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Morphological and biometric characteristics of the pectinate muscles and the taenia sagittalis of the right atrium in the human heart

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SUMMARY

The crista terminalis (CT) is a well-defined fibromuscular crest formed by the union of the venous sinus and the primitive right auricle, which extends along the posterolateral face of the right atrial wall. The pectinate muscles (PM) are muscular crests which extend anterolaterally from the CT to the auricle and may present in a series of variable shapes and sizes. The biggest and most prominent PM is called the taenia sagittalis (TS). PM with highly trabeculated muscle fibres predispose patients to the occurrence of arrhythmias. The present article is a descriptive study of the anatomical and biometric characteristics of the right atrium. We studied 30 hearts of adult Chilean individuals, aged between 18 and 84 years, of both sexes, with no apparent cardiac pathology, belonging to the Normal Human Anatomy Unit of the Basic Sciences Department of Universidad de La Frontera. The samples were washed with distilled water and immediately placed in formalin at 10%. The atria were first separated from the ventricles, then opened perpendicularly through the intercaval zone to give access to the interior. The distribution of pectinate muscles found, according to the classification of Loukas et al. (2008) and Siddiqui et al. (2013), was as follows: Type I, 20%; Type II, 23.3%; Type III, 23.3%; Type IV, 6.7%; Type V, 6.7%; Type VI, 20%. TS was found to be present in 46.6% of the hearts examined, two or more TS in 29.8% and no TS in 23.6%. The length of the pectinate muscles is variable; the shortest are located on the medial wall. Six types of pectinate muscle patterns were observed.

Key words: Pectinate muscles – Right atrium – Human heart – Biometry

INTRODUCTION

The crista terminalis (CT) is a well-defined fibromuscular crest formed by the union of the venous sinus and the primitive right atrium, which extends along the posterolateral face of the right atrial wall (Salustri et al., 2010). It is an important anatomical feature due to its close association with the sinoatrial nodal artery and the origin of the pectinate muscles (PM). These muscles are crests which extend anterolaterally from the CT to the auricle and may present in a series of variable shapes and sizes. The biggest and most prominent PM, which forms the internal bridge of the sulcus terminalis, is called as taenia sagittalis (TS) (Siddiqui et al., 2013). The PM run in an anteroposterior direction. The fibres appear parallel or perpendicular to the CT, with many or few junctions between them; this may result in the formation of trunks, on the basis of which atria have been classified into types, as presented in the work of Loukas et al. (2008) and Siddiqui et al. (2013). These authors found six (6) patterns, various of which predispose patients to the occurrence of arrhythmias.

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On the other hand, clinical problems of the morphology of PM have been described, such as cardiac catheterisation (Siddiqui et al., 2013), and in common heart flutter, as the CT has been described as a natural barrier to the cardiac conduction system (Loukas et al., 2008). In addition, the cardiac isomerism mentioned by Mori et al. (2019), using virtual dissection, should be considered, and this should be borne in mind when observing the interior of the cardiac cavities. Studies using transthoracic echocardiography have shown that two thirds of cases of right focal atrial tachycardia, observed in the absence of structural cardiac disease, develop along the CT. CT ablation has also been used in patients with inappropriate sinus tachycardia. The CT is the most obvious pectinate muscle, and the thickness of the right atrial wall is not uniform due to the variable patterns of the PM and TS (Siddiqui et al., 2013). PM with highly trabeculated muscular fibres predispose patients to the occurrence of arrhythmias.

Although the literature shows some studies on the Morphological characteristics of PM in relation to CT, it is necessary to complement the knowledge about them. This research is aimed at describing the anatomy and biometry of the pectinate muscles, as well as to standardize their distribution.

MATERIALS AND METHODS

This was a cross-sectional descriptive study focusing on the morphological and biometric characteristics of the PM located in the right atrium of 30 human hearts of adult Chilean individuals.

Samples

We studied a total of 30 hearts, belonging to the Normal Human Anatomy Unit of the Basic Sciences Department of Universidad de La Frontera. The hearts belonged to individuals of both sexes between the ages of 18 and 84 years, with no apparent cardiac pathology.

Fixing

The hearts were fixed in a formalin solution at 10%, after washing in running water. After the fixing period, the hearts were removed from the formalin and washed again in abundant running water to remove the excess formalin from the cardiac cavities. This process was carried out on each heart individually.

Dissection

First the atria were separated from the ventricles (in 26 hearts) by cutting at the level of the coronary sulcus. In four special cases, only the right atrium was opened, but the ventricle was not separated. These were opened in the intercaval area, and then with a perpendicular incision following the coronary sulcus to lateral and anterior in order to open the atrial cavity and expose the PM. Dissection of the posterior wall allowed the atrium to be opened like a book; to improve the visibility of the interior, the edges were pinned to a polystyrene plaque (Fig. 1).

Information collection

A fine copper wire was used, attached to a pin at the top (CT); the wire was extended following the curves of the musculature to the inferior edge

Table 1. Distribution patterns of the pectinate muscles.

