The Medial Wall of the Right Atrium

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Although gross anatomic studies are frequently considered to be outmoded and outdated, we believe that because of its present practical importance a renaissance of the clinical anatomy of the heart1 is long overdue. Increasing interest in the group of lesions responsible for the somewhat controversial condition at present called “obstructive cardiomyopathy” or “subaortic stenosis” has already prompted us to review the anatomy of the left ventricular outflow tract2 in the belief that much of the current discussion about function and angiocardiographic appearances pays too little attention to the structural features of the region.

The relationships of the heart and great vessels have, moreover, assumed a new clinical significance as a result of many intracardiac procedures now routinely performed in operating theaters and diagnostic laboratories. Certain palliative3 and radical4-5 operations in patients with transposition of the great vessels, for example, involve removal of part of the interatrial septum, and transseptal puncture6-8 offers a convenient route of entry from the right atrium into the left heart. Such procedures require a detailed and accurate knowledge of the clinical anatomy of the heart, and this current interest in the interatrial septum suggested that it might also be helpful to re-examine the medial wall of the right atrium: especially as the terms “interatrial septum” and “medial wall of right atrium” cannot in our view be regarded as synonymous.

Some years ago Walmsley9-10 stressed the importance of naming cardiac structures with more regard to their position in the living body and suggested that gross anatomy should be more concerned with the heart in situ. Cardiac terminology has a long and complicated history, and in this communication no attempt will be made to review or discuss it except insofar as is appropriate to the right atrium and the structures related to its medial wall as they have been shown to exist both in the living and the dead.

During early fetal life the heart rotates around a vertical axis so that the anterior (or sternocostal) attachment of the interventricular septum is displaced increasingly to the left while the posterior attachment of the interatrial septum is carried to the right. The interventricular and interatrial septa are approximately in the same plane and reach the adult angulation of about 45° to the median plane about midway through fetal life. From this time onward each atrium lies behind and to the right of its corresponding ventricle (fig. 1); the old concept that the atria lay above the ventricles was possibly based on the manner in which a heart tends naturally to be held in the hand of a pathologist or anatomist after its removal from the body.

The official nomenclature of the recent Nomina Anatomica11 however, implies that the heart has been so rotated on its long axis that only one of the three aortic valve cusps (or valvulae) is situated posteriorly (fig. 2). This cusp, therefore, has been called “valvula semilunaris posterior” and the others “valvula semilunaris dextra” and “sinistra,” respectively. Though changed in the Birmingham revision,12 these terms are again identical to those proposed in the Basel Nomina Anatomica of 1895.13

We have demonstrated repeatedly in transverse sections of the thorax of infants, children, adolescents, and adults that only one of the aortic cusps is truly anterior and that the other two, which are in the posterior plane, may justifiably be termed the right and left

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MEDIAL WALL OF RIGHT ATRIUM

Figure 1

Transverse section through thorax of a 90-mm human fetus. At this stage of development the interventricular and interatrial septa have gained the angulation characteristic of the adult heart. The two septa are approximately in the same plane and lie at an angle of about 45° to the median plane: it is for this reason that the right atrium lies as much in front of, as alongside, the left atrium.

posterior aortic cusps (fig. 2). The right coronary artery arises from the middle and most anterior part of the anterior aortic sinus (fig. 2) and the left coronary artery arises from the left posterior aortic sinus. The cusps associated with these sinuses are therefore frequently and justifiably termed the “right and left coronary” cusps; and the right posterior cusp, from which no coronary artery arises, is called the “noncoronary” cusp. There seems little doubt that the course and distribution of the right and left coronary arteries, rather than their true anatomic origin, determined the names given to the cusps by Vesalius,14 the B.N.A.,13 and the most recent Nomina Anatomica.11

The Medial Wall of the Right Atrium

In its upper anterior part, the medial wall of the right atrium is closely related to the aortic root and the first part of the ascending aorta. Figure 3, which is a transverse section through this region, illustrates its proximity to the ascending aorta and only the posterior part of the medial wall constitutes the interatrial septum. This section also demonstrates the important relationship of the right coronary artery, which may be easily reached

Circulation, Volume XXXIV, September 1966
Figure 2
Transverse section of the heart showing the atria, the root of the ascending aorta, and the infundibulum (conus arteriosus) of the right ventricle. This diagram shows the true position of the aortic valve cusps in the living thorax and demonstrates that this is not consistent with the nomenclature given to them in the most recent “Nomina Anatomica.” It also demonstrates that only the posterior half of the medial wall of the right atrium is constituted by the interatrial septum and that anteriorly it is closely related to the aorta.

through either the anterior part of the medial wall of the right atrium or the lumen of the aorta.

