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ANATOMO-HISTOLOGICAL ASPECTS OF THE CORONARY ARTERIES IN PIGS (SUS SCROFA)

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Abstract

Compared to known anatomical data, we appreciate that our observations underline certain particularities of the coronary arteries and their superficial and deep branches in the pig. The study was conducted in the Department of Comparative Anatomy of the USAMV Cluj-Napoca, in collaboration with the Department of Histology and Embryology of Veterinary Medicine Bucharest, on 4 pig hearts samples. The clinically healthy animals aged between 2 to 4 months were commercially slaughtered by bleeding. The hearts were collected with their vessels intact. Using step-by-step dissection techniques we have harvested the 4 hearts, and in two of them we have underlined the origins of the left and right coronary arteries to inject them with a coloring agent (PALUX and red pigment), and the other two hearts were harvested for histological processing. After injecting the coloring agent in the coronary arteries the two hearts were submerged in a 10% formalin solution over a period of 24 hours, to fixate. Histological processing comprised the following steps: sample harvesting, fixation, wash, dehydration, paraffin inclusion, cutting, paraffin removal, hydration, coloring, clarification and mounting. Aside from the deep branches of the superficial coronary arteries, both the paraconal artery, the circumflex artery and the right coronary artery give off direct deep branches for the myocardium and for all of the papillary formations of the atria and ventricles. The histological aspects of the left and of the right coronary arteries are. The elastic fiber density increases with age, and the fibers are more numerous in the external half of the tunica media. In younger ages, the coronary arteries have a muscular type aspect and they present a tendency to become musculo-elastic arteries along with the ageing. The elastin is produces by the smooth muscle fibers of the internal layer of the tunica media, but also by the fibers of the adventitia, situated at the border with the tunica media.

Key words*: coronary arteries, pig, histological processing, pallux.*

INTRODUCTION

Morphologically and functionally, the circulatory system is composed of two inextricably linked components: blood and lymph. Highlighting the blood circulatory system is easier because the administration of identifying substances can be done directly in their lumen, unlike lymphatic vessels that require prior identification using intra vitam dye solutions such as Evans blue (Stan F. 2008, 2014). Both components of the circulatory system can be identified in vivo using non-invasive methods, namely ultrasound, specifically using Doppler techniques, which are suited even for lymph nodes (Stan F. 2010).
In terms of blood supply, we could say that the heart is the domain of violated rules. It is a structure in which there are exceptions to every rule governing the local phenomena. Here, individual variability of the vascular distribution may be responsible for the limit between life and death, maybe more than in any other organ. The recent years have seen several technological advances in arterial assessment. Taking into account that the pig heart is very similar with the human heart, these experiments help bring new techniques for solving various cardiac problems. Literature data on coronary arteries were achieved very thoroughly, taking into account multiple artery origin variations (Wernaeky quoted by Agneoletti et al., 2005), and anatomical particularities of human blood vessels (Pop D. Popa, 1982).

MATERIALS AND METHODS

This study aimed to highlight certain particularities of the coronary system in pigs and it was performed in two stages.
The first stage took place in the Comparative Anatomy Department of the University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca, using stratigraphic dissection techniques to open the aortic bulb and identify the orifices of origin of the left and right coronary arteries. A catheter was placed in the lumen of the coronary arteries, and they were injected with the product PALLUX, colored with a red pigment. After injecting the coloring agent, the hearts were submerged in a 10% watery formaldehyde solution, in order to fixate them. The dissection was performed 24 hours later, gradually taking segmental photographs.
The second stage was performed in the Cellular Biology, Histology and Embryology of the University of Agricultural Sciences and Veterinary Medicine of Cluj-Napoca. The research was performed on samples of left and right coronary arteries from pigs of various ages. The harvesting was performed immediately after the euthanasia of the animal by exsanguination and the anatomical dissection. Histological processing required compulsory steps such as: sampling, fixation, washing, paraffin inclusion, cutting, staining. The staining techniques used in our histological study were: Hematoxylin-Eosin staining, Orcein staining and Mallory staining.