Type	Morphology	Number of samples	Occurrence %
I	TS absent Common branching trunk Few junctions	6	20
II	One TS present Common branching trunk Numerous junctions	7	23.3
III	Very similar to Group II but with few or not many junctions	7	23.3
IV	Two TS in a velamen-like arrangement common trunk, branching disorganised junctions	2	6.7
V	Two TS in a velamen-like arrangement More than 1 common trunk Few junctions	2	6.7
VI	More than one TS, special distribution with or without a common trunk Few junctions	6	20

Fig 1. Opening the atrium and fixing on polystyrene. Type I, characterised by absence of the taenia sagittalis.

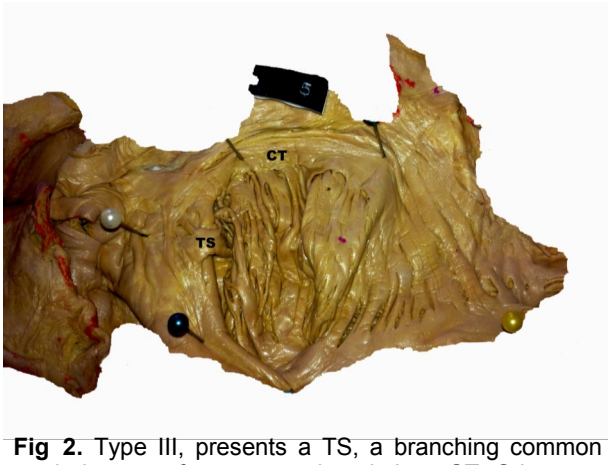

Fig 2. Type III, presents a TS, a branching common trunk, but very few or no trabeculations CT: Crista terminalis, TS: Taenia sagittalis.

(vestibule), the length of the thread was immediately recorded using a Vernier Digital Calliper. The thickness of the PM were then measured: the measurements are shown in table 1. The number of MP originating at the CT was counted, as was the number of PM terminating in the zone of the atrioventricular vestibule. The number of junctions between the muscles was also recorded, together with the presence or absence of the TS.

Morphological analysis

The MP were registered on the basis of the classification presented by Loukas et al. (2008) and García et al. (2010), considering the arrangement of the muscles from their origin, their branching from a common trunk and their junctions. The number and arrangement of taenia sagittalis were also included.

For all groups, the common origin was considered to be the crista terminalis, with perpendicular orientation to the limit formed by the vestibule of the atrioventricular ostium. Given these considerations, the six types found are classified as follows: Type I, characterised by absence of the taenia sagittalis. The pectinate muscles terminate in the vestibule forming a common trunk with branching, found in the majority of cases. There were few junctions between the PM in their course (Fig. 1). Type II presents a TS. The arrangement of the PM is variable; towards the vestibule they form a common trunk and consequently a branching pattern is apparent. Type III presents a TS, a branching common trunk, but very few or no trabeculations (Fig. 2). Type IV: two TS are observed, with a branching common trunk and a series of non-uniform or disorganised junctions (Fig. 3). Type V: two TS are detected, with more than one branching trunk, but few junctions. Type VI: the PM maintain their origin in the CT, but do not always descend perpendicularly from the crest. Some are parallel to it; their distribution has no precise order, and they run in different directions. Some highly trabeculated zones are observed, especially as a result of junctions between the TS and the MP (Fig. 4). The TS is very marked and originates from the CT, from which it descends obliquely towards the vestibule.

RESULTS

After observing the characteristics of each sam-

Fig 3. Type IV, two TS are observed, with a branching common trunk and a series of non-uniform or disorganised junctions. CT: Crista terminalis, TS: Taenia sagittalis.

Fig 4. Type VI, some are parallel to it; their distribution has no precise order, and they run in different directions. Some highly trabeculated zones are observed, especially as a result of junctions. CT: Crista terminalis, TS: Taenia sagittalis.

ple and analysing the different distribution patterns of the pectinate muscles in the atrium (according to the direction they take or the junctions between them), they were classified into six types as shown in Table 1. The mean length recorded for the pectinate muscles that originate in the CT was 13.8 mm; the mean length of those which terminate in the area of the vestibule, either freely or through a common trunk, was 34.33 mm. The mean number length of the junctions in the course of the pectinate muscles from the CT to the vestibule was 6.32. The TS was present in 76.4% of all the samples, and of these, 29.8% contained more than one TS, Table 2.

The great majority of the samples presented few trabeculations, or junctions between the muscles; if a junction between any two pectinate muscles is counted only once, the mean number was 6 junctions. This differs from what is apparently observed, since many pairs of fibres (PM) presented various junctions in different zones along their course from the CT to the vestibule.

Table 1. Classification by presence of taenia sagittalis (TS).

