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Morphological study of Crista terminalis and Musculi pectinati with its Applied Significance

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A B S T R A C T :

Introduction:

The **crista terminalis** is a muscular ridge. it begins on the right side of the superior vena caval orifice, then runs across the inner aspect of the right atrium, ultimately ends at the right side of the inferior vena caval orifice.[1]

CT serves as a crucial anatomical landmark due to its proximity to the MP and sinoatrial nodal artery, highlighting its importance in cardiac anatomy and clinical applications.[2]

The **musculi pectinati** (MP) are myocardial ridges that originate from the crista terminalis and extend towards the auricle, varying in number, shape, and size.[3]

Materials and methods:

This research included 30 human cadaveric hearts of both male and female cadavers.

This research was conducted at the **Department of Anatomy, J. N. Medical College, Belagavi,** on 30 formalin-preserved human hearts.

The superior vena cava and inferior vena cava were cut open along a linear axis posteriorly, allowing for optimal exposure of the right atrium.

The second incision was made at a 90-degree angle to the original cut, parallel to the coronary sulcus and 6 different patterns were observed.

Results:

Type 1: MP oriented nearly 90º to CT (56.66%)

Type 2:MP oriented parallel to CT (3.33%)

Type 3: Combination of Type 1 and Type 2 (6.66%)

Type 4: Branching of the MP (20%)

Type 5: Interlacing trabeculation (3.33%)

Type 6: Prominent muscular column of MP (10%)

Conclusions:

The findings underscore the 6 different patterns and complexity of the CT and MP, highlighting their potential function in the development of cardiac arrhythmias, such as AFL and AF.

The identified morphological variations may interfere with the heart's electrical conduction system, leading to the onset of arrhythmias. This knowledge can help clinicians to diagnose arrhythmias more effectively and to plan treatments.

Keywords: Crista terminalis, Musculi pectinati, Right atrium

1. Introduction-

The crista terminalis is a muscular ridge. it begins on the right side of the superior vena caval orifice, then runs across the inner aspect of the right atrium, ultimately ends at the right side of the inferior vena caval orifice.[1]

CT serves as a crucial anatomical landmark due to its proximity to the MP and sinoatrial nodal artery, highlighting its importance in cardiac anatomy and clinical applications.[2]

The musculi pectinati (MP) are myocardial ridges that originate from the crista terminalis and extend towards the auricle, varying in number, shape, and size.[3]

2. Objectives:

1. To study the morphological variations of the CT and MP in the adult human cadaveric hearts.
2. To determine the prevalence of each morphological pattern in the study population.

3. MATERIALS AND METHODS:

Comprehensive anatomical research was executed at the Department of Anatomy, J. N. Medical College, Belagavi, to investigate the structural arrangement of the CT and MP in the human hearts. The research involved a detailed examination of 30 formalin-preserved human cadaveric hearts, which were carefully dissected to expose the right atrium.

To facilitate observation of the Crista terminalis and Musculi pectinati, a strategic dissection approach was employed according to the steps given in Cunningham Manual. The SVC & IVC were cut open along a linear axis posteriorly, allowing for optimal exposure of the right atrium.

The second incision was made at a 90-degree angle to the original cut, parallel to the coronary sulcus. This meticulous dissection technique helped to protect the normal morphology of the MP & CT.

Following dissection, the hearts were rinsed with running tap water to remove any remaining blood clots, ensuring clear visualization of the anatomical structures. Using a magnifying glass, we conducted a thorough examination of the gross anatomy of the CT and MP, taking note of any variations or patterns present. The study's findings were categorized into six groups, based on the morphological patterns of the CT and MP.