RESULTS AND DISCUSSIONS

Anatomical aspects:

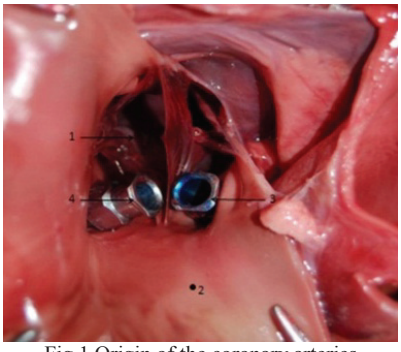

Fig.1.Origin of the coronary arteries

1. Aortic orifice of the left ventricle and sigmoid cusps; 2.Aortic bulb - opened - and sinuses of the primary aorta; 3.Left aortic sinus and orifice of origin of the left coronary artery; 4.Anterior aortic sinus and orifice of origin of the right coronary artery.

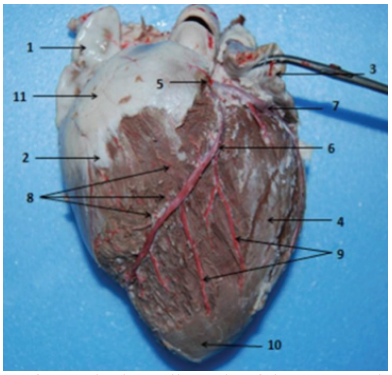

Fig.2. Left ventricular collaterals of the paraconal artery 1.Right atrium; 2.Right ventricle; 3.Left atrium; 4.Left ventricle; 5.Left coronary artery; 6.Paraconal artery (left interventricular artery); 7.Left circumflex artery; 8.Right ventricular collaterals; 9.Left ventricular collaterals (diagonal arteries); 10.Apex of the heart.

Fig.3. Terminal apical branches of the paraconal arteries 1.Left ventricle; 2. Apex of the heart; 3.Terminal segment of the path of the paraconal artery; 4.Terminal apical branches of the paraconal artery; 5.Apical region of the right ventricle.

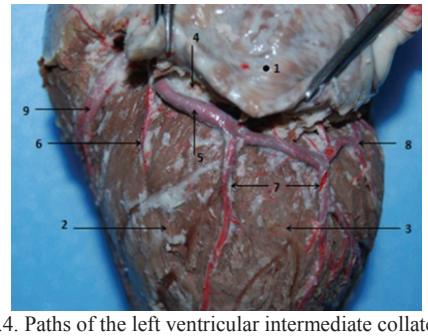

Fig.4. Paths of the left ventricular intermediate collateral arteries
1.Left atrium; 2.Left ventricle – lateral side; 3.Left ventricle - caudal border; 4.Left atrio-ventricular groove; 5. Left circumflex artery; 6.Basilar collateral branch of

the left ventricle; 7.Paths of the ventricular intermediate collateral arteries; 8.Terminals of the left circumflex artery; 9.Paraconal artery.

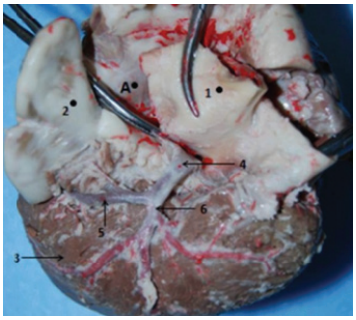

Fig.5. A - Anatomical aspect of the base of the heart
1.Aorta - region of the aortic bulb; 2.Right atrium (lifted); 3.Base of right ventricle; 4.Origin of the right coronary artery; 5.Path of the right coronary artery in the atrio-ventricular groove; 6.Birufcating branch of the right coronary artery.

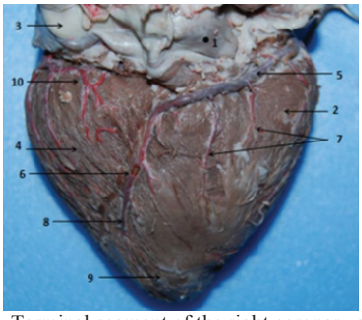

Fig.6. Terminal segment of the right coronary artery
1.Rigth atrium; 2.Right ventricle; 3.Left atrium; 4.Left ventricle; 5.Right coronary artery; 6.Descending interventricular branch of the right coronary artery; 7.Ventricular collaterals; 8.Temrinal segment of the right coronary arterial path; 9.Region of the heart's apex; 10.Terminals of the left circumflex artery.

