

## Blood supply of the papillary muscles of the left ventricle of the dog's heart (*Canis familiaris* – L. 1758)

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### Abstract

The irrigation of the papillary muscles, has incomplete information on the distribution of the arterial vessels. Objectifying to establish the origin of these arteries and their distribution in the left ventricle papillary muscles, we used 30 hearts of adult, male and female mongrel dogs. After the death, the heart was removed, washed and injected through the left coronary artery opening with an acetate solution of stained vinyl, neoprene latex 650 colored or 10% gelatin. The papillary muscles in all the applied techniques had been fixed with 10% formaldehyde solution. The dissection was carried out with the aid of a 40% sulfuric acid solution. For accomplishment of the radiography, we used mercury injection what assisted the assembly of the studied vascularization projects. Clearing technique of Spalteholz was applied for better visualization of the cardiac irrigation. We evidenced that the subauricular and subatrial papillary muscles are irrigated by the left coronary artery branches. The subauricular papillary muscle was blood-supplied by the interventricular paraconal and circumflex branches and the subatrial papillary muscle mainly by the circumflex branch. The sub-segments that supply the subauricular papillary muscle from the interventricular paraconal branch are the left collateral and ventricular branches and from the circumflex branch: left dorsal branches and intermedial (left ventricular marginal) and rarely from the left ventricular ridge (diaphragmatic branch). The subsegments of the circumflex branch that supply the subatrial papillary muscle are: intermedial (left ventricular marginal), from the left ventricular ridge (diaphragmatic branch), right dorsal branches and subsinuuous interventricular branch. In some cases we observed the collateral branch and the proper interventricular paraconal branch reaching the portion of the vertex of the subatrial papillary muscle.

### Key words:

Irrigation. Muscles. Papillary. Dogs.

### Introduction

Our study to concern the irrigation of the dogs' left ventricle papillary muscles. Papillary muscles are the structures of insertion of chordae tendineae from the left atrioventricular valve (Mitral valve) which is commonly involved by pathological processes reflecting on its function. The identification of the vascular behavior is

relevant not only for surgical approaches, but also provides morphological knowledge which can be eventually analog to humans. The papillary muscles are *conical projections into the left ventricle outflow tract* – where the chordae tendineae (*fiber-muscular chords between atrioventricular valves and the papillary muscles apexes*)<sup>1</sup> are attached.

This study was carried out using dogs because these are elected experimental model

mainly for cardiovascular morphologic-physiological investigation therefore, we managed to carry on macroscopical analyses of cardiac blood supply promoted by the left coronary artery, with the aid of Vinyl Acetate, Neoprene Latex and Gelatin injections, followed by corrosion, dissection or clearing techniques, preserving the left ventricle papillary muscles through formaldehyde solution. Contrast radiographies (mercury injection) were taken to assist the interpretation of the left ventricle papillary muscles blood supply.

Medical literature survey on papillary muscles blood supply is not scarce, as shown by Henle<sup>2</sup>, Spalteholz<sup>3</sup>, Pianetto<sup>4</sup>, Lücke<sup>5</sup>, Bellman and Frank<sup>6</sup>, Smith<sup>7</sup>, James<sup>8</sup>, Duran and Gunning<sup>9</sup>, Ranganathan and Burch<sup>10</sup>, Muti and Tavormina<sup>11</sup>, Madjarova<sup>12</sup>, Wiisten et al.<sup>13</sup>, Carvalho<sup>14</sup>, Di Dio and Rodrigues<sup>15</sup>, Weaver et al.<sup>16</sup>, Hammer<sup>17</sup>, Evans<sup>18</sup>, Piras et al.<sup>19</sup>, International Committee on Veterinary gross Anatomical Nomenclature<sup>1</sup>, Crick et al.<sup>20</sup> (1998), Taylor and Taylor<sup>21</sup>, Nair et al.<sup>22</sup>, Jensen, Fontaine and Yoganathan<sup>23</sup>, Teixeira-Filho et al.<sup>24</sup>, Souza<sup>25</sup>, Di Dio and Jatene<sup>26</sup> and Menicanti et al.<sup>27</sup>. Our study focused the *Canis familiaris* species, drawing the left coronary artery branches which supply specifically the left ventricle papillary muscles (Figure 1).