The ascending aorta produces a slight ridge on the anterosuperior aspect of the medial wall of the right atrium, which has been termed the torus aorticus. The torus aorticus extends downward to the level of the right posterior aortic sinus and can be seen bulging into the right atrium in figure 4. This frontal section demonstrates the obliquity of the aortic valve and also indicates the relationship that exists between the medial wall of the right atrium, the membranous part of the interventricular septum, and the vestibular (or subvalvar) part of the left ventricular outflow tract.

The right posterior aortic or noncoronary cusp is the lowest of the three cusps, the anterior cusp is intermediate in position, and the left posterior cusp invariably lies at a higher level than either of the other two. For this reason a true horizontal section demonstrating the right posterior cusp and the anterior cusp (fig. 5) passes below the level of the left posterior cusp. This difference in the level of the cusps is reflected in the level of the coronary arteries because, as already stated, the right coronary artery normally arises at a lower level than the left coronary.
MEDIAL WALL OF RIGHT ATRIUM

Figure 3
Transverse section through the heart of a 15-year-old girl at the level of the origin of the right coronary artery. This artery normally rises from the front of the aorta in the region of the anterior aortic sinus. The medial wall of the right atrium at this level is related anteriorly to the ascending aorta and posteriorly through the interatrial septum to the left atrium. On the left side of the ascending aorta lie both the infundibulum of the right ventricle and the pulmonary trunk.

time. The medial relations of the right atrium at this level (fig. 5), therefore, include the pericardial sac, the right coronary artery, the infundibulum of the right ventricle, the anterior and the right posterior aortic sinuses and the interatrial septum.

Many of these relationships may likewise be shown in vertical sections through the right heart (fig. 6) where the sequence from before backward of (1) the infundibulum of the right ventricle and the pulmonary trunk, (2) the obliquely placed ascending aorta and (3) the right atrium may be clearly demonstrated. It is noteworthy that the ascending aorta is separated from the right atrium by only a thin stratum of loose areolar tissue surrounding that part of the transverse sinus of the pericardial cavity which lies immediately posterior to the aorta.

The relationship of the ascending aorta to the medial wall of the right atrium has also been demonstrated in an entirely different manner. An adult heart was dissected in situ and the interior of the right atrium exposed by removing its lateral wall. A finger was passed down the ascending aorta into the right posterior aortic sinus and large headed pins were inserted into the medial wall of the right atrium so that in their passage to the left they passed through the root of the ascending aorta, thus demonstrating the region of the torus aorticus (fig. 7).

The ascending aorta and the inner surfaces of the aortic sinuses were then smeared with
barium sulphate paste and all except three of the pins removed. An x-ray picture of the heart and aorta, taken with these three pins left in situ to constitute “markers” of the torus, has been mounted alongside one from a right lateral cineangiogram taken during opacification of the left heart with sodium metrizoate (fig. 8). These figures demonstrate that the torus aorticus forms the upper and anterior part of the medial wall of the right atrium, and that the root of the aorta extends well down into the middle of the cardiac silhouette when viewed from the true lateral position.

Below the level of the torus aorticus the medial relations of the right atrial wall undergo a radical change (fig. 9). In transverse sections through the lower part of the right atrium the vestibular or subvalvar part of the left ventricular outflow tract replaces the aorta. The aortic vestibule is bounded anteriorly by both the muscular and membranous parts of the interventricular septum and posteriorly by the aortic cusp of the mitral valve. The only barrier between the right atrium and the aortic vestibule is seen to be the membranous part of the interventricular septum (fig. 9).

