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Pivotal Role of Major Aortic Arch Branches in Subtending the Mammalian Heart

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Abstract

Hypothesis and Background: A high prevalence of downwardly sloping type 3 Aortic Arch (AA) in elderly humans with Left Ventricular Hypertrophy (LVH) led us to hypothesize that Major Aortic Arch Branches (MAAB) acting through the AA and ascending Aorta are pivotal in subtending the heart in its anatomic position. Based on established commonality in comparative anatomy of terrestrial mammals we tested our hypothesis in the even-toed ungulate model.

Methods and Results: We observed 5 animals (2 sheep and 3 goats) at a licensed abattoir as they were being dressed, in a requested order. In vertical orientation, midline incision bisecting the entire chest and anterior abdominal wall was made and after retracting the ribs the heart was visualized. In stepwise fashion: abdominal organs, diaphragm, lungs and Vertebropericardial Ligaments (VPL) were removed; in all animals, the heart maintained its position in the thorax after the above steps. Subsequently, Sternopericardial Ligaments (SPL) were transected and the heart still maintained its position. Only after ascending aorta was severed just above the Aortic valve, did the heart lose its position and drop down to the pelvis.

Conclusion: In even-toed ungulate animal model, MAAB acting through AA and ascending aorta are pivotal in subtending the heart in its usual anatomic position. Invoking basic principles of comparative anatomy it would be safe to extrapolate that same may run true in humans. Indirect evidence of above in humans may reside in a high prevalence of downwardly sloping type 3 AA in elderly with LVH.

Keywords: Aorta; Anatomy; Aortic arch; Animal model

Abbreviations: AA: Aortic Arch; MAAB: Major Aortic Arch Branches; LVH: Left Ventricular Hypertrophy; VPL: Vertebropericardial Ligaments; SPL: Sternopericardial Ligaments; SVA: Supravalvular Ascending Aorta

Background

During cardiac catheterization and coronary angiography, the ease and predictability with which an upwardly pointing coronary catheter engaged the MAAB as it was being withdrawn led us to suspect and later prove that the MAAB take off is crested along the superior most aspect of the AA [1].

We then hypothesized and demonstrated that in humans in the upright position, a gravity generated lifelong downward drag on the rightward aspect of the AA exerted by the vigorously pulsating heavy heart of patients with LVH resulted in a downwardly sloping type 3 AA (Figure 1) in most elderly patients with LVH from any cause [2].

We suspect the same continual downward drag exerted by the heart on the AA may play a role in the narrow alignment or cresting of the MAAB takeoff along the superior most aspect of the AA [3].

Based on the above-mentioned observations we concluded that in humans the MAAB acting via the AA and ascending aorta may play a pivotal role in subtending the heart in its normal anatomic position in the thorax. Given the commonality in the comparative anatomy of all terrestrial mammals we first set out to prove our hypothesis in the even-toed ungulate model.

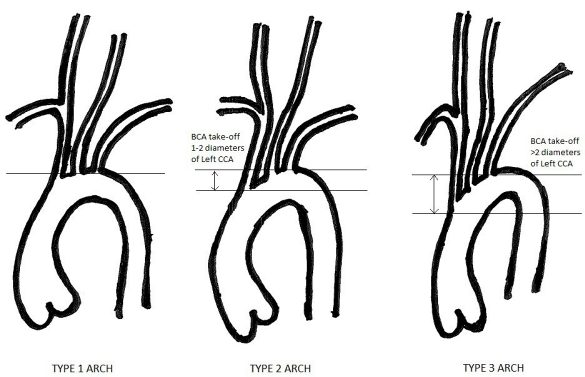

Figure 1: Aortic arch types (Used with the author's permission): The human AA is divided into three types, Type I, Type II and Type III depending upon the severity of arch angulation.

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Methods and Results

We observed 5 animals (2 sheep and 3 goats) at a licensed abattoir as they were being dressed for human consumption in a certain requested order. In vertical orientation, midline incision bisecting the entire chest and anterior abdominal wall was made and after retracting the ribs the heart was visualized.