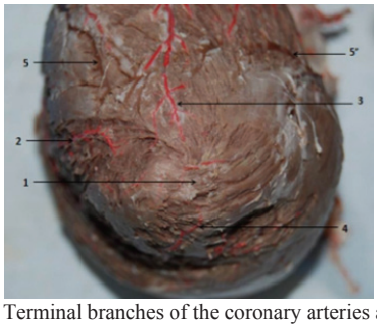

Fig.7. Terminal branches of the coronary arteries and of their collateral for the apical region of the heart.
1. Apex of the heart; 2.Terminales of the paraconal artery; 3.Branches of the intermediary (marginal) collateral arteries of the left circumflex artery; 4.Terminal branches of the right coronary artery; 5, 5'. Roots of the cardiac veins.

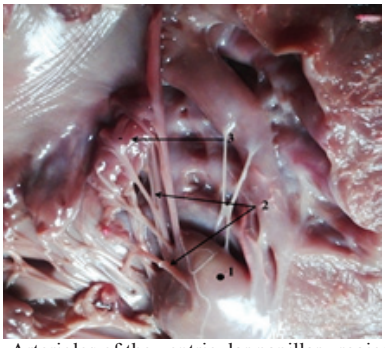

Fig.8. Arterioles of the ventricular papillary region and of the atrio-ventricular cusps
1.Ventricular papillary muscle; 2.Papillary and cuspidal arterioles; 3.Atrio-ventricular cusp.

Histological aspects:

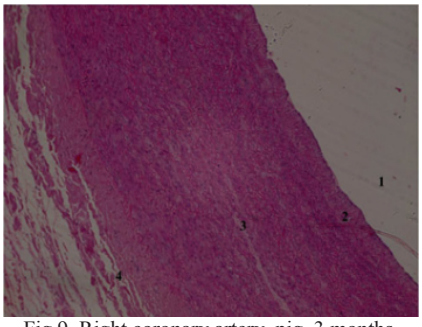

Fig.9. Right coronary artery, pig, 3 months, Hematoxylin-Eosin stain, ob. 10x.
1-lumen; 2-endothelium; 3-media; 4- adventitia
The media presents a dense juxtalumenal layer and a peripheral lesser dense layer, which is continued by the adventitia without any observable delimitation. No observable internal and external laminae.

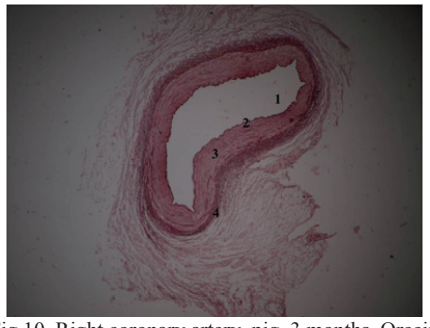

Fig.10. Right coronary artery, pig, 3 months, Orcein stain, ob. 10x.
1-lumen; 2-endothelium; 3-media; 4- adventitia

Observable agglomeration of elastic fibers at the limit between the media and the adventitia, which can be interpreted as the future external lamina.

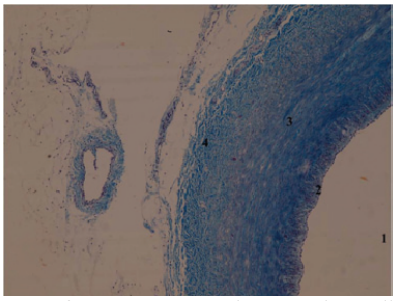

Fig.11. Left coronary artery, pig, 4 months, Mallory stain, ob. 10x.
1-lumen; 2-endothelium; 3-media; 4- adventitia
The adventitia presents a lymph vessel with an endothelial valve. Smooth muscular fibers predominate in the internal layer of the media, while conjunctive fibers are more numerous in its external layer.