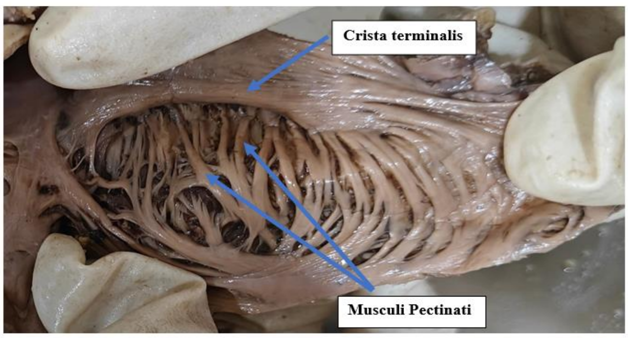
Type 1, MP oriented nearly perpendicular to the CT. Type 2, MP oriented parallel to CT. Type 3, Combination of Type 1 and Type 2. Type 4, Branching of the MP. Type 5, Interlacing trabeculation. Type 6, Prominent muscular column of MP.

Each heart was carefully documented through photographs, capturing detailed images of the CT and MP. This extensive documentation provided a valuable record of the anatomical findings, facilitating further analysis and comparison.

4. RESULTS:

Type 1: MP oriented nearly perpendicular to CT (Fig: 1) Our analysis revealed that Type 1 patterns were the most prevalent, accounting for 56.66% (n=17) of the total specimens. The high frequency of Type 1 patterns suggests that this arrangement may be the most common or "normal" pattern in the human heart.

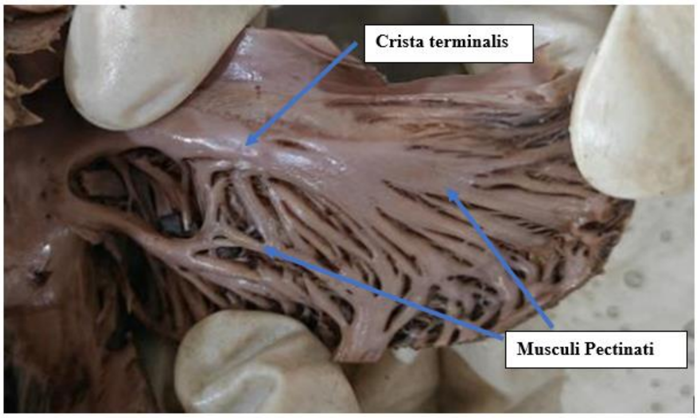
Figure 1: Type 1, Musculi Pectinati oriented nearly 90º to Crista Terminalis**.**



Type 2: MP oriented parallel to CT

This type was the least common, observed in only 3.33% (n=1) of the specimens.

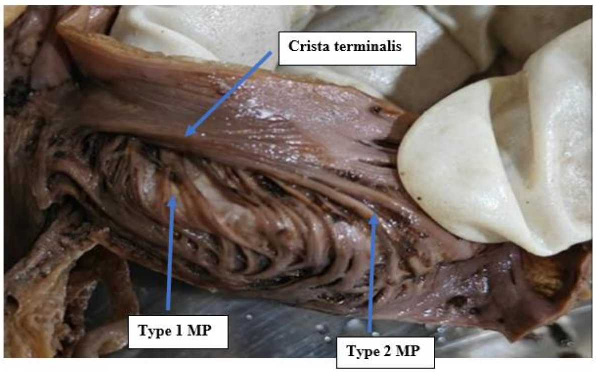
Figure 2: Type 2, Musculi Pectinati oriented parallel to Crista Terminalis.



Type 3: Combination of Type 1 and Type 2

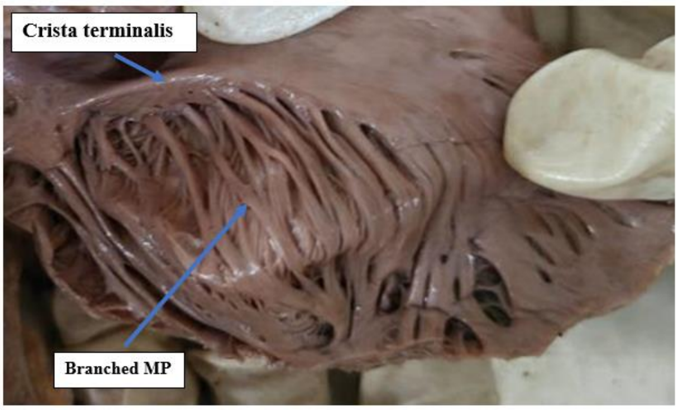
These patterns, which were the combined elements of both the patterns Type 1 and Type 2, were observed in 6.66% (n=2) of the specimens.

