, medicine has drawn scientists from around the world. Persian physicians have played an undeniable role in the advancement of medicine worldwide and their books have been taught as medical textbooks in the East and the West for years. In the Islamic Golden Age (9th to 12th century AD), *Abu-Sahl al-Masihi* (960-1010 AD), was one of the great Persian scholars contemporary to Avicenna and Al-Biruni. He wrote several valuable works on medicine, philosophy, mathematics, and astronomy in Arabic. The two books titled *Al-Mia fil-Tibb* (Book of the Hundred [on Medicine]) and *Ezhar al-Hekmat Allah Ta'ala fi Khalgh al-Ensan* (Manifestations of God's Wisdom in the Creation of Mankind) also known as *Tashrih Badan al-Ensan* (Human Anatomy) are among his important works in medicine. Particularly, in *Tashrih Badan al-Ensan*, *Abu-Sahl* detailed the structure and function of each organ within the human body. On heart anatomy, he presented interesting, and even innovative views. Despite the significance of his views on medicine among physicians of the Islamic era, his works have failed to be translated into Latin or other languages for unknown reasons, leaving him veiled in academic spheres. This paper aims to describe *Abu-Sahl al-Masihi*'s opinions on heart anatomy.

Keywords: Persian medicine; History; Anatomy; Heart

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Introduction

Medicine stands as one of humanity's oldest sciences, with contributions from scholars worldwide. Exploring historical texts on medicine unveils the scientific knowledge of various eras and the innovations unique to each period [1,2].

Between the third and seventh centuries, the ancient pre-Islamic era of Persian medicine developed in the city of Gondeshapur. It emerged as one of the foremost centers of antiquity, renowned for its medical education and qualifications, primarily rooted in the Greek system.

This academic prestige, which peaked in the seventh century began to decline in the following centuries apparently due to the creation of similar intellectual and hospital centers in Baghdad during the Islamic golden age. Accordingly, the Renaissance of Persian language, culture, and medicine was begun and established between 800 and 1300 CE [2-5].

During this era, influential scholars such as *Rhazes* (865-925 AD), *Majusi Ahvazi* known as *Haly Abbas* (930-994 AD), *Al-Akhawayni* (?–983 AD), and *Avicenna* (980-1037 AD) were born and made their significant contributions to the world within the Muslim lands. Centuries later, their works were used as medical textbooks in Europe. In many aspects, contemporary medicine is a continuation and evolution of ancient medicine [6-10].

Abu-Sahl al-Masihi, a Persian scientist from the Golden Age of Islam, remains relatively undiscovered by non-Iranians and Arabs due to the lack of translations of his works, particularly into Latin. Many novel findings and theories were used in his medical books to cover various health fields, including temperaments, anatomy, physiology, and treatment approaches [11].

One of the earliest concerns throughout the history of human civilization is cardiology and approaches to cardiovascular diseases. Scientific contributions to this critical field have been made by ancient Persian scholars like *Abu Sahl* [9,11].

The current review compiled *Masihi's* evidence-based concepts about the anatomy and physiology of the heart in contemporary medical literature and textbooks and those mentioned in his most important writing in medicine.

Biography

Isa ibn Yahya Masihi Jurjani (born in the 10th century AD in Jurjan), known as *Abu-Sahl al-Masihi*, was one of the major Persian scholars and an expert in the fields of medicine, philosophy, mathematics, and astronomy. Some reliable historical books provide limited information about his life [11-18]. According to these documents, *Abu Sahl* spent a period of his life alongside great Persian scientists such as *Avicenna* (980–1037 AD) and *Biruni* (973–1048 AD) in Mamunian's court (a Persian dynasty that ruled between 995 and 1017 AD). Some sources even consider *Abu Sahl* as *Avicenna*'s teacher in medicine [17-19].