Then in a stepwise fashion: 1) abdominal organs, 2) diaphragm along with the phrenopericardial ligament, 3) lungs and 4) vertebropericardial ligaments were removed; in all animals, the heart maintained its position in the thorax after each of the above steps (Figure 2). 5) Subsequently, SPL was transected and the heart still maintained its position. 6) Only after finally the ascending aorta was severed just above the Aortic valve, did the heart lose its position in the thorax and it literally dropped down into the pelvis.

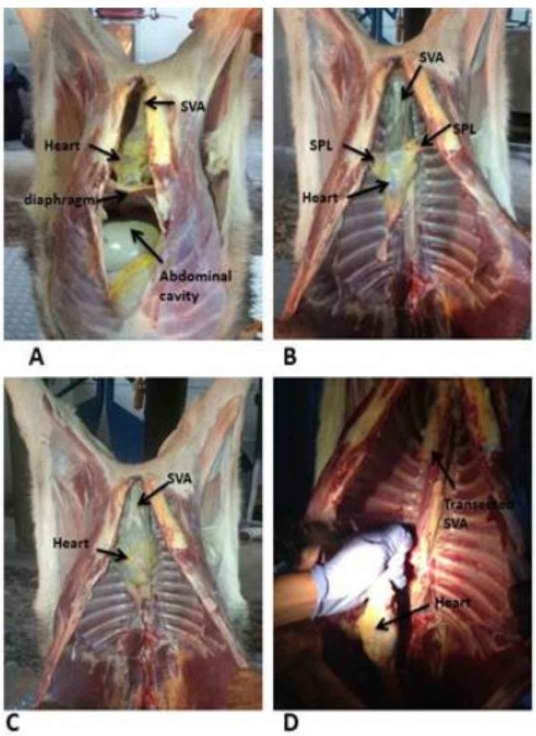

Figure 2: A) After bisecting the chest and anterior abdominal wall; B) After removing diaphragm, lungs and abdominal organs, heart maintained position; C) After removing SPL, heart maintained position; D) After transecting the aorta, heart dropped into the pelvis.

Discussion

The following structures anchor the heart in its normal anatomic position in the thorax*
1) The diaphragm 2) The great pulmonary vessels 3) The pericardium; which tethers the heart to surrounding structures including pre tracheal fascia and adventitia of great vessels 4) The sternopericardial, phrenopericardial and the vertebropericardial ligaments 5) The MAAB themselves firmly anchored to the thoracic outlet acting through the AA (transverse aorta) and the ascending Aorta literally sling the heart in a pendulum-like fashion in the thorax.
Thus In the upright position of the human subject, the heart exerts a continual downward drag on the rightward aspect of the AA; so the heavier the heart and the more vigorously it pulsates and the longer the subject lives the greater this downward drag is, resulting in the downwardly sloping type 3 AA in most older humans with LVH [2].

All humans are born with a type 1 (totally horizontal) AA [4-7]. With age, they develop a type 2 (moderately sloping) or a type 3 (severely sloping) AA [4-7]. Most patients with type 2 and type 3 AA are older and have LVH [2]. The causes of left ventricular hypertrophy are legion but the commonest is hypertension. Other pertinent causes are calcific aortic stenosis of the elderly and severe mitral regurgitation.

Based on the commonality in the comparative anatomy of terrestrial mammals it is reasonable to extrapolate from this experiment that if the MAAB acting through the AA and the ascending aorta play a pivotal role in subtending the heart of the even-toed ungulate in its usual anatomic position in the thorax then the same could be true for the humans and may be contributing factor for the high prevalence of the downwardly sloping type III-AA in elderly human with LVH from any cause.

Limitations

Our study is limited by the small number of subjects and narrowness of mammalian species studied.

Despite the known commonality in the comparative anatomy of terrestrial mammals, the only way to really claim a similar pivotal role played by the MAAB in subtending the human heart would require the same experiment in the human cadaver.

Thus larger animal and human cadaveric studies are needed to further corroborate our findings.

Conclusion

In the even-toed ungulate animal model, the MAAB acting through the AA and the ascending aorta are pivotal in subtending the heart in its usual anatomic position in the thorax.

Invoking basic principles of comparative anatomy it would be safe to extrapolate that the same may run true in humans.

Indirect evidence of above in humans may reside in a high prevalence of the downwardly sloping type 3 AA in elderly with LVH.

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