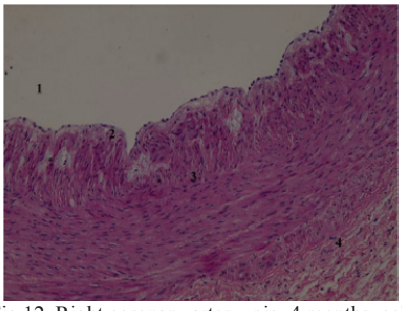

Fig.12. Right coronary artery, pig, 4 months, col. Hematoxylin-Eosin, ob. 20x.
1-lumen; 2-endoteliu; 3-media; 4- adventitia;
The endothelial nuclei appear very prominent. The subendothelial layer is poorly delimited. The media presents two layers of smooth muscular fibers. The internal (juxtalumenal) layer presents muscular fibers cut transversally or obliquely. At its periphery, the muscular fibers appear longitudinally cut.

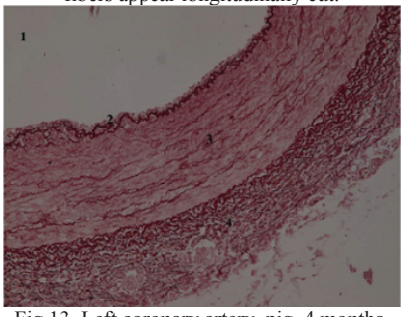

Fig.13. Left coronary artery, pig, 4 months, Orcein stain, ob. 20x
1-lumen; 2-endoteliu; 3-media; 4- adventitia;
Internal elastic lamina. Observable distribution of elastic fibers, which occupy the external layer of the media.

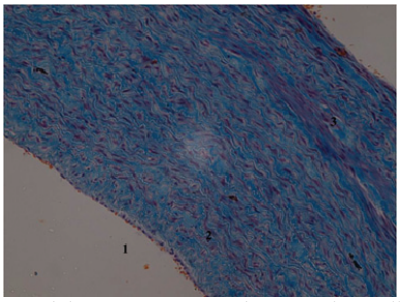

Fig.14. Right coronary artery, pig, 3 months, Mallory stain, ob. 20x.
1-lumen; 2-endoteliu; 3-media;
Observable muscular fibers and endothelium. In the external half of the media, the muscular fibers nuclei are more numerous. No observable elastic laminae.

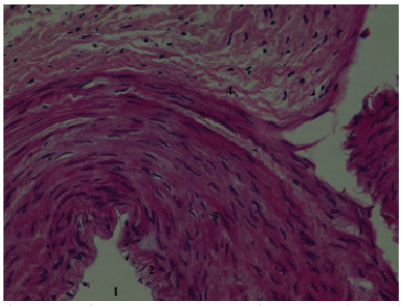

Fig.15. Left coronary artery, pig, 4 months, col. Hematoxylin-Eosin, ob. 40x.
1-lumen; 2-endothelium; 3-media; 4- adventitia.
Detail of the left coronal artery wall. Smooth muscle fibers predominate in the tunica media. The tunica adventitia presents rare conjunctive tissue nuclei (fibroblasts).

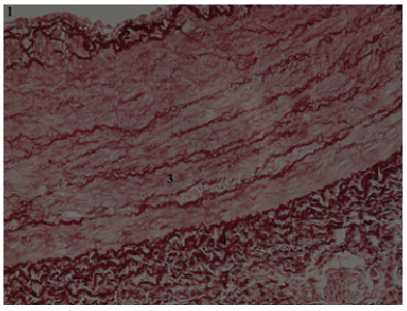

Fig.16. Left coronary artery, pig, 4 months, Orcein stain, ob. 40x.
1-lumen; 2-endothelium; 3-media; 4- adventitia
Observable distribution of the elastic fibers, which occupy the external layer of the tunica media.

CONCLUSIONS

During the dissection of the coronary vessels, we avoided the total removal of the

subepicardial adipose tissue, which was extremely abundant and adhesive to the blood vessels. This anatomical aspect represents a natural and physiologic particularity in this animal species.