As has been demonstrated in transverse sections at all levels, the interatrial septum forms only the posterior part of the medial wall of the right atrium, and because of the obliquity of the septum the right atrium lies as much in front of the left atrium as along-
MEDIAL WALL OF RIGHT ATRIUM

Figure 5

Transverse section of the heart of a 15-year-old girl at a slightly lower level than in figure 3. The right posterior cusp and the anterior cusp of the aortic valve can be seen but there is no evidence of the left posterior cusp, which is at a higher level. The right posterior aortic sinus creates a slight bulge on the medial wall of the right atrium—the torus aorticus. Behind the torus aorticus the medial wall of the right atrium is formed by the interatrial septum; in front are the right coronary artery and the infundibulum of the right ventricle.

Figure 6

Vertical section through the right heart of a 7-year-old boy. The infundibulum (conus arteriosus) is seen to lie directly in front of the anterior aortic sinus. The supraventricular crest is a prominent muscular mass in the posterior wall of the infundibulum (IN). The close relationship of the right atrium (R.A.) to the commencement of the aorta (A.) is apparent and the wall of the atrium and the aortic wall are separated only by loose areolar tissue that encloses a part of the transverse sinus of the pericardial cavity. P.T. is pulmonary trunk.
The heart of an adult man photographed in situ. After the thoracic cage and lung were removed the lateral wall of the right atrium was resected. The torus aorticus (T.A.) of the medial wall of the right atrium was then delineated with large headed pins. The torus is seen to lie above the opening of the coronary sinus and is in front of the annulus (limbus) fossae ovalis, which bounds the fossa ovalis in front and above. It will be seen from this specimen that the torus aorticus forms the upper and anterior part of the medial wall of the right atrium.

and illustrate that the area of overlap, demonstrated by the shaded area in figure 10 (C), is small and corresponds closely to the lateral projection (C) in figure 9.

In posteroanterior angiocardiograms the area of overlap is also seen to be relatively small and in this plane, too, the x-ray pictures and anatomic specimens show a close correlation; emphasizing as a point of practical importance that because the septal plane is at an angle of approximately 45° to the median plane, the left atrium is best entered from the right atrium in the right anterior oblique projection.

The complexity of the medial wall of the right atrium explains why it may be modified in certain types of heart disease, particularly when lesions of the mitral and aortic valves cause selective enlargement of the left atrial or aortic components. The left atrium, for example, may be so distended that the right
MEDIAL WALL OF RIGHT ATRIUM

Figure 8

(A) A radiograph of the heart shown in figure 7. All the pins except the three that are readily apparent were removed, and the inner surface of the ascending aorta and aortic sinuses were coated with barium sulphate paste. (B) A frame from a right lateral cineangiogram taken during opacification of the left heart is mounted alongside for comparison.

atrium assumes a crescent-shaped form extending over its convex anterolateral surface, or the aortic root may cause a considerable bulge on the upper anterior part of the medial wall of the right atrium. Other lesions of the aortic root, such as sinus of Valsalva aneurysms may also alter the normal anatomic relationships of this region and study of the sections presented will explain their usual sites of presentation.

Discussion
Few procedures highlight the relations of the medial wall of the right atrium so dramatically as transseptal puncture; some workers report no serious complications in large series, but others have recorded morbidity rates of 5.5% and 4.7%.15, 16 Accidental puncture of the free wall of the right atrium, always a hazard during right heart catheterization, especially in infants and small children, has also been reported in several adult cases16, 19–24 during attempted transseptal puncture and has led to tamponade that on occasions has proved fatal. In other cases, puncture of the right atrial wall—undetected at the time—has been assumed later because of blood found in the pericardial sac during operation.15, 21, 25 Though the site of rupture may be difficult to locate, the relations of the right atrium demonstrate that both the anterior and posterior pericardial spaces may be entered should an attempt be made to pass through the medial wall of the right atrium at either
Transverse section of the heart of a 15-year-old girl below the level of the torus aorticus. The left ventricular outflow tract (the aortic vestibule) has replaced the aorta anteriorly as a medial relation of the right atrium, and the two are separated merely by the membranous part of the interventricular septum. The interatrial septum is again seen to form only the posterior part of the medial wall, and the area of overlap between the atria has been projected to the surface in the anterior (A), right anterior oblique (B), and lateral (C) planes.