Figure 3: Type 3, Combination of Type 1 and Type 2.



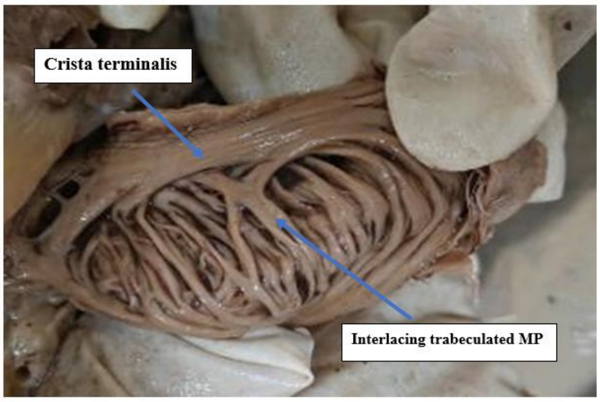
Type 4: Branching of the MP. were the second most common, observed in 20% (n=6) of the specimens.

Figure 4: Type 4, Branching of the Musculi Pectinati



Type 5: Interlacing trabeculation were observed in 3.33% (n=1) of the specimens.

Figure 5: Type 5, Interlacing trabeculation.



Type 6: Prominent muscular columns of MP were observed in 10% (n=3) of the specimens.

The morphological patterns observed in this study highlighted the complexity and diversity of cardiac anatomy.

Figure 6: Type 6, Prominent muscular column of Musculi Pectinati.

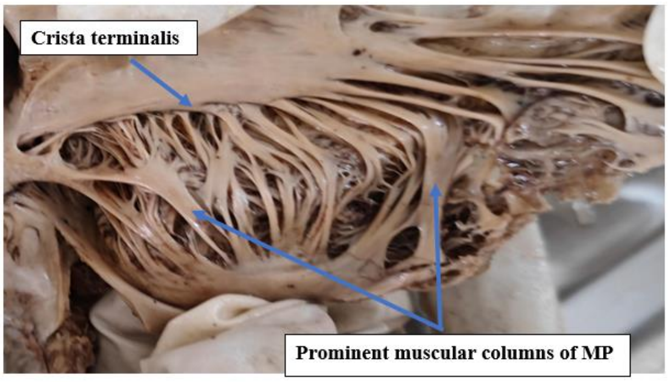
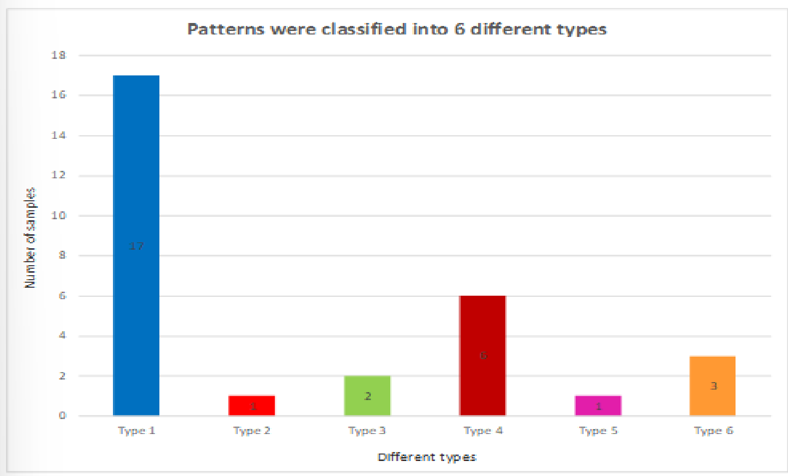


Table 1, The results of 6 different morphological patterns of CT & MP are outlined in the table below.