Various works in medicine and other branches of science have remained from *Abu Sahl*. *Kitab al-Mia fil al-Teb* (Book of the Hundred) is his largest and most famous writing, which can be considered a medical encyclopedia or *Kunnash*. This book has one hundred sections, each on an independent topic. In terms of scientific value, some historians have ranked this book at the same level as *al-Hawi* (*Rhazes* 865-925 AD), *Al-Qanun fi al-Tebb* (The Canon of Medicine) (*Avicenna* 980-1032 AD), *Kāmil al-Sinaā al Tibbiya* (The Royal Book)(*Haly Abbas* 930-994 AD), and *Zakhireye Kharazm shahi* (Treasure of the Khwarazm Shah)(*Ismaeil Jorjani* 1136 – 1040AD), and also some even considered it a model for *Avicenna*'s Canon of Medicine [11,17,18,20].

Kitab al-Teb al-Koli (Book of General Medicine), which is second to *Al-Mia fil al-Teb* in terms of volume, covers more general issues in medicine [21] (Figure 1).

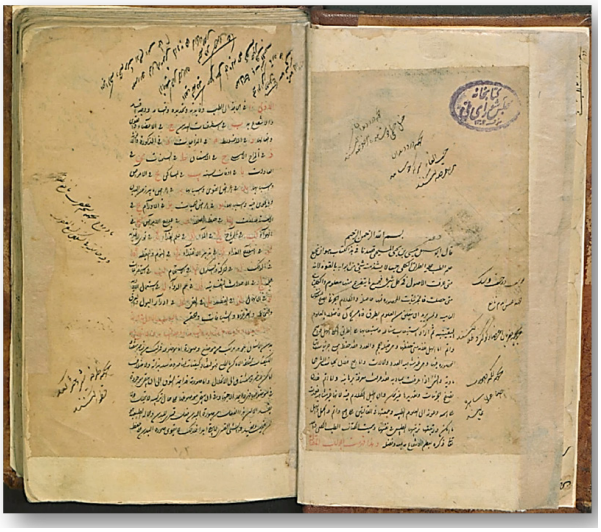

Figure 1. The first pages of *Masihi's Kitab al-Teb al-Koli* kept in Islamic Consultative Assembly Library

Methods

This research is a narrative historical review study incorporating specialized books and articles on the anatomy and function of the heart.

First, the valid and prime sources of Persian medicine, especially from the 9th to 12th century AD in Arabic or Persian languages using general keywords such as heart, anatomy, blood circulation, lungs, cavities, ventricles, atria, auricles, valves, arteries, and veins were screened. They included *Abu Sahl's* works *Tashrih-e Badan-e Ensan*, and *Al-Mia fil-Tibb* also, *Al-Hawi, Kamel al-Sana'a, Qanun fi al-Teb, Al-Aghraz fi al-Teb, Zakhireh Kharazmshahi, Sharh-e Tashrieh-e Qanun* (Commentary on Qanun's Anatomy)(13th cen-

tury) and *Tashrih al-Abdan* (14th century) from other famous Persian medicine scholars.
Reference medical books and articles related to the research topic were also collected from databases and reputable search engines such as PubMed, Google Scholar, ScienceDirect, SID, and UpToDate. Following this, the collected data underwent review, classification, and comparison from the perspectives of Persian medicine and conventional medicine.

Abu Sahl's viewpoint on heart anatomy

One of the famous works of *Abu-Sahl al-Masihi* is *Ezhar al-Hekmat Allah Ta'ala fi Khalgh al-Ensan* (Manifestations of God's Wisdom in the Creation of Mankind), which has been published in Iran under the title *Tashrih Badan al-Ensan* (Human Body Description) [22].
In this book, *Abu Sahl* first describes the structure of each body part and goes on to explain the benefits, shape, location, and function of each organ [17-22]. Compared with earlier scholars, *Abu Sahl's* detailed view and description of the various parts of the heart and their functions are remarkable. The topics covered by the book include the position of the heart, heart shape, parts of the heart, circulation, the association between the heart and lungs, heart cavities, blood, and the heart membrane [23]. This categorization was not previously used by other scholars [24-26].
What follows in this paper is a description of the heart by *Abu Sahl*, quoted from both *Tashrih badan al-Ensan* and *Al-Mia fi al-Teb*.

