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Myocardial Torsion and Cardiac Fulcrum

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Abstract

The function of the heart corresponds to a mechanical dimension that should be addressed in terms of its structure, which is where we find the origin of the idea that led our research to explain its organic-functional integrity. The real internal myocardial anatomy, and contrary to the classical concept, dissection finds a structure with defined planes that allows successive and concatenated physiological motions of narrowing, shortening-twisting, lengthening-untwisting and expansion. Faced with this mechanics, myocardial torsion represents the functional solution to eject the ventricular blood content with the necessary energy to supply the whole organism. The inevitable emerging question is that in order for the muscular bands surrounding the ventricles to twist they should have a supporting point, similarly to a muscle in a rigid insertion.

Keywords: Fulcrum • Myocardial tension • Physiological motion • Muscular bands

About the Study

This study approach correlates with a cardiac structure presenting the remarkable characteristic of being adriving-suction pump with the size equivalent to a human fist and an average weight of 270 grams, which ejects 4-6 liters/minute at a speed of 300 cm/s, consuming only 10 watts, and working without interruption for 80 years without maintenance, almost without noise, and no smoke [1-8].

Its work is equivalent to the daily withdrawal of 1 ton of water 1 m deep with a mechanical efficiency (work/energy relationship) of 50%, not achieved by man-made machines which only attain 30% efficacy [9]. This allows ejecting 70% of the left ventricular volume with only 12% shortening of its contractile unit, the sarcomere [10].

Ten young-bovine hearts (800-1000 g) and eight human hearts (one embryo, 4 g; one 10 years old, 250 g; and six adult, mean weight 300 g) were used for a detailed macroscopic and microscopic study.

We have found in all the bovine and human hearts studied a nucleus underlying the right trigone, whose osseus, chondroid or tendinous histological structure depends on the specimen analyzed.

The microscopic analysis revealed in the hearts a trabecular osteochondral matrix (fulcrum) with segmental lines in bovines and in the ten year old human heart central area of the fulcrum formed by chondroid tissue.

In the fetus was found pre-chondroid areas in a myxoid stroma. In the adult human hearts, the histological analysis revealed a matrix similar to that of a tendon. All the hearts studied presented myocardial attachment to the rigid structure of the fulcrum (Figures 1 and 2)
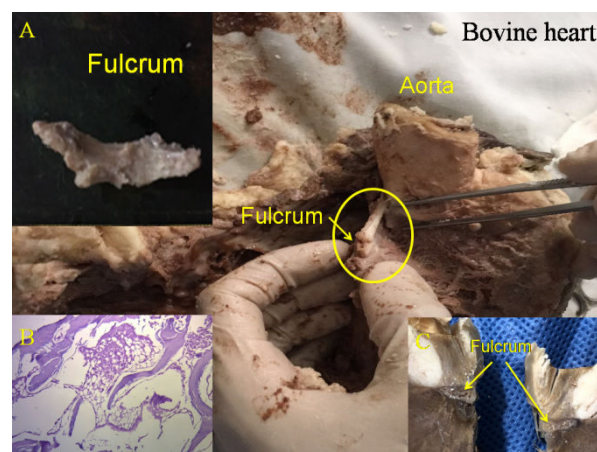

Figure 1. Cardiac fulcrum (bovine heart). A: resected piece; B: mature trabecular bone forming the cardiac fulcrum tissue. Hematoxylin-eosina stain at low magnification (10 x); C: cardiac fulcrum in other view.

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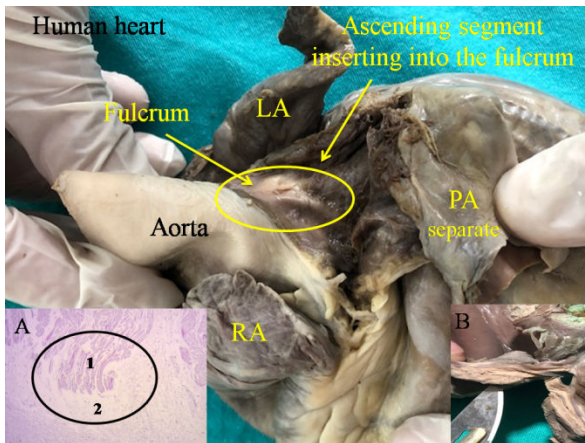
Figure 2. Fulcrum in the adult human heart. A. Cardiomyocytes penetrating the fibro-colagenous tissue. 1: Cardiomyocytes; 2: Fibrocolagenous matrix. The circle details the insertion site. B: resected piece.

Myocardiocites were not found neither at the left or rigth trigonous nor at the base of the valves.This point of attachment implies, as in any muscle, its ability to achieve the necessary leverage and also to act as a bearing or pad, preventing the force of ventricular rotation, either by torque or torsion strain from transferring to the aorta, thus dissipating the energy produced by the helical muscle motion, and avoiding aortic constriction or bending during systolic ejection.