Anatomical aspects:

Right coronary artery:

1. The right coronary artery emits numerous and strong deep collaterals for the right ventricle.
2. The branches of the right coronary artery are fewer in number and have a smaller caliber. Their paths are aproximatively straight and ascending.
3. The deep collateral arteriolar branches split into a arteriolar-capillary network; the vessels of this network have a parallel arrangement.
4. The manner of distribution of the subendocardial arterioles in the ventricular papillary muscles is particular. The arterioles continue their path towards the atrio-ventricular cusps, accompanying the chordae tendineae.

Left coronary artery:

1. The left coronary artery emits collateral arterioles for the side adjacent to the base of the pulmonary arterial trunk and one or two arterioles for the left medial atrio-auricular wall;
2. At the level of the terminal split into the paraconal artery and the circumflex artery, there is a strong deep collateral artery for the left ventricular myocardium.
3. The deep collateral artery traverses medially the great cardiac vein.
4. The paraconal artery emits numerous collateral arterioles for the right ventricular myocardium. We consider that, in respect to the lack of this type of collaterals on the paraconal path, these particular arterioles also service the left ventricle; we have identified only one arteriole excepted from this.
5. The apex terminals of the paraconal artery emit deep arterioles for the trabeculae carnae of the area corresponding to both of the ventricular cavities.
6. Numerous deep arterioles with a perpendicular latero-medial path stem from the medial sides of the superficial diagonal collaterals of the left ventricle.
7. Numerous deep arterioles stem from the superficial collaterals of the circumflex artery.
8. The circumflex artery emits numerous deep collaterals for the atrium.

Histological aspects:

1. The left and right coronary arteries have similar histological aspects.
2. The frequency of the elastic fibers increases with age, being more numerous in the external half of the media.
3. At younger ages, the coronary arteries have the aspect of a muscular artery type, with the tendency to become musculo-elastic arteries as the animal ages.
4. The elastin is produced both by the smooth muscle fibers of the internal layer of the tunica media and by the fibroblasts situated in the adventitia, at the limit with the media.

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REFERENCES

Amălinei C., 2005. Aparatul cardio-vascular, Histologie specială. Ed. Junimea, Iaşi, p. 7-28.

Bacha J. Jr., Wood L. M., 2000. Color atlas of veterinary histology. Lea and Febiger, Beckembaum, 2nd ed.

Barone R.,1996. Angiologie. In: Anatomie comparée des mammifères domestiques. Vigot Frères, Paris, 5: 5-443.

Braunwald E., Libby P., Bonow RO., Mann DL., Zipes DP., 2008. Braunwald's heart disease. A text book of cardiovascular medicine. 8th edition.

Carp C., 2002. Tratat de cardiologie. Editura Academiei Romane, Bucureşti.

Chirilean I., 2006. Studiu morphologic al sistemului arterial coronarian la câine (Canis familiaris). Teză de doctorat, USAMV Cluj-Napoca, Facultatea de Medicină Veterinară.

Cornilă N., 2001. Morfologia microscopică a animalelor domestice (cu elemente de embriologie). vol.II, Ed. BicALL, Bucureşti.

Cotea C., 2004. Biologie celulară, Embriologie generală, Histologie generală. Ed. Tehnopress, Iaşi.

Coţofan V., Palicica R., Carmen Ganla, Hrilcu V., Enciu V., 2000. Anatomia animalelor domestice. Vol.III., Editura Orizoturi Universitare, Timişoara.

Damian A., 2001. Anatomie comparată - sistemul cardiovascular. Editura Academicpres, Cluj-Napoca.

Damian A., Miclăuş V., Melania I., Crişan, Irina Irimescu, Rus V., Tuns F., 2014. The structural features os several large arteries in pigs. Anatomia Histologia Embryologia, Vol. 43, Supplement 1 July, John Wiley & Sons Inc., C/O The Sheridan Press, Hanover.

Falcoz PE., Chocron S., Binquet C., et al, 2005. Revascularization of the right coronary artery: grafting or percutaneous coronary intervention. Ann Thorac Surg, 79:1232-1239.

Ganţă C.V., 2000. Particularităţi morfologice ale orificiilor atrioventriculare la mamifere şi păsări. Conferinţa naţională de Biotehnologie şi ingineria mediului. Universitatea Valahia, Târgovişte, 350-352.