The safest place to puncture the interatrial septum, or to commence its removal, is through the fossa ovalis where the interatrial tissue is thin and fibrous. Identification of the annulus (limbus) fossae ovalis is an important aid to exact location of this place, and provides a useful landmark for the eye, or guide to the exploring finger or catheter tip. One of us has performed a large number of left heart catheterizations from this site through foramina that were either probe patent or made so, without incident. It must be remembered, however, that the A-V node and bundle of His lie in the lower anterior part of the medial wall of the right atrium near the junction of the interatrial and interventricular septa and that troublesome disturbances of conduction may arise from too vigorous probing in this area. Such transient disorders of rhythm are less likely to occur.
MEDIAL WALL OF RIGHT ATRIUM

if the tip of the catheter is immediately maneuvered to engage the undersurface of the annulus fossae ovalis, and during this procedure frequent reference should be made to the lateral x-ray screen in order to avoid the lower anterior region of the medial wall. Biplane television screening greatly facilitates and adds to the safety of such procedures.26

The most vulnerable structure in the medial wall of the right atrium is the root of the aorta, which has been inadvertently punctured many times15, 16, 22, 25 during attempts to enter the left atrium, and the illustrations in this paper have been selected to show the extensive and intimate relationship that exists between these two structures. Perhaps less well appreciated are the relations of the right coronary artery and the left ventricular outflow tract.

The coronary arteries are now recognized to be at risk during various types of diagnostic investigation. Coronary occlusion and subsequent myocardial infarction have been reported during retrograde thoracic aortography,27 and during right heart catheterization in Fallot's tetralogy28 when the catheter tip was passed upward into the overriding aorta through the defective interventricular septum. Coronary symptoms with electrocardiographic changes suggestive of acute coronary insufficiency19 have been reported during transseptal catheterization. Though angina has often been attributed to "shock," and occlusion to embolism, it would appear evident that direct or indirect trauma to the right coronary vessels must be considered as a possible or even likely cause of such complications (figs. 4 to 6).

Traumatic atrial septal defects have resulted from needle puncture of the interatrial septum,16, 29 and transseptal left heart catheterization without needle puncture has also been described.30 So far as we know, there has been no published account of a traumatic defect between the right atrium and the left ventricle, but the close anatomic relationship that exists between these two chambers (fig. 9) certainly makes this a distinct possibility.

Summary

The correct orientation of the heart in situ has been stressed and the anatomic relationships of the medial wall of the right atrium have been described and illustrated.

Each atrium lies behind and to the right of its corresponding ventricle and, as the plane of the septa is angled at approximately 45°...
to the median plane, the right atrium lies as much in front of the left atrium as alongside it.

The area of overlap between the atria is small in both the anteroposterior and lateral views and the interatrial septum, which constitutes only the posterior half of the medial wall of the right atrium, is most accessible in the right anterior oblique projection.

The anterior half of the medial wall of the right atrium is closely related from above downward to the first part of the aorta including the aortic valve, and to the left ventricular outflow tract through the membranous part of the interventricular septum. The right coronary artery and the right ventricular outflow tract are also important anterior relations.

Transverse sections of the thorax in all age groups have shown that only one aortic valve cusp is truly anterior and it is suggested that the terms anterior, and right and left posterior should be used to designate the cusps and sinuses of the aortic valve.

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Physiology does not consist in a knowledge of recondite phenomena, of difficult names, and of complicated instruments. It should fundamentally consist in the living mental picture of what the great organs below a man's skin are like, what they are doing, how they can be examined, what happens when they are not working properly, how their actions hang together, how they may be influenced for good and for evil. But physiology, as it is written, contains more than this, and, in sparing measure, it is well that the 'Institutes of Medicine' should not be restricted to the visibly 'useful,' or to the obviously 'utilisable.'—Augustus D. Waller: An Introduction to Human Physiology, ed. 2. New York, Longmans, Green, & Co., 1893, p. vii.
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