

## SIX FUNCTIONALLY SIGNIFICANT MUSCULAR

### BUNDLES IN HUMAN LEFT ATRIUM

M. T. RAKHAWY, N. N. RIZK AND E. N. GHALY

*Department of Anatomy, Faculty of Medicine, Cairo University.*

#### INTRODUCTION

Investigation concerning the architecture of the atrial musculature dates back to Keith in 1903. Descriptions of the atrial musculature of some mammals were given by Tandler (1913), Paper (1920), Robb (1934) and Thomas (1959). Nathan and Eliakim (1966) described the general directions of the fibres in the posterior wall of the human left atrium. Literature concerning the orientation and attachments of the individual muscular bundles of the human left atrium, however, is relatively deficient.

The atrial musculature has been described to extend around the proximal parts of the pulmonary veins (Burch, 1954; Klavins, 1963; Carrow and Calhoun, 1964; Hooker *et al.*, 1964; Kosir 1964; Forabosco, 1965; Nathan and Eliakim, 1966 and Almedia *et al.*, 1975). Several functions of these Sphincteric-like structures have been proposed. Nathan and Eliakim (1966) discussed three functions: throttle-

like mechanism, active expulsion of blood and control of pulmonary circulation. Ganong (1975) mentioned that the inertia of blood moving towards the atrium tends to keep the blood in it. The proper mechanisms which prevent blood regurgitation to the pulmonary veins or its stagnation in the auricle during atrial systole need clarification. The present study attempts to throw more light on the orientation and attachments of the various muscular bundles of the human left atrium trying to get a more lucid understanding of the functional mechanisms of this region. This might prove helpful in the management of certain cardiac diseases.

#### MATERIALS AND METHODS

Thirteen human specimens (eight males and five females) were studied. Two were newly born and the others ranged between 25 and 45 years of age. Each specimen (complete heart and the hilar part of each lung) was obtained within six hours from the postmortem, fixed in 10% formalin for three days and

subjected to fine dissection. Wrinkling of the atrial walls was prevented by filling the atrium with either a pad of cotton (in six specimens) or air under constant pressure (in the remaining specimens). Cotton was introduced piecemeal through the pulmonary veins, while air was pumped by a sphygmomanometer through one of the pulmonary veins after clamping all other vessels of the heart. The pressure was raised just to keep the atrium distended. The pulmonary veins were dissected out, the various muscular bundles cleaned and the coronary vessels removed to expose the atrioventricular ring.

Parts from the pulmonary veins near their atrial junctions were processed for histological examination, sectioned transversely at seven micron thickness, stained with haematoxylin and eosin and followed serially for the orientation of the cardiac muscle fibres.

## RESULTS

The musculature of the left atrium was found to consist of six bundles of muscle fibres which were seen to arise from one of either two common origins. Origin «A», the right end of the posterior part of the left fibrous atrioventricular ring, gave origin to four bundles; while origin «B», the right end of the anterior part of the same ring, gave origin to the remaining two bundles (Fig. 1). The bundles were

numbered according to their position in the posterior wall of the atrium from below upwards and to the right then in the anterior wall downwards and to the left.

Bundle 1 (posterior atrio-auricular bundle) (Fig. 2) : was found to arise at origin «A» and extend horizontally to the left as a band 5—10 mm. breadth just above the fibrous ring (Figs. 2, 8, 10 & 11). It curved below the left auricle and surrounded it spirally to insert at its apex. Some fibres were seen to extend on the anterior wall of the left atrium to join bundle 2 (Fig. 12).

Bundle 2 (horizontal atrial bundle) (Fig. 3) : started at origin «A» and extended to the left and slightly upwards. It curved above the auricle to the anterior wall where it continued to the right and slightly upwards towards the right atrium. It was seen as a well defined inter-atrial bundle in the anterior wall of the atrium about 3 cm. above the level of the fibrous ring (figs. 3, 8, 10, 11 & 12).

Bundle 3 (vertical atrial bundle) (Fig. 4) : started at origin «A» and ascended as a wide band (3 cm. breadth) upwards and to the left along the posterior wall. It curved around the upper border of the atrium and descended along the anterior wall downwards and to the left. It was inserted at the left end of the anterior part of the left atrio-ventricular fibrous ring (Figs. 4, 10, 11 & 12).