1-The Shape and Position of the Heart

According to *Abu Sahl*, the heart is spruce or cone-shaped and made of fibers that extend in different directions, thereby facilitating efficient contraction and expansion of the heart. He deemed these fibers harder than muscle and called them "*Shazaya*" [23].
Abu Sahl's predecessor, *Ali Ibn Abbas Ahvazi* has proposed similar propositions in *Kamel al-Sana'a* concerning the extension of the fibers in different directions [24].
Abu Sahl's analysis of why the heart is cone-shaped is very interesting:
"*On the base of the heart, there are ducts from which numerous vessels originate and in which a lot of vessels terminate. Consequently, this part should be larger than other parts. In the middle part of the heart only reside the ventricles; hence, the center is smaller than the base. Neither of these two (i.e., arteries and ventricles) exists at the apex. Its volume is thus smaller than the base or middle part. That is why the heart has attained a shape strangely similar to a cone*" [23].
He has explained that the heart is positioned in the middle of the chest with the apex inclined to the left [23,27]. This is a safe place for the heart, as it is secured by the lungs, rib cage, and spine. In addition, the space between the heart and the rib cage wall can protect it from external harm such as blows, heat, or cold. This space also helps preserve the natural heat of the heart [23]. *Masihi* does not get into detail on why the heart apex is inclined; while *Ahvazi*, before him, has attributed the divergence of the apex to the location of the vital spirit and the aorta originating from the left side [24].
Anatomic insights of conventional medicine fail to depict the rationale concerning the shape and position of the heart as described in Persian medicine.

2-Heart structure

Ventricles

The heart consists of two pumps, the atria, and ventricles, that are separated by a septum. The right pump receives oxygen-free blood and guides it to the lungs; while the left pump conducts oxygenated blood from the lungs to the entire body [28].
According to *Abu Sahl*, the heart consists of two *Tajvifs* or ventricles connected with small pores [23,27]. He states that the right chamber receives the blood that comes from the liver, on which the heart feeds. The left chamber is where the vital spirit is created.
Concerning the thickness of the left ventricle, he explains that "*The matter of the left side is heavier so that it can balance the weight of the blood accumulated in the right ventricle, and that the heart would not need to incline to the right from the center of the chest"* [23].
Previous physicians, including *Akhawayni* and *Ahvazi*, have also suggested, based on the ideas of Hippocrates and Galen, that there are two ventricles in the heart. They all believed that the blood resided to a greater extent in the right side of the heart and spirit or air mainly in the left side [24, 25,29].
Given modern findings about the heart, it seems that the viewpoints of Persian physicians regarding the two-chambered structure of the heart must have been based on heart function [30].
According to conventional anatomy, there is no connection between the blood in the right and left heart chambers except in the prenatal period. After birth, the closure of the foramen ovale prevents blood flow from the right atrium to the left atrium [28]. Nonetheless, *Abu Sahl* and his predecessors have pointed to subtle opening(s) between the two ventricles, whereby blood and spirit could transmit from the right to the left side of the heart and vice versa [23-25,27].

