DOI: 10.7860/JCDR/2022/52729.15925

Original Article

Anatomy Section

Morphological Study of Left Ventricular False Tendons in Human Cadaveric Heart Specimens

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ABSTRACT

Introduction: Left Ventricular False Tendons (LVFT) are normal and common anatomical variants of the left ventricle. They may be associated with findings of cardiac pathology or they may be an isolated finding from 2D echocardiogram. These structures may mimic pathologic structures, such as intraventricular chorda rupture, vegetation or thrombus, but considered as false tendon.

Aim: To study the morphology, age and gender specific proportions of false tendons in cadaveric heart specimens.

Materials and Methods: A descriptive cross-sectional study was conducted in Mysore Medical College and Research Institute, Mysuru, Karnataka, India, from October 2015 to March 2017. A total of 100 human cadaveric heart specimens of both males (n=50) and females (n=50) aged 18-76 years were collected from Department of Anatomy and postmortem specimens from Department of Forensic Medicine. The morphology of tendons was studied regarding its location, gross appearance and parameters such as its length and width. The statistical analysis was done using Chi-square test and Analysis of Variance (ANOVA) test appropriately using the software Statistical Package for Social Service (SPSS), version 20.0 for windows.

Results: False tendons were seen in 49 of heart specimens. Total 40 of the specimens showed one LVFT and nine showed two LVFT. Out of total 44 (58.67%) specimens aged 50 years or less had false tendons, while in older specimens, only 5 (20%) were found to have false tendon (p-value <0.05). The common location of false tendons was Posteromedial Papillary Muscle (PMPM) to mid interventricular septum 11 (18.9%), followed by PMPM to free wall 9 (15.5%). The tendons were fibrous in 53 (91.4%), fibromuscular in 4 (6.9%) and 1 (1.7%) was muscular in nature. Out of 50 female and 50 male heart specimens, 24 and 25 had LVFT, respectively (p-value=0.891).

Conclusion: Sound knowledge of heart morphology can avoid false diagnosis in patients with false tendon, as it can simulate other pathological murmurs and structural heart disease in echocardiography.

Keywords: Interventricular septum, Posteromedial papillary muscle, Pseudotendons

INTRODUCTION

The Left Ventricular False Tendons (LVFT) commonly defined as false tendon which is discrete, thin, cord like fibromuscular structures that connect two walls, the Papillary Muscle (PM), or PM to a wall, usually the ventricular septum, it also often crosses subaortic outflow and left ventricular cavity [1]. They are normal and common anatomical variants of the left ventricle occurring in 50% of hearts and may get calcified with age. They are frequently observed in men but their incidence does not appear to be age related [2]. They may be single or multiple and sometimes branched. The LVFT, also referred to as pseudo-tendons, aberrant fibrous bands, false tendons, intracardiac strings, anomalous left ventricular bands, musculi-transversi, and ventricular cords. The term anomalous, false, aberrant is given due to the variation from the normal insertion of chordae tendineae that is not attached to mitral leaflets. It was first reported by British anatomist and surgeon Sir William Turner in 1893 as filaments of tissue crossing the cavity of left ventricle [3]. But variety of chordal anomalies has been described including congenital absence, abnormal length, and anomalous insertion [4].

The development of echocardiography has allowed the demonstration of LVFTs in-vivo and the subsequent association of these structures with numerous clinical phenomena [5]. Since about a century ago, false tendons in the left ventricular cavity have been noted as anatomic variants at autopsy. Recently, cardiologists are concerned about their possible association with innocent heart murmurs and its possible role in ventricular arrhythmias due to the presence of conduction tissue [6]. The present study was taken up since few literatures are available on cadaveric studies [7-12] for determining the incidence of false tendons, various types and insertion with their significance in the field of cardiology especially in adult population.

MATERIALS AND METHODS

A descriptive cross-sectional study was conducted in Mysore Medical College and Research Institute, Mysuru, Karnataka, India, from October 2015 to March 2017. The study was conducted after approval from Institutional Ethics Committee, (letter dated 07-11-2015: ECR/134/Inst/KA). The study was done on 100 human heart specimens of both male and female cadavers aged 18 to 76 years of age.

Sample size calculation: Sample size was estimated statistically by ‘estimation technique for proportion’ with level of significance (α)=5%, admissible error=10% with proportion of tendons=0.55. Thus, sample size of heart specimens was 99 (which were rounded off into 100).

Inclusion and Exclusion criteria: Any filamentous, fibrous or muscular linear structures crossing LV cavity from the PM or from the anterior or posterior free wall of the LV, attaching to the interventricular septum and probe must pass through either side of the tendon to delineate the trabecular work [7], were included in study. Any gross evidence of injured, lacerated, anomalies, surgeries, and decomposed heart specimens, trabecular structures, or linear structure adherent to the wall, or anomalous chordae tendineae attaching elsewhere other than mitral valve apparatus, or ridge or subaortic membrane were excluded from the study.