Bundle 4 (right atrio-venous bundle) (Fig. 5) : was seen to arise at origin «A», to curve upwards and to surround the right part of the left atrium spirally as a band of about 2 cm. breadth. It continued as two bundles, each bundle running spirally around each of the right pulmonary veins to end in its intima (Figs. 5, 10, 11 & 12).

Bundle 5 (left atrio-venous bundle) (Fig. 6) : was seen to arise from origin «B». It extended upwards and to the left along the anterior wall, curved around the upper border of the left atrium and descended on the posterior wall to the left and slightly downwards. It was observed to surround the two left pulmonary veins spirally, either starting as two bundles one below each vein and surrounding them in a clock-wise direction or starting as one bundle between the two veins and surrounding the upper vein in a clockwise direction while surrounding the lower pulmonary vein in an anti-clockwise direction (Figs. 6, 7, 8, 10, 11 & 12).

Bundle 6 (anterior atrio-auricular bundle) (Fig. 9) : started at origin «B» and passed in the anterior wall of the left atrium to the left and slightly upwards. It curved forwards above the left auricle to surround it spirally and to insert in its walls especially at the apex. It had the same breadth and almost a mirror image of bundle 1 (Fig. 9 & 12).

These six bundles were observed to surround the left atrium completely (Fig. 10 - 12) and some times they even overlapped each other thus the atrial wall would be formed of two or three layers in these areas of overlap. Smaller bundles were seen to branch from the main six bundles to join adjacent bundles.

The media of the pulmonary veins were seen histologically to consist of one layer of circular cardiac muscle fibres. This circular arrangement was seen to change gradually into oblique and finally longitudinal pattern which overlapped the original circular fibres internally in about one fifth of the circumference of the vein (Figs. 13 & 14.)

Examination of the serial sections of the pulmonary veins showed that the cardiac muscle fibres eventually insert in the intima of the veins (Fig. 15).

## DISCUSSION

The six muscular bundles of the left atrium could be divided functionally into three groups. Each group is formed of two bundles that act either synergically or have two corresponding actions. The first group is formed of bundles 1 and 6 (posterior and anterior atrio-auricular bundles). These are mirror images of each other, and their terminal spiral parts squeeze the auricle from its apex towards its base

i.e. from the insertion towards the origin. Subsequently the main horizontal parts of the bundles (nearer to the origin) will contract affecting the atrial cavity itself. So the spiral parts augment each other to empty the auricle then the two horizontal parts complete each other to form a constricting circle that helps in emptying the atrium.

The second group is formed of bundles 2 and 3 (horizontal and vertical atrial bundles). Although they have an almost perpendicular course, their actions are similar. Bundle 2 acts mainly horizontally constricting the atrium from left to right and from before backwards. However, as its termination is higher than its origin (about 3cm.) it has a vertical downward push towards the ventricle. Bundle 3 acts mainly vertically downwards; however, as its insertion is in the left end of the anterior part of the left atrio-ventricular ring, its contraction will pull this insertion towards origin «A» i.e. from before backwards and from left to right. Thus bundle 2 acts mainly horizontally and partly vertically while bundle 3 acts mainly vertically and partly horizontally. However, each of the two bundles is contracting the atrium from above downwards, from before backwards and from left to right. As these two bundles are relatively broad (about 3 cm. they are considered to be the main propellers of blood towards the ventricle.