Auricles

Each atrium in modern medicine has its auricle. The left atrium, located on top of the left ventricle, plays a key role as a reservoir and conductor of blood to the

left ventricle [31]. The left auricle at the root of the pulmonary artery is a continuation of the left atrium and drives blood into the left ventricle. It acts as an adaptive chamber when blood volume increases [32].
The right auricle, which is sometimes referred to as the atrium proper due to originating from the early embryonic atrium, is a muscular, cone-shaped, ear-like sac. It encompasses the anterior space of the right atrium, which is located in the anterior and to the right of the heart, covering the ascending aorta from the outside. The right atrium and its auricle play important roles in conducting blood into the right ventricle [28].
Since Hippocrates, there have been discussions about two soft and hollow ear-shaped projections on both sides of the heart [29,33,34]. *Rhazes*, *Ahvazi,* and *Akhawayni* also recognized the auricles and had interpretations of their position and function [24-26,34]. *Ahvazi* believed that they were posited in the right ventricle at the junction with the arterial vein (Pulmonary artery) and in the left ventricle at the site of the venous artery (Pulmonary vein) [24]. *Akhawayni* also deemed that the arteries originated from the left auricle, and air transferred from this auricle to the lungs, and blood perfused through it to the organs. Blood was thought to enter the heart and the lungs from the right auricle [25].
Abu Sahl introduced the *Ozanein/Ozoni al-Qalb* or auricles as two thin, hollow, nervous (flexible and resistant to tearing and elongation) projections, located in the place where blood enters the right ventricle (*Vatin* or vena opening) and air enters the left ventricle (*Abhar* or aorta opening) [23,27].
He has specifically explained their function: *"Absorption of the blood from the liver on the right side and taking up the air by the lungs on the left side by the heart is very strong. If the heart receives them without a moderator, both the liver and lungs would tear up, especially when the heart abruptly absorbs a huge amount of each. This is because the amount of substances present in the liver and lungs is not equal to the amount that is absorbed. Therefore, because of the abstained nature of the vacuum, their tissue would get torn. Thus, there are two deep, thin, and nervous branches at the location where the blood and air from these two organs enter the heart, acting as a reservoir wherein these substances are first accumulated. Accordingly, the heart receives blood and air from a place where the pressure is moderated under the absorption capacity of the heart, especially in cases where the heart has to suddenly receive a large amount of blood or air at once"* [23].
Compared to recent anatomy, *Abu Sahl* did not explain anything about atria and their function. Thus, one may conclude that he considered atria and auricles as working under one united mechanism, emphasizing their role as a reservoir and conductor of air and blood to the two ventricles. This interpretation, compared with those of preceding scholars, is unique and can be compared to the function of these structures of the human heart, especially the left ones, in conventional medicine.
The perspective of scholars before *Masihi* in terms of the position of auricles corresponds to descriptions of modern anatomy, which holds that they are located at the entrance point of vessels into the atria [24,25,30].

Vessels and valves

Similar to scholars before him, *Abu Sahl* believed in four ducts associated with the right and left ventricles. Based on what he described, a vessel called "*Vatin*" conducts liver blood into the right ventricle; while another vessel transfers the blood and spirit from the heart to the lungs [23-27]. *Vatin* can be compared to the vena cava in conventional anatomy; while the latter is equivalent to the pulmonary artery [28].
Masihi points to a vessel on the left that carries the constituent essence of spirit (air) from the lungs to the heart [23]. The function of this vessel corresponds to pulmonary veins that transfer oxygenated blood to the left ventricle [28]. He eventually introduced the "*Abhar*" vessel that transfers blood and spirit to the whole body. This vessel is the aorta [23,27,28].
Based on what was discussed, it can be inferred that *Abu Sahl* was aware of the blood and air circulations between the heart and lungs similar to his predecessors [24,26,35].
Abu Sahl also described a multibranched membrane at the opening of the four vessels so that the flow of blood in or out of the heart is in one direction [23,27]. His interpretation of the reason for the existence of these membranes is very interesting and worthy of attention. Their function is similar to the role of cardiac valves including the tricuspid, mitral, and semilunar valves [28].
Regarding the vessel connecting the right ventricle and lungs, *Masihi* explained that *"the opening of the vessel that connects the ventricle to the lungs and evicts Dokhan (smoke) towards the lungs is covered and closed from outside with a membrane"* [27]. According to evidence from studies conducted on the history of Persian medicine, one can understand that Iranians had recognized pulmonary circulation before the settlement of Arabs in the land (before 637 AD). Therefore, it seems that *Abu Sahl* referred to this issue under the influence of the ancient Persian medical texts, unlike others who cited Greek texts [36,37]. Based on conventional medicine, the expulsion of smoke from the heart towards the lungs is comparable to the excretion of carbon dioxide from venous blood under pulmonary circulation [38].
As for the arteries that originate from the heart and