## Material and Method

Thirty hearts of mongrel adult dogs (*Canis familiaris*), males and females, of undetermined ages, weighing between 4 and 27 kg, were supplied by the Zoonoses Centre were used in our study. Thorax opening and heart removal were pursued by cutting: the pulmonary vessels next to the heart, the cranial cava and caudal veins about 1cm to the right atrium and ascending aorta next to its arch. The hearts were then submerged into a 35°C saline solution with heparine (10ml/l to prevent clot formation) and were pressed to remove blood residues. Dissection started sectioning the aorta longitudinally to evidence the left coronary

artery opening, which was canalized with polyethylene drill, to apply the following techniques:

**RADIOGRAPHY:** Radiographies were taken after injection of Acetone and Mercury through the polyethylene drill (Figure 2). All the hearts had been radiographed, to follow the same one had been submitted the excessive techniques (ten in each).

**VINYL ACETATE ARTERIAL MODELING:** Through the drill, were injected Acetone, stained Vinyl Acetate (Vinilite<sup>®</sup>) diluted into Acetone. Each segment of the left coronary artery was filled with a different color (Fig. 3). The heart was then cooled and dissected, with the aid of 40% sulfuric acid fixing only the left ventricle papillary muscles.

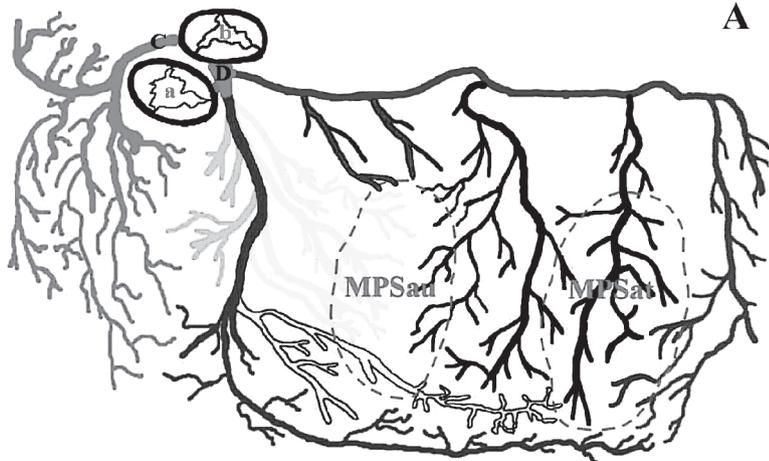
**NEOPRENE LATEX ARTERIAL MODELING:** Following the technique applied on the previous procedure, we injected stained Neoprene Latex 650 diluted into water. In the same way, hearts were cooled and dissected.

**CLEARING FOR SPALTEHOLZ TECHNIQUE:** After the injection of Acetone and 10% Gelatin, the hearts were cooled, then were fixed into 10% formaldehyde solution, water-washed, and dehydrated on ethanols series and thus, cleared according to technique of Spalteholz (Figure 2).