	Type 1	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**
Pattern observed	MP oriented nearly 90º to CT.	MP oriented parallel to CT.	Combination of Type 1 and Type 2.	Branching of the MP. (Fig: 7)	Interlacing trabeculation (Fig: 8)	Prominent muscular column of MP. (Fig: 9)
Number of heart samples	17	1	2	6	1	3
Percentage (%)	56.66%	3.33%	6.66%	20%	3.33%	10%

Graph 1: Classification of 6 different types



5. Discussion

Our study observed a range of morphological patterns, emphasizing the uniqueness of each heart specimen. The variability observed in this study emphasizes the importance of need to account for individual anatomical differences in clinical and surgical applications.

Table 2, Comparison of all the previous studies with present study

Sr no.	Authors and year of the study	Type 1 (MP oriented 90^0 to CT)	Type 2 (MP oriented parallel to CT)	Type 3 (Combination of Type 1 and Type 2)	Type 4 (Branching of MP)	Type 5 (Interlacing trabeculation)	Type 6 (Prominent muscular column of MP)
1.	Siddiqui A et al. (2013)	68 (45%)	27 (18%)	16 (11%)	14 (9%)	14 (9%)	12 (8%)
2.	Keshri R et al. (2023)	16 (53%)	1 (4%)	7 (22%)	2 (7%)	3 (10%)	1 (4%)
3.	Rastogi R, et al. (2016)	32 (40%)	15 (18.75%)	14 (17.50%)	8 (10%)	7 (8.75%)	4 (5%)
4.	Ana Barriga et al. (2019)	6 (20%)	7 (23.3%)	7 (23.3%)	2 (6.7%)	2 (6.7%)	6 (20%)
5.	Loukas et al. (2008)	(40%)	(20%)	(15%)	(10%)	(10%)	(5%)
6.	Garcia et al. (2010)	(32%)	(24%)	(4%)	(16%)	(16%)	(8%)
7.	Present study (2024 – 2025)	17 (56.66%)	1 (3.33%)	2 (6.66%)	6 (20%)	1 (3.33%)	3 (10%)

Type 1 patterns, marked by MP at a nearly 90° angle to the CT, have been observed with varying frequencies in previous studies.

Research by Siddiqui et al. (2013)[4] revealed 45% frequency (n=68), whereas Keshri et al. (2023)[2] reported 53% (n=16), Rastogi et al. (2016)[5] found 40% (n=32), and Ana Barriga et al. (2019)[6] observed a lower frequency of 20% (n=6). Loukas et al. (2008)[7] & Garcia et al. (2010)[8] also observed frequencies of 40% and 32%, respectively.

Our study found the frequency of 56.66% (n=17) for Type 1 patterns, aligning with results of Keshri et al.[2] (2023). Results of Siddiqui et al. (2013)[4] and Rastogi et al. (2016)[5] were found to be exceeding our findings. This consistency implies that Type 1 patterns may be a normal arrangement in human hearts. These patterns may be associated with normal cardiac conduction and function, and have potential use as a reference for comparison with other pattern types, facilitating the identification of variations or abnormalities in cardiac structure and function.

Earlier studies have documented varying frequencies of Type 2 patterns, characterized by MP parallel to the CT. Frequencies reported included, Siddiqui et al. (2013): 18% (n=27)[4], Ana Barriga et al. (2019): 23.3% (n=7)[6], Keshri et al. (2023): 4% (n=1)[2], Rastogi et al. (2016): 18.75% (n=15)[5], Loukas et al. (2008): 20%[7], Garcia et al. (2010): 24%[8]

In contrast, our study found a significantly lower frequency of 3.33% (n=1) for Type 2 patterns, suggesting that they may be less common than previously thought. This discrepancy may be attributed to differences in sample size, population demographics, or methodological approaches. Notably, Type 2 patterns may be linked with the increase risk of cardiac arrhythmias because of their unique muscle fiber arrangements, highlighting the importance of precise mapping during electrophysiology procedures.