transfer blood and vital spirit, *Abu Sahl* mentioned that their tissue is nearly six times thicker than that of the veins, explaining that *"the blood in the veins is thick, heavy, and slow-moving. If the vein wall is not thin, the blood cannot easily penetrate organs. In contrast, the content of arteries is thin and warm blood and gentle spirit. If artery tissue were not thick and dense, the tissue would tear apart, the spirit scatters, and blood leak quickly"* [23].

Modern anatomy recognizes that the three-layered walls of arteries and veins are different in terms of thickness. Specifically, the middle layer, which is composed of smooth muscle, is thicker in arteries than in veins [39].

Abu Sahl's interpretation of heart vessels is unique compared to those of previous Persian scholars and is comparable to the anatomy of blood vessels in modern medicine.

Membrane

The pericardium is a two-layered, fibroserous sac that covers and protects the heart and vascular roots [28]. Persian medical scholars such as *Masihi* have pointed to a one-layer peritoneal membrane covering the heart that is distinctive and separated from the heart body except at the base. The membrane has been proposed to protect the heart against harm [23-27].

3- Movements of the Heart

After *Abu Sahl* described heart anatomy in detail, he explained that no organ works more consistently, harder, or faster than the heart because the heart is always in motion, expanding or contracting. In contrast, lung movement is slower and has noticeable lags. He also mentioned that heart movements are almost five times the respiratory system [23].

Based on the search findings, it appears that the typical pulse-respiration quotient (PRQ) at rest in healthy adult humans is approximately 4, and, in children aged 6 to 12 years. This ratio typically falls within the range of approximately 4.5 to 5 during nighttime sleep. Nonetheless, it's essential to acknowledge that the PRQ may fluctuate based on elements like body position and breathing pattern [40-42]. As evident, the ratios mentioned by *Abu-Sahl* closely resemble recent research findings. His in-depth analysis of the movements of the heart is therefore unprecedented in comparison with his predecessors.

Conclusion

This paper briefly introduced *Abu-Sahl al-Masihi*, his works, and some aspects of his description of the heart. Much of what he offers in *Al-Mia fil-Tibb* and *Tashrih badan al-Ensan* is compatible with conventional medicine. In some cases, such as the biventricular structure of the heart, the pores between them, the relationship between the heart and lungs, and the multibranched membrane at the opening of the vessels, his commentaries resemble those of his predecessors.

Masihi's analytical descriptions of the position of the heart in the chest, its conical shape, the two ventricles explanations, the interpretation of auricles function, the difference between heart and lung movements, and the comparison of the thickness of the arteries and veins wall can be considered unique and innovative (Table 1).

Table 1. Abu Sahl's unique description of the heart compared to his predecessors

	Parts	Abu Sahl′s point of view	Similar to predecessors	Being unique
Heart Description	Shape	Spruce or cone-shaped	+	The reason for the conical shape of the heart
	Position	In the middle of the chest with the apex inclined to the left	+	-
	Ventricles	Two ventricles connected with pores	+	The reason for the imbalance of two ventricles weights
	Auricles	Two thin, hollow, nervous projections	+	Auricles function as reservoirs and conductors of air and blood
	Vessels	Two vessels connect to each chamber of the heart	+	The difference between the wall thickness of arteries and veins
	Valves	Multiple-branched membrane over the entrance of the vessels	+	Valves function in directing the blood flow
	Membrane	One-layer membrane separated from the heart except at the base	+	-
	Movement	The heart can move consistently, harder, and faster than the other organs	-	The difference between heart and lung movement ratio

It is not clear why *Abu Sahl* and his works have remained unknown and why his books have not been translated into other languages. However, based on

his writings, and his profound comments and interpretations of medical topics, traditional medicine researchers and those interested in the history of medicine need to collect, translate, and modify *Abu Sahl*'s works to obtain valuable findings and contribute to medical science. Studies can also pave the way for other researchers to utilize his propositions.