Type	Occurrence (%)	Morphology
Type A	23.6	no TS
Type B	46.6	one TS
Type C	29.8	2 or more TS

DISCUSSION

The PM originate at the CT, which is located on the anterior wall of the atrium, and course to the vestibule; this finding agrees with Loukas et al., 2008; Sánchez-Quintana et al., 2002; Siddiqui et al., 2013). In the present study, the arrangement and course of the muscle fibres was not constant, as reported by Ho and Sánchez-Quintana, 2009 and Sánchez-Quintana et al., 2002; junctions occur between contiguous PM over their course (producing trabecular tissue), with one or more junctions along the course of each muscle fibre (Sánchez-Quintana et al., 2002). This may be one of the causes which predisposes individuals to suffer different types of arrhythmia.

The PM may also come together as they reach the vestibule, forming one or more common trunks. As mentioned above, the fibres may form different patterns. One of these is in the form of a velamen extending from the CT to the vestibule and consisting of larger calibre fibres with numerous junctions; this might have serious implications during procedures like catheterisation (Loukas et al., 2008; Siddiqui et al., 2013).

Regarding the morphometry of the structures of the right atrium, Sánchez-Quintana et al. (2008) measured the terminal crest in terms of its width and thickness (average measurement 51 mm and 0.8 mm, respectively), and the average TS length of 12 mm. García et al. (2010), obtained measurements of the average length of the right atrium 64.85 mm, TS 28.7 mm and CT 60.5 mm. Unlike these studies, this study provides information about the approximate number of pectinate muscles per atrium averaging 13.8 MP, their average individual length was 34.33 mm (from the terminal crest to the vestibule), the average thickness was 1.91 mm and the number of joints that can exist between them averaged 6.32 joints. With respect to the latter (Sánchez-Quintana et al., 2002), it indicates that the majority of PM present abundant unions among themselves, which is consistent with what was observed in this study.

Morphological and biometric analysis of the pectinate muscles identified six distinct patterns, as reported by Loukas et al. (2008); and Siddiqui et al., (2013). Type IV, with a branching appearance, coincides for all authors, although in the present study it was one of the least frequent. It should be noted that Type VI not only presents more than one TS or prominent MP, but that its morphology differs profoundly from all the other patterns found; furthermore, it was found more frequently in the present study than in those of Loukas et al. (2008), García et al.(2010) and Siddiqui et al. (2013).

The sagittal tapeworm was classified according to its presence results that describe it mostly coincide with the consulted authors, and can be reviewed in Table 3.

The results for the TS in this work, considering the “n” of samples, are comparable to those of García et al. (2010); however, there is a clear difference in that those authors found a higher percentage of atria with no TS, i.e. in group A. For their part, the data from Loukas et al. (2008) in group A are comparable to our data, which showed 15%, which is comparable to the result of 23.6% in the present study. Turning to the atria that presented one TS, Group B in García et al. (2010) presented a frequency of 28%; in Loukas et

Table 3. Presence of taenia sagittalis (TS) in human hearts, in different studies.

Taenia Sagittalis	Loukas et al. 2008	García et al. 2010	Siddiqui et al. 2013
no TS	15%	44%	20%
one TS	65%	28%	55%
more than one TS	20%	28%	25%
N	300	25	151

al. (2008) on the other hand this was the largest group, with 65%. The same was true of the present study, with 46.6%.

Finally, we comment on the atria that presented more than one TS, Group C: in the present study, as in Loukas et al. (2008), this group was more numerous than Group A. All three studies found a percentage of approximately 26%. However, in García et al. (2010) the percentage was the same as found for Group B. The different Groups and percentages reporting the presence of TS are shown in Table 3. Finally, Siddiqui et al. (2013) report fairly similar figures to the other authors: the largest group in their study was Group B, with 55%, while the other two groups contained similar percentages as in the authors cited previously.

With respect to the number of pectinate muscles, only Papez (1920) has given an approximate number: in accordance with the division of the right atrium that he uses, he indicates that approximately 9-14 muscles originate from the right anterior crest, while around 10 muscles originate from the posterior crest. These results are similar to the present work since the ones that have their origin from the terminal ridge are 13.

It is worth mentioning that in the present study a quantification of the joints between the pectinate muscles along their path from the terminal ridge to the vestibule was performed. However, these data are not comparable with other studies, which only mention the junctions or trabeculations without recording their number.

It is important to carry out a deeper study of the junctions between the PM, and of the presence and arrangement of the TS. In discussion of the junctions between the pectinate muscle fibres, several of the authors mentioned indicate that a larger number of junctions might lead to the occurrence of certain pathologies related to nervous conduction, such as arrhythmias (Sánchez-Quintana et al., 2008).

Finally, we note the existence of case reports in which the authors mention variation in the CT – the structure where the PM originate – which presents variations in calibre and may be very prominent (Rusu, 2007; Salustri et al., 2010; Na et al., 2011). This could cause disturbances in blood flow or the nervous conduction system, or cause erroneous diagnosis for example of a tumour.

The presence and disposition of TS was considered, and it could be an obstructive element during the performance of procedures, such as catheterization.

It is therefore important to carry out more specific studies of these structures, which could be very helpful in clinical practice.

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