Ghetie V., Bica Popii O., Chitescu St., Nicolescu V., Oprisescu V., Balanescu Fl., 1967. Anatomia animalelor domestic. Ed. Didactica si Pedagogica, Bucuresti, pg. 467, 468 - 503.

Ginghina C., 2010. Mic Tratat de Cardiologie. Editura Academiei Romane.

Junqueira L.C. & Carneiro J., 2004. Histologia Básica. 10 ed. Rio de Janeiro: Guanabara Koogan.

Kazzaz D., and Shanlin W., 1950. The Coronary Arteries of the Dog demonstrated by Vinyl Acetate Injections and Corrosion. Anat. Rec., 107-43.

Miclăuş V., 2012. Biologie celulară şi histologie generală. Ediţia a II-a revizuită. Ed. Risoprint, Cluj-Napoca.

Mirancea N., Mirancea D., 2010. Ultrastructura celulelor şi ţesuturilor. Editura Ars Docendi, Universitatea Bucureşti, 703 pagini, ISBN 978-973-558-520-4.

Mogoanta L., Popescu C.F., Georgescu C.V., Comanescu V., and Pirici D., 2007. Ghid de tehnici de histologie si imunohistochimie. Editura Medicala Universitara, Craiova.

Mureşan E., I. Pamfilie, O. Bica Popii, C. Radu, 1979. Anatomie, histologie, embriologie. Ed. Didactică şi Pedagogică, Bucureşti.

Olivey H.E., Compton L.A., and Barnett J.V., 2004. Coronary vessel development: the epicardium delivers. Trends Cardiovasc. Med. 14, 247-251.

Papilan V.V., 1977. Tratat elementar de histologie. Cluj-Napoca, vol. I şi II.

Paştea E., 1975. Anatomia, histologia şi embriologia animalelor domestice, vol. I-II, A.M.D. Institutul Agr., Bucureşti.

Philippe F., 2002. Coronarographie et Angioplastie Coronaire, Masson.

Popovici I., Damian A., Popovici N.C., Chirilean I., 2000. Anatomie comparată - Angiologie. Ed.Genesis, Cluj-Napoca, pg. 39 – 47.

Predoi G., Belu C.. 2001. Anatomia animalelor domestic, Ed. All, Bucureşti.

Ropers D., Moshage W., Daniel Wg., Jessl J., Gottwik M., and Achenbach S., 2001. Visualization of coronary artery anomalies and their anatomic course by contrastenhaced electron beam tomography and three-dimensional reconstruction. Am J Cardiol,87: 193-197.

Sisson S., Grossman J.D., 1964. The Anatomy of The Domestic Animals - Fourth Edition, revised, Philadelphia and London, W.B. Saunders Company, pg. 756.

Stan F., 2008, Aspecte morfologice privind vascularizaţia limfatică al glandei mamare la cătea, Lucrări Stiintifice Universitatea de Stiinte Agricole Si Medicină Veterinară "In Ionescu De La Brad" Iasi 2008, vol 51(10) Medicină Veterinară partea 1/2 p.177-182.

Stan F., 2014, Morphological study of lymphatic drainage and lymph nodes of mammary glands in doe. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Veterinary Medicine*, 71*(1), 213-219.

Stan Florin Gheorghe, 2010,Power Doppler ultrasonography vs. Color Doppler of the Sentinel Lymph Node of Mammary Glands at Female Dog, Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Veterinary Medicine*, 67 (1)*, p. 298-304.

Stern H., Ranzenhofer E.R., and Liebow A., 1989. Preparation of Vinyl Casts of the Coronary Vessels and Cardiac Chjambers. J. Lab. Invest., 3:337.

Tuns Flaviu Mircea, 2014. Evaluarea morfologică şi imagistică a aspectelor adaptative ale aortei ascendente şi trunchiului arterial pulmonar la porc. Teză doctorat. Cluj-Napoca.

X X X, 2005. Nomina Anatomica Veterinaria. Fifth Edition, General Assembly og the World Association of Veterinary Anatomists, Knoxville, U.S.A.

Zărnescu O., 2012, Histologie animală generală, Editura Universităţii din Bucureşti, 326 p. ISBN: 978-606-16-0141-7.