Conflict of Interests
None.

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References
[1] Masic I. On occasion of 800th anniversary of birth of Ibn al-Nafis-discoverer of cardiac and pulmonary circulation. Med Arh 2010;64:309-313.
[2] Emami Meybodi M. The views of muslim scholars in anatomy. Meshkat 1994;43:69.
[3] Martins E, Silva JA. The influence of gondeshapur medicine during the sassanid dynasty and the early islamic period. Arch Iran Med 2019;22:531-540.
[4] Nayernouri T. A brief history of ancient Iranian medicine. Arch Iran Med 2015;18:549.
[5] Sadeghi S, Ghaffari F, Alizadeh M. Al-Masā 'il fī al-tibb: Ḥunain ibn Isḥāq's historic medical text with a distinctive style of Islamic medical education. J Med Biogr 2021;29:29-34.
[6] Sadat Mahmoudi Nezhad G, Dalfardi B. Rhazes (865–925AD), the icon of Persian cardiology. Int J Cardiol 2014;177:744-747.
[7] Dalfardi B, Nezhad GSM, Mehdizadeh A. How did haly abbas look at the cardiovascular system? Int J Cardiol 2014;172:36-39.
[8] Yarmohammadi H, Dalfardi B, Rezaian J, Ghanizadeh A. Al-Akhawayni's description of pulmonary circulation. Int J Cardiol 2013;168:1819-1821.
[9] Zarshenas M, Zargaran A. A review on the Avicenna's contribution to the field of cardiology. Int J Cardiol 2015;182:237-241.
[10] Zargaran A, Mehdizadeh A, Zarshenas MM, Mohagheghzadeh A. Avicenna (980–1037 AD). J Neurol 2012;259:389-390.
[11] Taghavi-Shirazi M, Ghods R, Hashem-Dabaghian F, Zargaran A. Abu-Sahl al-Masihi (died circa 1010 AD): The Persian physician in the early medieval era. J Med Biogr 2020;28:132-135.
[12] Afshar A. The discourse of medicine in the Čahār Maqāla (Four Discourses) of Nezami Aruzi of samarghand. Arch Iran Med 2015;18:618-620.
[13] Owjabi A. Zahir-al-din Bayhaqii, the author of tatemmat sewan al-hekma. Philosophy Book of the Month 2008;15:75-82.
[14] (2016, August 09). Tahoor Encyclopedia, A Brief History of Nations. Available: http://tahoor.com/en/Article/View/118846
[15] Dehqan M, Chelongar MA. The flowering of islamic medicine during the fatimid caliphate in Egypt. J Res Hist Med 2014;3.
[16] Hilloowala F. An analysis of Ibn Abi Usaybi`ah's `Uyun al-anba' fi tabaqat al-atibba'," USA: The University of Arizona. 2000;8.
[17] Keramati Y. Abu Sahl Masihi," in The Great Islamic Encyclopedia, Vol. 5, K. Musavi Bojnurdi, Ed. Tehran: The center for the great Islamic Encyclopedia, 2006, pp 574-579.
[18] Tadjbakhsh H. Abu Sahle Masihi," in History of Veterinary medicine and medicine of Iran, Vol 2, Tehran: University of Tehran Press2000; pp 229-230.
[19] Velayati A. Abu Sahl Masihi. in The Medical Encyclopedia of Islam and Iran. Vol 1. Amir Kabir Publication Company 2011; pp 475-481.
[20] Karmi G. A mediaeval compendium of Arabic medicine: Abu Sahl al-Masihi's. Book of the Hundred. J Hist Arabic Sci 1978;2:270-290.
[21] Nezami Aruzi Samarqandi A. Chahar-Maghaleh (Four Discourses). Eshragi publications. Tehran.