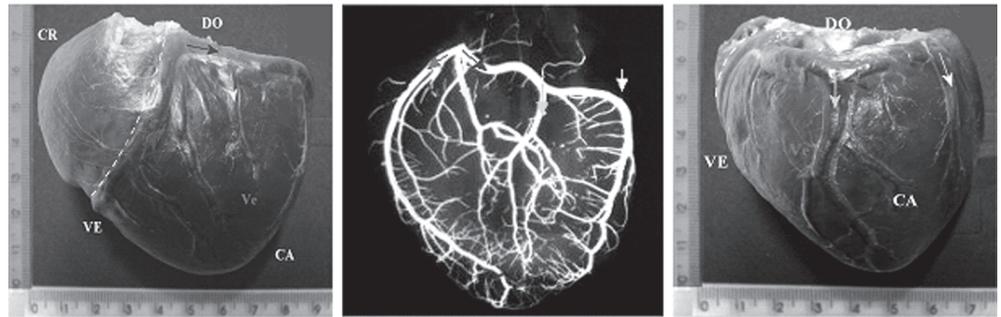
These techniques were pursued to illustrate and identify the branches of the left coronary artery that supplies the left ventricle papillary muscles. The Anatomical Nomenclature International Committee on Veterinary Gross was adopted.

## Results, discussion and conclusion

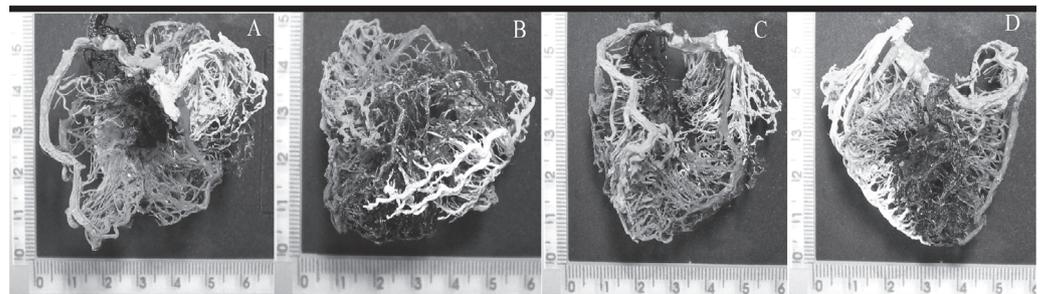
In 310 B.C. the topographical anatomy of the heart was described by Erasistratus and Herophilus in Alexandria, and until the current days, referring theories to its structure suffered advances and modifications, resulting on the basic knowledge about circulation, as it is currently



**Figure 1** - Drawing evidencing: semilunar pulmonary valve (a) and semilunar aortic valve (b), right coronary artery (C), left coronary artery (D) and its subsegments, the subaortic papillary muscle (MPSau) and subatrial papillary muscle (MPSat)



**Figure 2** - Heart injected with mercury and cleared. The legends indicate the relations: cranial (CR), caudal (CA), dorsal (DO) and ventral (VE); the portions of the hearts: right ventricle (Ve), interventricular septum (HATCHED), left ventricle (Ve). The red arrow indicates the branch to interventricular paraconal of the left coronary artery and the blue arrow the circumflex branch. The yellow arrow indicates a left dorsal sub-segment, the green the intermediary (left ventricular marginal) and in white the subsinuuous interventricular branch



**Figure 3** - Cast in Vinyl Acetate of the branches of the left coronary artery, where only the Papillary Muscles had been fixed and the remain on the dissected heart

understood “one closed net of vessels in which the blood, pumped for the heart, has unidirectional flow determined by the valves “. The heart all the vessels impel continuously the blood and the lymph (the main fluids of the body, relatively recent knowledge)<sup>26</sup> in one flow. Diverse studies have shown the heart, as an organ in constant activity during all animal life, requires a

significant blood supply and a differentiated net of vases.

The vases determine the reserve of regional coronary flow in the absence of extravascular compressive forces, being presumed that the vascular structures can be restricting flow-factors. Based on this, the sanguine flow is a balanced function between

the intravascular arterial region and the extravascular tecdial pressure however the vascular structures control the sanguine flow<sup>13</sup>. These vascular formations distributed over the ventricular wall delimit well-defined territories constituting sanguine suppliment regions or cardiac segments studied by some authors<sup>3,5,15,19,25,28,29</sup>. This knowledge has appliace on the surgical interventions, objectifying the revascularization and restoration of the ventricular myocardium.