Procedure

Specimens were collected from Department of Anatomy and postmortem specimens from Department of Forensic Medicine. After exploring the pericardial cavity, the heart was detached from the major venous channels (superior vena cava and inferior vena cava) and aorta was cut 3 cm above the coronary sinus and then the heart was extracted with intact epicardium and coronary vessels. The specimens were tagged, stored in 10% formalin solution and were dissected. The heart was held in anatomical position. After identifying all the chambers, an incision was put at the right border of heart exposing the right atrium and ventricle cavity and interventricular septum. Now an incision was made on the interventricular septum from the level of aortic valves till its base of septum exposing the entire left ventricle cavity as whole with PMs, and chordae tendineae, so to prevent damage to any left ventricular tendons running across the cavity [13].

Parameters such as incidence, age, gender specific proportions of false tendons, its location such as free wall to free wall, free wall to septum, posteromedial and Anterolateral Papillary Muscle (ALPM) to septum and between PMs were studied. Measurements such as length and width were taken with help of vernier calipers. Classification of tendons to fibrous (1.4 mm), fibromuscular (1.5-2.4 mm) and muscular (>2.5 mm) were done based on the width of the tendons [7].

STATISTICAL ANALYSIS

The data were summarised using descriptive statistics like mean, standard deviation and inferential statistics using Chi-square test and Analysis of Variance (ANOVA) test appropriately. All the statistical calculations were performed using the software Statistical Package for the Social Sciences (SPSS) version 20.0 for windows.

RESULTS

In the present study, the incidence of LVFTs in heart specimens was 49%. Total 40 of the specimens showed one LVFT and nine showed two LVFT, hence total number of tendons being 58. The age of the specimens ranged between 18-76 years with median age being 42 years. Association between age range and distribution of LVFT is shown in [Table/Fig-1] and the difference was statistically significant (χ^2=11.22, df=1, p-value <0.05). Association of LVFT with gender is shown in [Table/Fig-2]. Pearson Chi-square test found no statistically significant difference between gender and the distribution of LVFT. (χ^2=0.231, df=2, p-value=0.891). The common location of LVFT was PMPM to mid interventricular septum (N=11, 18.9%), followed by PMPM to free wall (N=9, 15.5%) [Table/Fig-3-4]. The mean length and width of the LVFT is shown in [Table/Fig-5]. The types of tendons are fibrous, fibromuscular, muscular, which were of 53 (91.4%), 4 (6.9%), 1 (1.7%), respectively. Association of types of tendons and width is shown in [Table/Fig-6]. There is statistically significant difference in the width of the fibrous, fibromuscular and muscular LVFTs (f-value=91.6, p-value=0.001, df=57).

Age (years)	LVFT		Total	Statistical significance
	Absent	Present		
≤50	31	44	75	(χ^2=11.22, df=1, p<0.05)
>51	20	5	25	

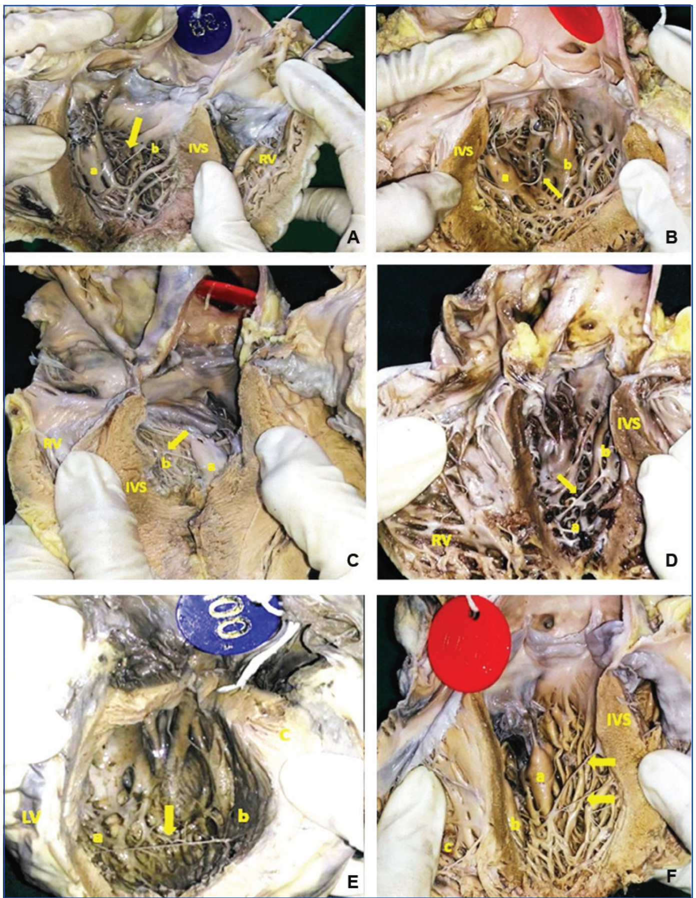
[Table/Fig-1]: Association between age range and distribution of Left Ventricular False Tendons (LVFT).