Studies have shown varying rates of Type 3 patterns, which blend features of Type 1 and Type 2 patterns. Researchers have reported frequencies ranging from 6.66% to 23.3%, with Siddiqui et al. (2013)[4] observed 11% (n=16), Rastogi et al. (2016)[5] reported 17.50% (n=14), Ana Barriga et al. (2019)[6] found 23.3% (n=7), and Keshri et al. (2023)[2] noted 22% (n=7).

In the current study, we observed a frequency of 6.66% (n=2) for Type 3 patterns, which is lower than the frequencies reported by most previous studies. Our results indicate that Type 3 patterns may be more rare than initially believed. The inconsistent frequencies reported across studies underscore the intricate and heterogeneous nature of cardiac anatomy. Type 3 patterns may be related to altered cardiac conduction velocities, potentially impacting cardiac resynchronization therapy and may predispose to increased susceptibility to cardiac damage during catheter ablation procedures.

Frequencies of Type 4 patterns, characterized by branching of MP, have varied across previous studies. Ana Barriga et al. (2019)[6] reported the lowest frequency at 6.7% (n=2), while Garcia et al. (2010)[8] found the highest at 16%. Other studies fell within this range, including Siddiqui et al. (2013)[4] at 9% (n=14), Rastogi et al. (2016)[5] at 10% (n=8), and Keshri et al. (2023)[2] at 7% (n=2).

Notably, our present study revealed a frequency of 20% (n=6) for Type 4 patterns, surpassing most previous reports. This finding implies that Type 4 patterns may be more common than initially believed, potentially impacting electrical conduction and atrial function due to the unique branching pattern of MP fibers. As a result, Type 4 patterns may be linked with an enhanced risk of cardiac perforation during catheter-based interventions, but also potential benefits from tailored approaches to cardiac pacing and defibrillation.

Previous studies have reported varying frequencies of Type 5 patterns, characterized by interlacing trabeculation of MP and CT. Siddiqui et al. (2013)[4] observed a frequency of 5% (n=7), while Rastogi et al. (2016)[5] reported a frequency of 6.25% (n=5). Ana Barriga et al. (2019)[6] found a frequency of 3.3% (n=1), and Keshri et al. (2023)[2] reported a frequency of 4% (n=1). These studies demonstrate the variability in Type 5 pattern frequencies.

In this study, we noted a frequency of 10% (n=3) for Type 5 patterns, which is higher than the frequencies reported by most previous studies. Individuals with Type 5 patterns may be more prone to damage during cardiac catheterization due to their unique arrangement of myocardial plate (MP) and crista terminalis (CT). This distinct anatomy may have implications for cardiac conduction and electrophysiology, presenting unique challenges for cardiac pacing and resynchronization therapy. As a result, Type 5 patterns may require individualized strategies for cardiac arrhythmia management.

Research has shown that Type 6 patterns, characterized by Prominent muscular column of MP and CT, have been observed at varying frequencies. Previous studies have reported frequencies ranging from 1.7% to 3.12%. Siddiqui et al. (2013): 8% (n=12)[4], Ana Barriga et al. (2019): 20% (n=6)[6], Keshri et al. (2023): 4% (n=1)[2], Rastogi et al. (2016): 5% (n=4)[5], Loukas et al. (2008): 5%[7], Garcia et al. (2010): 8%[8].

In a current study, we found a frequency of 5% for Type 6 patterns, exceeding previous reports. This higher frequency suggests that Type 6 patterns may be more prevalent than initially thought. Individuals with this pattern may be at increased risk of cardiac catheterization-related complications, and the unique structure of Type 6 patterns may have significant implications for atrial function and mechanics. As a result, Type 6 patterns may be related to increased vulnerability to cardiac damage during catheterization procedures, highlighting the need for precise catheter placement and navigation to avoid complications.

This study's findings on morphological patterns may have significant implications for understanding cardiac conduction and electrophysiological processes. Our results highlight the complex and multifaceted nature of cardiac anatomy. The discoveries made in our study may lead to breakthroughs in personalized medicine, more effective cardiac interventions, and a deeper understanding of heart function, ultimately saving lives and improving patient outcomes.

6. Conclusion:

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