The human heart possesses an extensive secondary circulation with vary types anastomosis canals, always ready to work<sup>30</sup>. In human and canine hearts numerous arterial connections exist, the majority in the epicardium and endocardium surfaces in which, this last, is related to the papillary vases and trabeculas in great number<sup>6</sup>. We find anastomoses between coronary artery, its branches and subsegments, located on the pericardium surface, in the intramuscular pathway and in the endocardium, in accordance to the results of other authors<sup>3,5,30</sup>, as well as abundant anastomosis in the region of the papillary muscles<sup>3,5,6,8,9,10,12,16,27</sup>.

Some authors report a constant presence of two papillary muscles on the left ventricle of the man, to whom sanguine suppliment has multiple origins. The anterior papillary muscle (in the dog, subauricular papillary muscle) is supplied for one or some branches from the descendant coronary artery or from "the diagonal" branches of left ventricular arteries, but also from marginal terminal branches of the *ramus circumflexus arteriae coronariae sinistrae*. The posterior papillary muscle (in the dog, subatrial papillary muscle) is supplied by the terminal branches of the diaphragm surface, by the left ventricle, and by the terminal branches of the *ramus circumflexus arteriae coronariae sinistrae* and by the right coronary artery<sup>8,10,19</sup>, data that confirm our findings in the dog.

Some authors<sup>10</sup> point out the pathway, the area distribution and arteries arrangement which supply these muscles as being related

to its global morphologic statement, other authors<sup>19</sup> correlated these papillary muscles to the anatomical-surgical segments being more precisely on the description. Observing that anterior inter-ventricular arteries, lateral branch (dominant on the irrigation of this muscle) and the left marginal branch which irrigates the anterior papillary muscle correspond to the respective segments of the inter-ventricular artery, of the lateral branch and left marginal branch. The anterior inter-ventricular arteries, lateral branch, left marginal branch and posterior inter-ventricular (dominant in the irrigation of this muscle) irrigate the posterior papillary muscle correspond to the respective segments of the anterior inter-ventricular artery, of the lateral branch, of the left marginal branch, of the posterior ventricular branch and the posterior inter-ventricular artery. The same study was carried out in pigs<sup>16</sup>, concluding that the distribution of the arteries supplying the papillary muscles seems to the man and other study<sup>24</sup> carried on Hereford cattle, concluding that the cranial papillary muscle (subauricular papillary muscle, in the dog) is supplied by the collateral branch of the paraconal descendant artery, being in all the cases, single or together with the *ramus circumflexus arteriae coronariae sinistrae*. The caudal papillary muscle (subatrial papillary muscle, in the dog) is supplied by the arteries derived from the *ramus circumflexus of the left arteria coronaria sinistra* and also from the rami subsinuuous and paraconal descending.

Some important anatomical differences were observed, between the hearts of pig and human, in relation to the position: compressed in the thorax of pigs and dorsal-ventral flattened in human, such facts can affect the postoperative performance in transplant<sup>20</sup>. In another study the left ventricle papillary muscles were related to the ischemia, but rarely breach ouving to the sinusoid arteries can complete normal arterial flow<sup>26</sup>. The reorganization of the papillary muscles, applied in surgical techniques for the reduction of the left ventricular volume it is a supplement for the coronary revascularization<sup>22</sup>.

The analysis of the applied methods in this research, allowed concluding that the left coronary artery is distributed in the left ventricle, left atrium, interventricular septum and is continued all over the heart, through anastomosis and its branches:

**Septal** branches in the whole interventricular septum;

**Paraconal Interventricular** runs over the *anterior interventricular sulcus* directioning to the cardiac apex, surrounding it turning into *posterior interventricular sulcus* direction and its sub-segments:

- *right ventricular branches* to the left surface of the right ventricle and *interventricular septum*;

- *left ventricular branches* to the left surface of the left ventricle;

- *collateral branch*, from the left ventricular edge into the cardiac vertex direction.