Discussion

In anatomical investigations we have found in all the bovine and human hearts studied a nucleus underlying the right trigone, whose osseus, chondroid or tendinous histological structure depends on the specimen analyzed, and is oriented towards the muscle fibers of the ascending segment which intimately penetrate its structure to attach themselves [11]. This point of attachment would serve to support both the origin and end of the myocardial band, as the fibers that initiate the right segment, origin of the myocardial band, attach to the anterior part of this nucleus as well as to the pulmo-tricuspid cord. This osseus, chondroid or tendinous attachment point is found in the vicinity of the tricuspid valve (right), the aorta (posterior) and the pulmo-tricuspid cord (anterior). To find it, it is necessary to unfold the myocardial band and move the pulmonary artery, the pulmo-tricuspid cord and the right segment to the left of the observer, stripping the root of the aorta (as a scarf that separates from the neck). Next, the muscular plane of the descending segment is separated from that of the ascending segment to follow the latter up to its insertion in the cardiac fulcrum. This maneuver reveals the fulcrum in front of the aorta and below the right trigone and the origin of the right coronary artery, detached from the aortic continuity and inserted as a complementary element between the aorta and the myocardium. This structure, origin and end of the myocardial band, has a more rigid consistency than the trajectory between the trigones [12]. An osseus formation, called os cordis, in bovine, sheep and chimpanzees hearts, is reported in the veterinary literature in the same location where we have studied this structure both in bovids and humans. Beyond its mere mention in other species, no reason for its presence or function was ever assigned to this structure, and it has not been described in humans [13,14]. The findings in the human hearts are

surprising from the point of view of interpretation, since it is logic to consider its presence in all the evolutionary mammalian chain. It should be assumed that this structure, analyzed in different species, has the common function of providing support to the myocardial band to generate the power needed by any muscle, which is different in diverse mammals. Therefore, its presence is constant in all the hearts studied, both in bovids and humans, but its structural characteristic is different, and this diversity in the intimal analysis of the cardiac fulcrum is undoubtedly associated with the resistance it must oppose to the activity of the myocardial band in hearts of different sizes. A fact defying logic is having found in the adult human heart a formation presenting consistent characteristics, both to observation and palpation, in the same location and with similar triangular morphology. However, the histological analysis revealed a matrix similar to that of a tendon. At this point, fundamental questions arise. Why does the human fulcrum have characteristics similar to a tendon, despite it fulfills the same function of attaching the myocardial band? Why does it not have the same structure of the fetal or child human heart?

Our interpretation is that perhaps the osseous fulcrum is a vestigial organ specific of mammalian evolution. A vestigial structure must be understood as the preservation during the evolutionary process of genetically established attributes which have lost all or part of their ancestral function in a certain species. As a result, it is found in the initial process of human gestation, but later loses its osseous character, remaining as a tendinous matrix able to achieve myocardial band insertion to attain a muscle power which is much lower than that of larger mammals. Recall that in bovines the fulcrum found in this investigation is of bone nature.

Conclusion

A histological analysis has also been carried out on the trigones trying to find cardiomyocytes in them, as a possibility of insertion of the band in these structures. In our investigation, only collagen tissue was observed without cardiomyocytes in the trigones, confirming that the fulcrum is the support of the band, both in its beginning and in its termination. The myocardial band cannot be anatomically suspended and free in the thoracic cavity because it would be impossible to eject blood at a speed of 300 cm/s. Therefore, there must be a point of attachment, which was identified as the cardiac fulcrum (supporting point of leverage). In this supporting point, the muscle fibers are inevitably forced to "intertwine" with the connective, chondroid or osseous fulcrum, and our anatomical and histological investigations have shown that this insertion attaches both the origin and end of the myocardial band.

In analogy, as with skeletal muscle, we found in the myocardial muscle that its contraction takes place between a fixed point of support (insertion of the ascending segment in the fulcrum) and a more mobile one (insertion of the right segment in the anterior face of the fulcrum). This last point was shown in the dissection of a fragile character, totally opposite to the solidity of the opposite end of the band in its attachment to the fulcrum.

We consider that by attaching to the origin of the aorta and the pulmonary artery, the muscle band uses them as mechanical support, as it inserts in fibrous and consistent structures essentially the osseous, chondroid or tendinous cardiac fulcrum found both in bovine

and human hearts in our investigations. The left ventricular opposing rotation of the base and apex on these fixed points generates muscle torsion. This counterclockwise apical motion allows the development of elevated pressures reducing strain, exactly as wringing a towel. This concept had already been issued by Richard Lower, being the same in mice and humans. The investigation shows cardiac coherence from the myocardial band to the suction during the isovolumic diastolic phase and intraventricular vortex. This structural composition keeps correspondence with the activation of the myocardial band. The stimulus runs by its muscle pathways, but in order to fulfill the function proposed by its helical arrangement, it is essential for it to simultaneously activate the left ventricular descending and ascending segments. The transmission of the stimulus between them generates the necessary ventricular torsion (a situation similar to "wringing a towel") that enables the ejection of the blood content in a limited time span with the necessary force to adequately supply the whole body. The following suction phase of the heart is not feasible due to the small difference with peripheral pressure. Neither can it be passive. The untwisting of the heart in the first 100 ms of diastole (isovolumic diastolic phase) generates the negative intraventricular force to draw blood into the left ventricle, even in the absence of the right ventricle, as shown in experimental animals. This suction phase ("suction cup" mechanism) is active with energy expenditure, and implies that the heart cycle consists of three stages: systole, suction and diastole. This explains its high mechanical efficiency and also the procedures that were used in medical practice without a clear understanding of their mechanisms, as right ventricular exclusion, ventricular resynchronization and univentricular mechanical assistance surgeries. This consideration is of vital importance, as the assessment of myocardial torsion could be considered more reliable than functional class or ejection fraction and become an essential clinical predictor of heart failure.

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