The third group is formed of bundles 4 and 5 (right and left atrio-venous bundles). These bundles are considered to be responsible for the milking and contraction of the pulmonary veins near their atrial junction before the contraction of the atrium itself. Each of these two bundles has a terminal spiral part that surrounds either the right or left pulmonary veins and a main part in the walls of the atrium. They insert in the intima of the veins. The gradual change from the circular to the longitudinal orientation of the cardiac muscle fibres seen histologically is a confirmation of the spiral arrangement of the fibres around the veins. The circles formed by this spiral arrangement have the smallest diameter distally near the insertion and the widest proximally near the origin. Contraction and shortening of these bundles result in narrowing of the circles they form. The occlusive effect of this narrowing will appear first in the smallest distal circles at the veins, and subsequently appear in wider circles proximally. This chronological sequence ensures milking and occlusion of the pulmonary veins before the main vertical parts of the bundles affect the atrial wall. This prevents blood regurgitation to the veins during atrial systole. As the main vertical parts of these two bundles (4 and 5) lie one in either wall of the left atrium, they form together a vertical constricting circle that adds to the propulsive push of blood towards the ventricle.

If the atrio-auricular bundles are compared with atriovenous bundles, it can be noticed that each has a small terminal spiral part around the auricle or one of the pulmonary veins and inserts in it, and a main atrial part in either wall of the atrium. The atrial parts of the atrio-auricular bundles form together a horizontal atrial circle, while those of the atrio-veous bundles form a vertical atrial circle. As the terminal spiral parts form smaller circles and are nearer to the insertion while the main atrial parts form bigger circles that are nearer to the origin, the contraction of the auricle and the pulmonary veins precedes the atrial contraction and prevents blood stagnation or regurgitation.

### SUMMARY

The left atrial musculature was studied in 13 human specimens from both sexes and of various ages. It was found to consist of six muscular bundles arising from two main origins at the atrio-ventricular fibrous ring. The bundles have definite course and insertions. They could be grouped into three functionally related pairs. The first pair is formed of the anterior and posterior atrio-auricular and bundles which insert in the left auricle are believed to empty the auricle before the atrial systole. The second pair, the horizontal and vertical atrial bundles, are thought to be the main propellers of blood towards the ventricle. The third group is formed by the right and left atrio-venous bundles. These form spiral loops that surround the proximal parts of the four pulmonary veins and insert in their intima. They are supposed to be

responsible for milking and occluding the pulmonary veins before the atrial contraction.

### REFERENCES

1. **Almedia, O.; Bohm, G.M.; De paula Carvalho, M. and Paes De Carvalho, A.** : The cardiac muscle in the pulmonary vein of rat : a morphological and electrophysiological study. *Jour. Morphol.*, **175/4** : 409 - 433 (1975).
2. **Burch, G.E. and Romney, R.B.** : Functional anatomy and "throttle valve" action of the pulmonary veins. *Amer. heart J.* **47** : 58 (1954).
3. **Carrow, R. and Calhoun, M.L.** : Extent of cardiac muscle in the great veins of the dog. *Anat. Rec.*, **150** : 249 (1964).
4. **Porabosco, A.** : Preliminary observations on the musculature of the pulmonary veins in the albino rat. *Boll. Soc. Ital. Biol. Sper.*, **41/5** : 259 - 260 (1965).
5. **Ganong; W.F.** : Review of medical physiology; 7th ed., Ch. 34, Lange Medical Publications (1975).
6. **Hooker, C.W.; McAllister, H. A. Jr. and Ellis, F.W.** : Active contractions of the large thoracic veins in certain mammals. *Anat. Rec.*, **148**:292 (1964).
7. **Keith, A.** : Anatomy of the valvular mechanisms around the venous orifices, with some observations on the morphology of the heart. *J. Anat. Physiol.*, **37** : 221 (1903).
8. **Klavins, J. V.** : Demonstration of striated muscle in the pulmonary veins of the rat. *J. Anat.*, **97** : 239 (1963).
9. **Kosir, A.** : Presence of myocardial tissue in the pulmonary veins of the mouse. Abstract 358 *Excerpta Med.* (I) :18 : 80 (1964).

10. **Nathan, H. and Eliakim, M.** : The junction between the left atrium and the pulmonary veins: an anatomic study of the human hearts. *Circulation*, 34 : 412 - 422 (1966).
11. **Papez, J.W.** : Heart musculature of the atria. *Am. J. Anat.*, 27 : 255 (1920).
12. **Robb, J.S.** : The structure of the mammalian auricle. *Med. Woman's J.*, 41 : 143 - 151 (1934).
13. **Tandler, J.** : Anatomie des Herzens. *Handbuch der Anatomie des Menschen*. von Bardelben., 3 (**Abt. 1**) : 140 - 183 (1913).
14. **Tomas, C.E.** : Muscular architecture of the atria of the hog and dog hearts. *Am. J. Anat.*, 104 : 207 (1959).