**Circumflex** situated in the coronary *sulcus* in direction to the posterior interventricular sulcus and its subsegments:

- *left dorsal branches*: originate at the initial portion of the circumflex branch and run into the cardiac apex;

- *intermediate branch (left marginal ventricular)* is originated at the level of the previous face of the left ventricular edge and is extended next to the cardiac apex;

- *the ventricular edge branch* it is originated at the level of the left ventricular edge and is extended to the cardiac apex;

- *right dorsal branches* originated on the right face of the left ventricle, caudally to the subsinuuous interventricular branch;

- *interventricular subsinuuous branch*: runs in the posterior inter-ventricular *sulcus* in the direction of the paraconal inter-ventricular sulcus.

Drawings of the branches of the left coronary artery were made, illustrating subauricular and subatrial papillary muscles and sub-segments that supply these muscles, of all the analyzed hearts (Figure 4). We noted that:

**The Subauricular Papillary Muscle** is irrigated by the branches of the left coronary artery:

- \* *Interventricular Paraconal* and its sub-

segments:

- in its terminal portion, to the level of the ventricular apex in 9 of the 30 hearts (30 %);

- by the collateral branch in 29 of the 30 hearts (96.66 %);

- by the left ventricular branches, at least one branch, in 29 of the 30 hearts (96.66 %).

- \* *Circumflex* e its sub-segments:

- by the left dorsal branches, at least one branch, in 26 of the 30 hearts (86.66 %);

- by the intermediate branch (left ventricular marginal), at least one of its branches, in 26 of the 30 hearts (86.66 %);

- by the left ventricular edge branch, at least one of its branches, 2 of the 30 hearts (2.88 %).

**The Subatrial Papillary Muscle** is supplied by the left coronary artery branches:

- \* *Interventricular Paraconal* and its sub-segments:

- by its terminal portion, to the level of the ventricular apex in 9 of the 30 hearts (30 %);

- by the collateral branch in 10 of the 30 hearts (33.33 %);

- by the left ventricular branches, at least one of its branches, in 10 of the 30 hearts (33.33 %).

- \* *Circumflex*:

- by the left dorsal branches, at least one of them, in 1 of the 30 hearts (3.33 %);

- by the intermediate branch (left ventricular marginal), in all the 30 studied hearts (100 %);

- by the left ventricular edge branch, in at least one of its branches, only 2 of the 30 hearts (2.88 %);

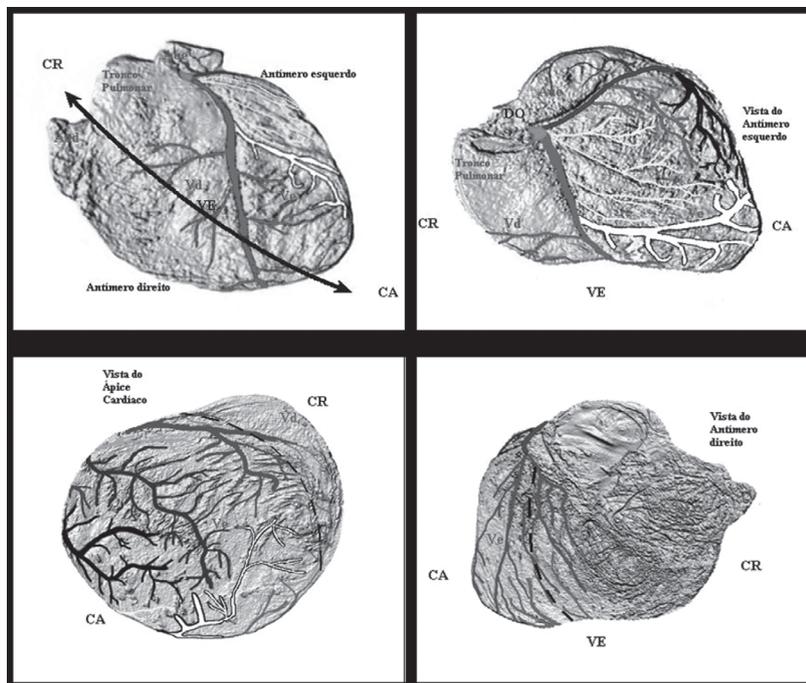
- by the right dorsal branches, at least one of them, in 16 of the 30 hearts (53.33 %);

- by the interventricular subsinuuous branch, in at least one of its branches, all the 30 studied hearts (100 %).