[22] Esfahani M. Introduction of Tashri Badan al-Ensan. Iran University of Medical Sciences Tehran. Research Instiute for Islamic and Complementary Medicine. 2008; p 3.
[23] Masihi A, Tashri Badan al-Ensan. Iran University of Medical Sciences, Research Instiute for Islamic and Complementary Medicine. Tehran 2008.
[24] Majusi Ahvazi A. Kamil al Sinaat al-Tibbiyya. Vol 1. Jalaleddin. Tehran 2008.
[25] Akhawayni R. Hedayat al-Motaallemin fi Tebb. University of Mashhad. Mashhad 1992.
[26] Rhazes. Al-Mansouri fi al-Tibb. Tehran University of medical sciences. Tehran 2008.
[27] Masihi A. Kitab al-Mia fil-Tibb. Iran University of Medical Sciences, Research Instiute for Islamic and Complementary Medicine. Tehran 2008.
[28] Drake R, Vogl A, Mitchell A. Gray's Anatomy for Students. 4th ed. Churchill Livingstone Canada 2019.
[29] Mavrodi A, Paraskevas G. Morphology of the heart associated with its function as conceived by ancient Greeks. Int J Cardiol 2014;172:23-28.
[30] Amini Behbahani FA, Emamdjomeh H, Nazem E, Keshavarz M. Different views of the heart in traditional medical sources. Int J Cardiol. 2012;158,433-434.
[31] Blume GG, McLeod CJ, Barnes ME, Seward JB, Pellikka PA, et al. Left atrial function: physiology, assessment, and clinical implications. Eur Heart J Cardiovasc Imagin. 2011; 12:421-430.
[32] Syed FF, DeSimone CV, Friedman PA, Asirvatham SJ. Left atrial appendage exclusion for atrial fibrillation. Cardiol Clin 2014;32:601-625.
[33] Bestetti RB, Restini CBA, Couto LB. Development of anatomophysiologic knowledge regarding the cardiovascular system: from egyptians to harvey. Arq Bras Cardiol 2014;103:538-545.
[34] Abdoli M, Mahlooji K, Mozaffarpur SA, Zargaran A. The cardiac auricles. Eur Heart J 2017;38:313-314.
[35] Firouzi Bostanabad R, Zargaran A, Ghods R, Asghari M, Nojavan F, et al. Heart history taking and physical examination from the perspective of Persian medicin. J Islam Iran Tradit Med 2018;9:135-142.
[36] Zargaran A, Zarshenas M. Discovery of the pulmonary circulation in ancient Persia. Eur Heart J 2016;37:1491-1492.
[37] Zargaran A. Pulmonary circulation discovery before Ibn Nafis-Ancient persian and greek theories: a narrative review. JAMA Cardiol 2022;7:105-107.
[38] Hall JE, Hall ME. Guyton and Hall Textbook of Medical Phys-

iology. 14th ed. Elsevier USA 2020.
[39] Rizzo D. Fundamentals of Anatomy and Physiology. Cengage Learning. USA 2015; p 344.
[40] Scholkmann F, Wolf U. The pulse-respiration quotient: A powerful but untapped parameter for modern studies about human physiology and pathophysiology. Front Physiol 2019;10:371.
[41] Scholkmann F, Zohdi H, Wolf U. The resting-state pulse-respiration quotient of humans: Lognormally distributed and centred around a value of four. Physiol Res 2019;68;1027-1032.
[42] Matić Z, Kalauzi A, Moser M, Platiša MM, Lazarević M, et al. Pulse respiration quotient as a measure sensitive to changes in dynamic behavior of cardiorespiratory coupling such as body posture and breathing regime. Front Physiol 2022;13:946613.