## EXPLANATION OF FIGURES

### ABBREVIATIONS

#### USED THROUGH OUT THE FIGURES

Ad.	:	Origin «A».
A.	:	Adventitia.
B.	:	Origin «B».
C.	:	Cardiac muscle fibres in the media.
I.	:	Intima.
L.a.	:	Left auricle.
L.I.P.V.	:	Left inferior pulmonary vein.
L.o.	:	Longitudinal fibres.
L.S.P.V.	:	Left superior pulmonary vein.
R. a.	:	Right auricle.
R.I.P.V.	:	Right inferior pulmonary vein.
R.S.P.V.	:	Right superior pulmonary vein.
S.V.C.	:	Superior vena cava.
V.	:	Ventricle.

All the diagrams are illustrations of the posterior aspect of the left atrium. The arrows show the direction of the fibres from the origin to the insertion. Continuous lines

illustrate fibres in the posterior wall and interrupted lines illustrate fibres in the anterior wall of the left atrium.

Fig. (1) : A diagram illustrating the atrio-ventricular fibrous ring (stripped lines). The position of the two common origins : 'A' and 'B' is also shown.

Fig. (2) : A diagram illustrating bundle 1 (posterior atrio-auricular bundle). It passes horizontally above the fibrous ring and the terminal part surrounds the left auricle spirally. Some fibres extend along the anterior wall of the left atrium joining bundle 2 (interrupted lines).

Fig. (3) : A diagram illustrating bundle 2 (horizontal atrial bundle). The fibres pass to the left and slightly upwards, curve around the left border of the atrium above the left auricle and extend to the right and slightly upwards towards the right atrium in the anterior wall of the left atrium.

Fig. (4) : A diagram illustrating the course of bundle 3 (vertical atrial bundle). The fibres ascend from origin 'A' upwards and to the left, curve around the upper border and descend in the anterior wall downwards and to the left.

Fig. (5) : A diagram of bundle 4 (right atrio-venous bundle). The fibres ascend from origin 'A' in a curved course upwards then surround the right part of the left atrium and the right pulmonary veins spirally.

Fig. (6) : A diagram of bundle 5 (left atrio-venous bundle). The fibres ascend from origin 'B' along the anterior wall of the left atrium upwards and to the left. They curve around the upper border and descend in the posterior wall downwards and to the left. They surround the two left pulmonary veins in a clockwise direction.

Fig. (7) : A diagram showing the fibres of bundle 5 passing between the two left pulmonary veins to surround the superior vein in a clockwise direction and the inferior vein in an anticlockwise direction.

Fig. (8) : A photograph of bundle 5 as illustrated in fig. (7) the arrows show the direction of the fibres around the left pulmonary veins. Bundle 1 and 2 can also be seen. (Magn. X 0.3).

Fig. (9) : A diagram illustrating the course of the fibres of bundle 6 (anterior atrio-auricular bundle). They arise from origin 'B' and extend horizontally to the left and slightly upwards. They curve above the left auricle to ensheath it spirally.

(10) : A diagram of the posterior wall of the left atrium illustrating the course of the six bundles together. The course of the fibres in the anterior wall is not drawn to avoid complexity.

Fig. (11) : A photograph of the posterior wall of the left atrium showing origin 'A' giving origin to bundles 1-4. Bundle 5 below the left inferior pulmonary vein is also seen. The arrows illustrate the direction of the fibres from the origin towards the insertion.

Fig. (12) : A photograph of the anterior wall (anterior view) of the left atrium showing the course of the six bundles in the anterior wall. Bundle 1 curves below the left auricle to ensheath it spirally and send some fibres to join bundle 2. The anterior part of bundle 2 is seen directed towards the right atrium. Bundle 3 is noticed descending deep to the other bundles downwards and to the left. Bundles 5 and 6 are also seen. The arrows point to the direction of the fibres from their origins.