Gender	Number of left ventricular false tendons			Statistical significance
	0	1	2	
Female	26	19	5	χ^2=0.231, df=2, p=0.891
Male	25	21	4	
Total	51	40	9	

[Table/Fig-2]: Association of left ventricular tendons with gender.

Location	n (%)
ALPM-Mid IVS	7 (12.1%)
ALPM-Apex LV	1 (1.7%)
ALPM-FW	7 (12.1%)
ALPM-PMPM	7 (12.1%)
APEXLV-FW	2 (3.5%)
APEX LV-Mid IVS	1 (1.7%)
FW-FW	5 (8.6%)
FW-Mid IVS	2 (3.5%)
PMPM-LVOT	1 (1.7%)
PMPM-Base IVS	5 (8.6%)
PMPM-FW	9 (15.5%)
PMPM-Mid IVS	11 (18.9%)
Total	58 (100%)

[Table/Fig-3]: Frequency of location of Left Ventricular False Tendon (LVFT) with different attachments.
ALPM: Anterolateral papillary muscle; IVS: Interventricular septum; FW: Free wall; PMPM: Posteromedial papillary muscle; LVOT: Left ventricular outflow tract



[Table/Fig-4]: A) IVS cut opened through RV side to show muscular tendon arising from Posteromedial Papillary Muscle (PMPM) to Free wall (a: PMPM, b: FW); B) Inter papillary muscle LV tendon (a: ALPM, b: PMPM); C) Aorta and IVS cut opened to show left ventricle with thin filamentous type LVFT from the base of Posteromedial Papillary Muscle (PMPM) to free wall (a: PMPM. b: FW); D) Fibrous type LVFT arising from apex of left ventricle to free wall (a: Apex LV, b: FW); E) Thin LV tendon from anterior wall to posterior wall (a: anterior wall, b: posterior wall); F) Fibrous LVFT arising from posteromedial PM to mid IVS (a: PMPM, b: ALPM, c:RV). Here, two tendons are seen.
IVS: Interventricular septum; RV: Right ventricle; LVT: Left ventricular tendon; PMPM: Posteromedial papillary muscle; ALPM: Anterolateral papillary muscle

Variables	Minimum	Maximum	Mean	Standard deviation
Length (mm)	2.780	27.590	14.610	5.610
Width (mm)	0.030	3.750	0.707	0.549

[Table/Fig-5]: Length and Width of Left Ventricular False Tendons (LVFT).

Types of LVFT	Number of tendons	Mean width (mm)	Standard deviation	Statistical significance
Fibrous	53	0.58	0.25	(F=91.6, p-value=0.001 df=57
Fibromuscular	4	1.59	0.45	
Muscular	1	3.75	-	

[Table/Fig-6]: Association between types of tendons and width of Left Ventricular False Tendons (LVFT).
ANOVA was used

DISCUSSION

The LVFTs have little clinical significance per se, but these anatomical variants are important because of their potential to be mistaken for more important pathologic entities. These tendons are not the chordae tendineae connecting the PM to the mitral valve leaflet. Therefore, "false tendon" has become more popular [14]. Advent of echocardiography has rekindled the interest in this field and helped the demonstration of LVFT in vivo and its association with clinical conditions. LVFT may cause precordial murmurs, which is functional, so-called innocent murmur [7,8] and tendon attaching to the base of the interventricular septum or the sub aortic region may cause gradient or plays a role in pathogenesis of discrete subaortic stenosis [15]. It also causes premature ventricular contractions [16]. False tendons may give rise to reentry mechanism producing more severe arrhythmias such as ventricular tachycardia and fibrillation [7,17]. Left ventricular tendons may cause obstruction while navigating devices in the left ventricle [18]. Studies have shown that, left ventricular tendons can be falsely associated with left ventricular aneurysm [19]. LVFT can simulate mural thrombus by producing intracavitary echoes in echocardiography. So, false positive diagnosis can be minimised by identifying and distinguishing this structure [20]. Echocardiogram (Echo) studies have documented false tendons as potential for erroneous diagnosis of thrombi, tumors, subaortic membrane, flail mitral leaflet [9,21]. LVFT could be contributory factor of dysrhythmias during LV catheterisation studies [22].

