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ANATOMICAL FEATURES OF RIGHT ATRIUM

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Abstract

The anatomy of the inside surface of the right atrium became more interesting with the development of ablation techniques for treatment of atrioventricular nodal reentry tachycardia (AVNRT).

The aim of this study was to present the dimensions of the ostium of the coronary sinus, the tricuspid valve anulus and the triangle of Koch, and to describe the arrangement of the superficial atrial muscle fibers in and around the area of the triangle of Koch.

The examination was made on 100 human hearts obtained after autopsies of patients who died from no cardiac reasons. The diameter of the orifice of the coronary sinus, the circumference of the tricuspid valve anulus and the dimensions of the triangle of Koch (sides a, b, c and the area) were measured and the arrangement of the superficial, subendocardial muscle fibers was analyzed.

The mean values of the lenght of the side a was 26.1 ± 3.0 mm, side b 20.2 ± 3.6 mm and side c 24.5 ± 2.5 mm. The mean value of the area of the triangle of Koch was 256, 2 ± 6.7 mm^2.The mean value of the diameter of the ostium of the coronary sinus was 9.3 ± 1.8 mm.The mean value of the length of the tricuspid leaflet was 107.8 ± 10.3 mm. We presented the usual pattern and the variations of atrial subendocardial muscle fibers orientation.

Key words: right atrium, triangle of Koch, coronary sinus, tricuspid valve

Introduction

The anatomy of the inside surface of the right atrium became more interesting with the development of ablation techniques for treatment of atrioventricular nodal reentry tachycardia (AVNRT) (1, 2).

The interior surface of the right atrium consists of three parts: a smooth-walled venous component, posteriorly, leading anteriorly, to the vestubule of the tricuspid valve and the auricule. The smooth-walled venous part receives the opening of the venae cavae and coronary sinus. The wall of the vestibule has a ridged surface and that of the auricle is trabeculated (3).

The *superior vena cava (vena cava superior - SVC)*, that returns the blood from the upper half of the body, opens into the upper and back part of the atrium, the direction of its orifice being downward and forward. Its opening has no valve.

The *inferior vena cava***,** larger than the superior, returns the blood from the lower half of the body, and opens into the lowest part of the atrium, near the atrial septum. Its orifice is directed upward and backward, and, along its lateral, or right margin it is guarded by a flap-liked valve of varyng size, the *valve of the inferior vena cava* (*Eustachian valve*). The valve is a fold of endocardium. It is semilunar in form, its convex margin being attached to the anterior margin of the orifice; its concave margin, which is free, ends in two cornua, of which the left is continuous with the anterior edge of the limbus of oval fossa while the right is lost on the wall of the atrium. In the fetus this valve is of large size, and serves to direct the blood from the inferior vena cava, through the foramen ovale, into the left atrium. In the adult it occasionally persists, and may assist in preventing the reflux of blood into the inferior vena cava; more commonly it is small, and may present a cribriform or filamentous appearance.

The *coronary sinus (sinus coronarius - SC)* opens into the right atrium, between the orifice of the inferior vena cava, the oval fossa and the vestibule of the atrioventricular opening. It returns the majority of blood from the heart itself and is it is often guarded by a thin, semicircular valve, the *valve of the coronary sinus (valve of Thebesius*). The upper part of this valve joins with the Eustachian valve and from this commissure, a tendinous structure, called the *tendon of Todaro*, runs forward to the sinus septum (the septum between the sinus septum and the oval fossa), and inserts into the central fibrous body..

The *foramina venarum minimarum (foramina Thebesii*) are the orifices of minute veins (*venaecordis minimae)*, which return blood directly from the muscular substance of the heart.

Antero-inferior in the right atrium is the large, oval vestibule leading to the orifice of the tricuspid valve.

A triangular zone (*the triangle of Koch*) is found between the attachment of the septal leaflet of the tricuspid valve, the anteromedial margin of the orifice of the coronary sinus, and the round, collagenous, palpable, subendocardial tendon of Todaro. The triangle indicates the site of the atrioventricular node and its atrial connections.

Anterosuperior to the insertion of the tendon of Todaro, the septal wall is the atrioventricular component of the membranous septum, intervening between the right atrium and subaortic outlet of the left ventricle. The atrial wall bulges anterosuperiorly above the membranous septum. This area is the aortic mound (torus aorticus) and marks the location of the non-coronary sinus of the aorta with its enclosed valvar cusp.