Fig. (13) : A photomicrograph of a part of the transverse section in a pulmonary vein showing its media to be formed of only circular fibres of cardiac muscle. This is the case in the major part (4/5) of the circumference of the vein. (Haematoxylin and eosin-X 90).

Fig. (14) : A photomicrograph of a transverse section in the part of the pulmonary vein (1/5 of its circumference) where the circular arrangement of the

fibres becomes longitudinal and overlaps the original circular layer internally illustrating the spiral arrangement of the cardiac muscle fibres around the pulmonary vein.

(Haematoxylin and eosin-X 90).

Fig. (15) : A photomicrograph of a part of the transverse section of a pulmonary vein showing the insertion of the cardiac muscle fibres in the intima.

(Haematoxylin and eosin-X 90).



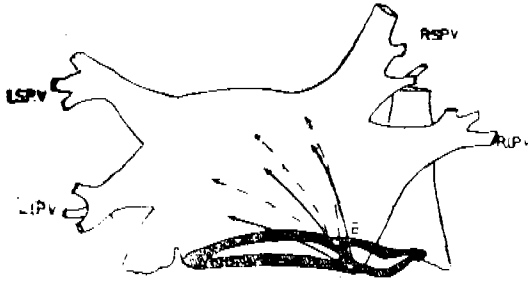


Fig. (1)

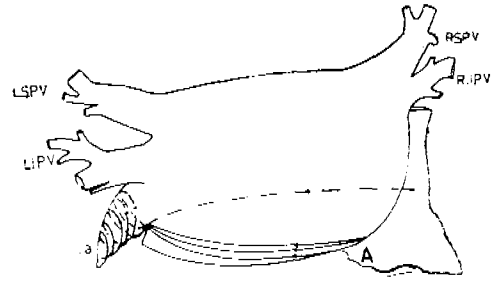


Fig. (2)

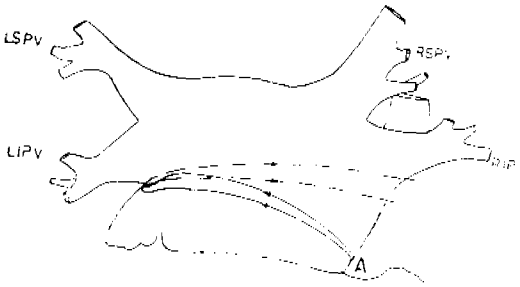


Fig. (3)

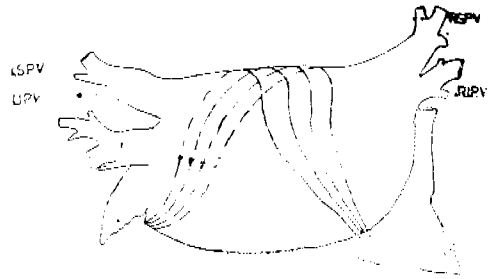


Fig. (4)

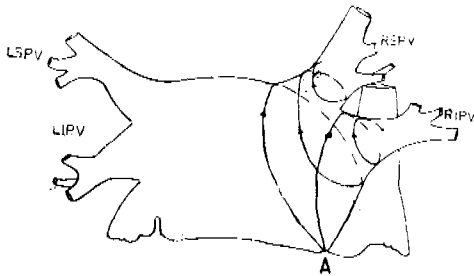


Fig. (5)

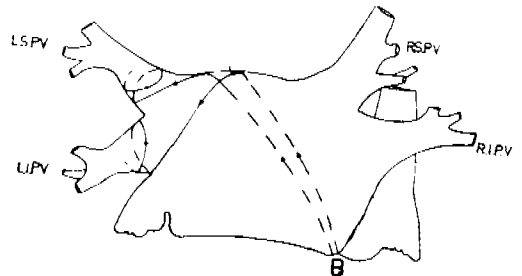


Fig. (6)