It was possible to observe some anastomosis between the interventricular paraconal branches and its collateral sub-segment, and the circumflex sub-segments branches: intermediary (left ventricular marginal), branch of the left ventricular edge

and subsinuuous interventricular, intensively all over the surface and in all the segments, mainly in the cardiac apex, the majority close to the surface epicardium. As well as papillary and trabeculas vases at endocardium level had been observed.

<b>Left Coronary artery:</b>	
<b>a. Septal</b>	
<b>a. Interventricular paraconal and sub-segments:</b>	
	right ventricular branches
	left ventricular branches
	Collateral branch
<b>a. Circunflexa and sub-segments:</b>	
	left dorsal branches
	intermedial branch (left marginal ventricular)
	left ventricular ridge branch
	right dorsal branch
	subsinuuous interventricular branch



**Figure 4** - Diagrammatic drawing of the irrigation of the left coronary artery (A - B - C - D). The legends indicate the relations: cranial (CR), caudal (CA), dorsal (DO) and ventral (VE) and the portions of the heart: right ventricle (Vd), right auricula (Aud), interventricular septum (HATCHED), left ventricle (Ve) and left auricula (Aue). It is used nomenclature of the arterial vessels, branches of the left coronary artery

**Irrigação dos músculos papilares do ventrículo esquerdo do coração de caninos (*Canis familiaris*, L. 1758)**

**Resumo**

A irrigação dos músculos papilares tem informações incompletas sobre a distribuição dos vasos arteriais. Objetivando estabelecer a origem destas artérias e sua distribuição nos músculos papilares do ventrículo esquerdo, utilizamos 30 corações de cães adultos, machos e fêmeas de raça não definida e de várias idades. Após o óbito, o coração

**Palavras-chave:**  
Irrigação. Músculos.  
Papilares. Coração. Cães.

foi removido, lavado em água corrente e em seguida injetado através do óstio da artéria coronária esquerda com uma solução de acetato de vinil corado, neoprene látex 650 corado ou gelatina a 10%. Os músculos papilares em todas as técnicas utilizadas foram fixados com solução de formol a 10 %. A dissecação foi realizada de forma acelerada com o uso de solução de ácido sulfúrico a 40 %. Para realização das radiografias utilizamos injeção de mercúrio o que auxiliou a montagem dos esquemas da vascularização estudada. Utilizamos a técnica de diafanização de Spalteholz para melhor visualizar a irrigação cardíaca. Evidenciamos que os músculos papilares subauricular e subatrial são irrigados pelos ramos da artéria coronária esquerda. O subauricular pelos ramos interventricular paraconal e circunflexo e o subatrial predominantemente pelo ramo circunflexo. Os subsegmentos que suprem o subauricular do ramo interventricular paraconal são os ramos: colateral e ventriculares à esquerda; e do ramo circunflexo são os ramos: dorsais à esquerda e intermédio (marginal ventricular esquerdo) e mais raramente o ramo da borda ventricular esquerda (ramo diafragmático). Os subsegmentos do ramo circunflexo que suprem o subatrial são os ramos: intermédio (marginal ventricular esquerdo), da borda ventricular esquerda (ramo diafragmático), ramos dorsais direito e ramo interventricular subsinuoso. Em alguns casos observamos o ramo colateral e o próprio ramo interventricular paraconal atingirem a porção do vértice do subatrial.

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