The *fossa ovalis* is an oval depression on the septal wall of the atrium, and corresponds to the the foramen ovale in the fetus. It is situated at the lower part of the septum, above and to the left of the orifice of the inferior vena cava.

The *limbus fossae ovalis* (*annulus ovalis*) is the prominent oval margin of the fossa ovalis. It is most distinct above and at the sides of the fossa; below, it is deficient. A small slit-like valvular opening is occasionally found, at the upper margin of the fossa, leading upward beneath the limbus, into the left atrium; it is the remains of the fetal aperture between the two atria.

The *intervenous tubercle* (*tuberculum intervenosum; tubercle of Lower*) is a small projection on the posterior wall of the atrium, above the fossa ovalis. It is distinct in the hearts of quadrupeds, but in men is scarcely visible. It was supposed by Lower to direct the blood from the superior vena cava toward the atrioventricular opening.

The right atrium, in and around the triangle of Koch, can be divided into four areas with relativevly similar orientation of the superficial muscle fibers (4). The variability in the arrangement of these fibers may be one of the factors influencing the route for impulses entering the AV node, which is located beneath the intersection of sinus septal, vestibular and anterosuperior areas. The posterorinferior area located behind and beaneath the orifice of the coronary sinus, contains mostly longitudinaly oriented fibers that extend from pectineate muscles to the isthmus between the orifice of the coronary sinus and the septal leaflet of the tricuspid valve. The sinus septal (SS) area is made up of circumferential fibers that run between the orifices of coronary sinus and inferior vena cava, encircling the oval fossa. The fibers in the vestibular (V) area provide a continuation of the P fibers toward the AV node, but also turn in a spiral pattern around the orifice of the coronary sinus as well as anteroposteriorly to join the SS fibers. Anterosuperior (A) area generaly contains two groups of superficial fibers: circumferential fibers passing in front of the oval fossa, and longitudinal fibers protruding over the AV node.

The **aim** of this study was to present the dimensions of the ostium of the coronary sinus, the tricuspid valve anulus and the triangle of Koch, and to describe the arrangement of the superficial atrial muscle fibers in and around the area of the triangle of Koch.

Material and methods

The examination was made on 100 human hearts obtained after autopsies of patients who died from no cardiac reasons. The hearts were removed intact, together with the proximal parts of the great arteries and veins, and fixed in 10% formaldehyde, for at least 72 hours. The right atrium was opened through an incision between the superior and inferior caval venous orifices, and then by extending an incision perpendicular to the first along the lateral wall of the atrium into the right appendage.

The diameter of the orifice of the coronary sinus, the circumference of the tricuspid valve anulus and the dimensions of the triangle of Koch were measured by caliper. The numeric values of the triangle of Koch were determined by measuring its sides (a, b, c): side a is the length of the tendon of Todaro, side b is the distance from the tendon of Todaro to the septal leaflet of the tricuspid valve (at the right angle to the leaflet) passing through the coronary sinus and side c is the distance from the insertion of the side b to the central fibrous body, along the septal leaflet of the valve. The area of the triangle is calculated as $P = b \times c/2$.

For analyzing the arrangement of the superficial muscle fibers, the right atrium was divided into four areas: posteroinferior (P), sinus septal (SS), vestibular (V) and anterosuperior (A) (Fig.1). Atrial endocardium was carefully peeled, and inspected using magnifying glass (x10). The orientation of the fibers was described as: horizontal (parallel to the AV junction), longitudinal (parallel to the interatrial groove at the right angle to the AV junction) and oblique (oblique to the AV junction).

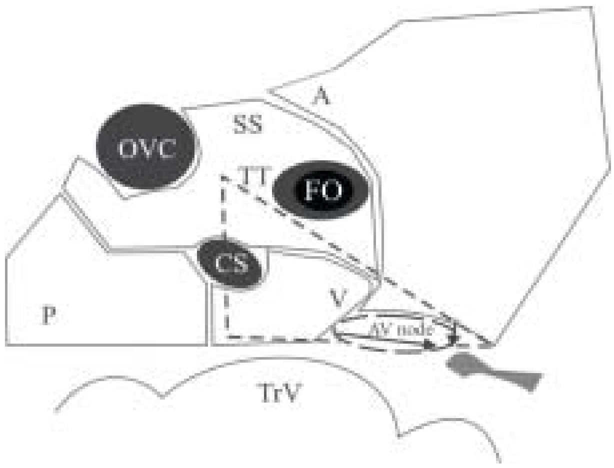

Fig. 1. Right atrium divided into four areas: posteroinferior (P), sinus septal (SS), vestibular (V) and anterosuperior (A)

Results

The results obtained for the dimensions of the triangle of Koch have shown that the mean value of the length of side a was 26.1 ± 3.0 mm, of side b 20.2 ± 3.6 mm and of side c 24.5 ± 2.5 mm. The mean value of the area of the triangle of Koch was 256. 2 ± 6.7 mm^2.