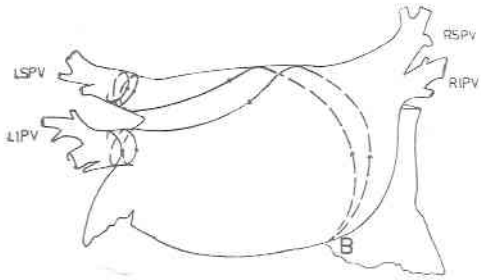


Fig. (7)



Fig. (8)

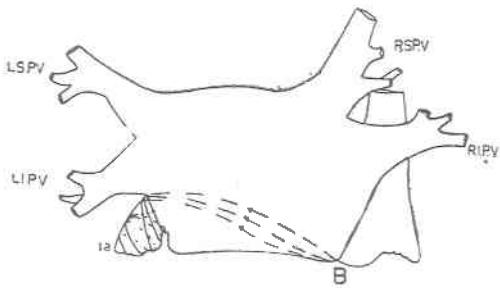


Fig. (9)

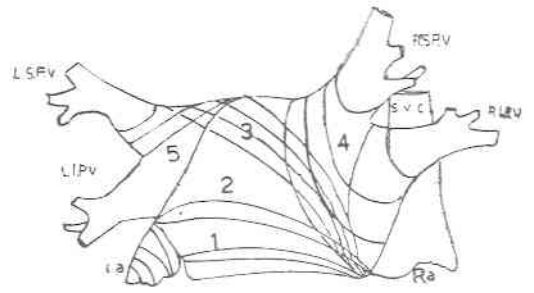


Fig. (10)

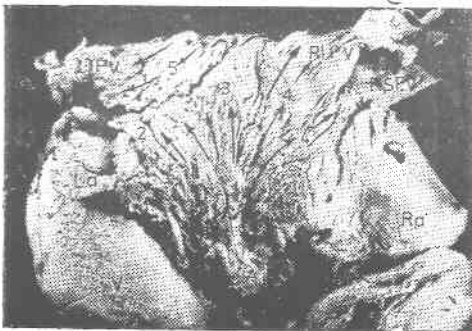


Fig. (11)



Fig. (12)

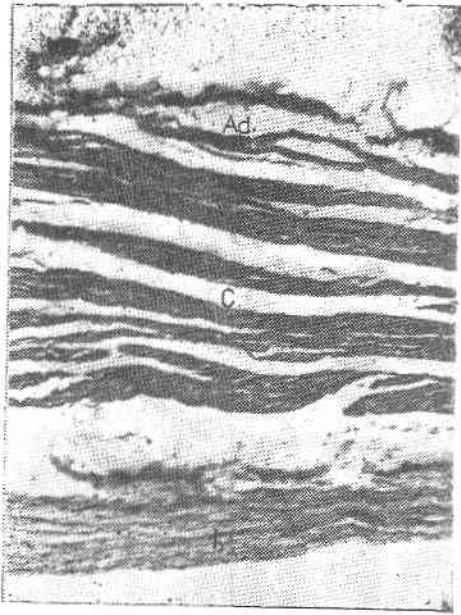


Fig. (13)

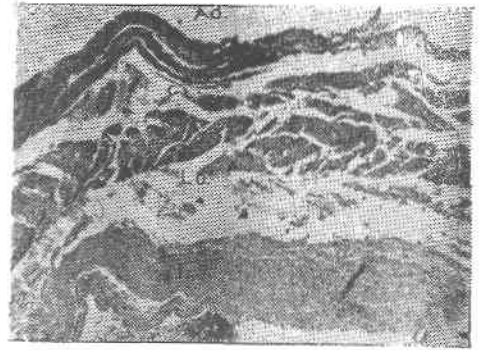


Fig. (14)

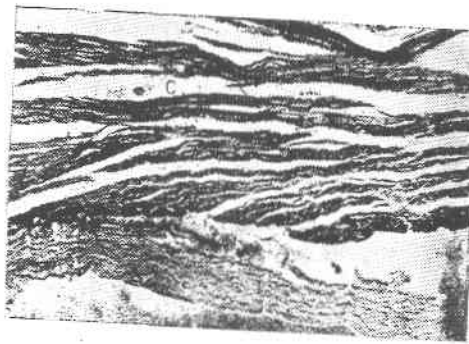


Fig. (15)