The mean value of the diameter of the ostium of the coronary sinus was 9.3 ± 1.8 mm.

The mean value of the length of the tricuspid leaflet was 107.8 ± 10.3 mm.

The analysis of the arrangement of the atrial subendocardial muscle fibers yieldedthe folowing results:

In the posteroinferior (P) area superficial, sudendocardial muscle fibers had longitudinal orientation in 91%, oblique orientation in 6% and horizontal in 3% of the specimens.

In the vestibular (V) area 95% of specimens had horizontal orientation of the subendocardial fibers, 3% had oblique and 2% longitudinal fiber orientation.

In the sinus septal (SS) area 94% of specimens had horizontal fiber orientation, 5% oblique and 1% longitudinal orientation.

In anterosuperior (A) area two types of fiber orientation (oblique and horizontal) were present in 90% of cases. In 7% of specimens the endocardial fibers had longitudinal and in 3% oblique orientation of muscle fibers.

Discussion

Authors who perform electrophysiological procedures of radiofrequent catheter ablation (Mc Guire), consider that the triangle has uniform size among patients and they analyze the triangle in boundaries that are significantly smaller than the anatomically accepted ones (5). These data present values obtained indirectly using mathematical formula, during electrophysiological procedures or under direct vision during surgical procedures for cure of supraventricular tachycardia. These authors were interested in the part of the anatomically accepted area of the triangle of Koch alone, since AV node tissue and slow and fast conducting pathways, are located near the apex of the triangle, 1 cm in front of the orifice of the coronary sinus, which is within the scope of this measuring. The results obtained with the postmortal measuring of the anatomical boundaries of the triangle of Koch in our study, are in agreement with published data, and have demonstrated differences in the area of the triangle among patients (5, 6).

During electrophysiological procedures the ostium of the coronary sinus (OCS) provides a useful route for mapping and ablation of left-sided accessory pathways. In addition, the OCS is an electrophysiologically active structure. Previous studies have demonstrated the capability of spontaneous depolarization and slow conduction in the smooth muscle of the CS, providing inherent automaticity (7, 8). Also, the atrial myocardial sleeve that covers the proximal CS provides the ability for conduction and automaticity, forming an electrical connection between the two atria. Studies have shown that this connection is of clinical importance as it may be a source of arrhythmias such as atrial fibrillation (9). Active myocardium within the CS may serve either as a source for abnormal automaticity generating a focal tachycardia or as a part of a reentrant circuit. In patients with atrial fibrillation, CS myocardium may also initiate recurrent atrial fibrillation. Since the CS is one of the connections between the right and left atria, with Bachmann's bundle forming the other important connection, reentrant tachycardia involving the CS muscle and both atria are sometimes seen in patients with marked atrial enlargement, especially after a surgical maze procedure.

Marked changes in fiber orientation in the zone of intersection of fibers from SS, V and A areas (at the apex of the triangle of Koch) could account for discontinuity in the spread of the excitatory wave front (2, 10, 11, 12). In our study 91% of examined specimens had the usual architecture of the subendocardial atrial muscle fibers, and most variations were in area A (longitudinal fiber orientation in 7% of the specimens), which was in agreement with the literature. Privious studies have shown that conduction of the impulses within the muscular walls of the atriums reflect the arrangement of well developed muscular bundles. Experimentaly were demonstrated two broad bands of atrial approaches to the AV node, one from the inferior region beneath the orifice of the coronary sinus (V area), and the other from the SS area (2, 6, 10). These approaches reflected the geometry of the right atrium produced by the orifices of the caval veins, the coronary sinus, and the oval fossa.

The relationship between the above described gross morphologic picture of the atrial approaches and the compact AV node is of enormous importance. The orientation of the superficial muscle fibers correlated with the known patterns of activation. Propagation of impulses in a direction parallel to muscle fibers is faster than propagation in a direction at right angles to the fiber (anisotopic conduction). Thus, the variability in the orientation of the fibers in the approaches may influence the input of impulses to the AV node. The variation of changes in orientation from one area to another, or within the same area, may potentiate reentrant circuit.

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