The LVFT are normal anatomical variants seen in left ventricle with a frequency between 0.5% and 77.9% with echocardiography [7,23,24]. In congenital heart specimens alone 61.8% were noted [7]. Potential genetic inheritance of false tendons has been reported [25]. As autopsy was not performed on many cases, giving less opportunity for anatomic confirmation of these bands. In the present study 49% of tendons were observed. Nine (18%) of the 49 specimens were observed with more than one tendon. There is no statistically significant difference between the number of tendons present in a single heart with the gender and age. The literature shows that there is no significant difference in incidence of left ventricular tendons in acquired or congenital heart diseases or normal patients [26]. In the present study, the disease status was unknown. LVFT are more commonly seen in males than females [2]. In the present study, tendons were seen in 50% in males and 48% in females, more or less equal and statistically insignificant which was similar to the study of Abdullah NM et al., [27].

The LVFT gets calcified with age, and their incidence does not appear to be age related [2]. However, studies of Cocchieri M and Bardelli G, Philip S et al., Gerlis LM et al., Brenner JI et al., Perry LW et al., showed that incidence of LVFT is more likely to be seen in younger age group like neonates, infants, children [6,7,11,24, 28]. Philip S et al., reported a maximum of 77.9% in <18 years as they were easily identifiable in this age group because of better delineation of images by echocardiography [7], moreover that many trabeculations could be over diagnosed and chance of resorption is very high in children, can partially explored why incidence is less in the cadaveric specimens when compared to echocardiographic results. Although many have studied about these structures with echocardiography [Table/Fig-7], very little literature is available using cadaveric specimens by dissection method [Table/Fig-7] [6-12,24,26-34].

The location of the tendons varies from free wall to free wall, free wall to septum, posteromedial and ALPM to septum and between PM [9]. Most commonly observed location was posteromedial PM to mid interventricular septum (n=11, 18.9%), followed by PMPM to free wall (n=9, 15.5%). Luetmer PH et al., observed false tendons (12%) between two PMs second in frequency and location of tendons had no association with gender and age [9]. Although Grzybek M et al., reported to have observed the tendons connecting the interventricular septum to the anterolateral or posteromedial PM more in newborn, infant, adult hearts and rarely in foetal hearts [12].

Author and year of publication	Place of study	Age (year)	Sample size	Prevalence of LVFT (%)
Autopsy method				
Abdullah AK et al., 2019 [27]	Iraq	18-71	215	62 (28.8%)
Ferrer FS et al., 2014 [8]	Spain	65-88	41	2 (4.8%)
Philip S et.al., 2011 [7]	India	0-18	68	42 (61.8%)
Deniz M et al., 2004 [10]	Turkey	-	28	13 (46%)
Kervancioglu M et al., 2003 [30]	Turkey	All ages	8	5 (62.5%)
Grzybek M et al., 1996 [12]	-	18-71	180	40%
Luetmer PH et al., 1986 [9]	Minnesota	All ages	483	265 (55%)
Boyd MT et al., 1987 [29]	Minnesota	All ages	474	323 (68%)
Gerlis LM et al., 1984 [11]	Leeds	<15	686	329 (48%)
Present study, 2022	India	18-76	100	49%
Echocardiographic method				
Pisiak S et al., 2015 [31]	Poland	16-87	1679	100 (6%)
Ferrer FS et.al., 2014 [8]	Spain	0-14	150	83%
Philip S et al., 2011 [7]	India	0-18	476	371 (78%)
Cocchieri M and Bardelli G, 1992 [6]	Italy	1-13	273	80 (29%)
Abdulla AK et al., 1990 [26]	Italy	All ages	100	18%
Malouf et al., 1986 [34]	Lebanon	All ages	488	123 (25%)
Brenner JI et al., 1984 [24]	Maryland	≤18	203	31 (14%)
Suwa M et al., 1984 [33]	Japan	All ages	1117	71 (6%)
Vered Z et al., 1984 [32]	Israel	All ages	2079	42 (2%)
Perry LW et al., 1983 [28]	Washington DC	≤15	3847	31 (0.8%)

[Table/Fig-7]: Comparison of prevalence of Left Ventricular False Tendons (LVFT) in different age groups in various studies [6-12,24,26-34].

The characteristics of the tendon such as length and thickness of tendon varied in each specimen. Grzybek M et al., reported that tendons individual parts of anterior or posterior PM were generally thin and short, tendons connecting ALPM to PMPM were narrow and of medium thickness, tendons connecting interventricular septum to PM were generally long [12]. Also, the false tendons were found to be thicker in foetal, newborn and infant hearts than in adult hearts. Luetmer PH et al., observed that length of the tendons ranged from 7 mm to 35 mm and longest were seen in tendons connecting septum to PM [9]. Luetmer PH et al., and Abdulla AK et al., reported the thickness of the tendon variable ranging from 1 mm to 3 mm [9,26]. In the present study, the thickness ranged between 0.03 mm to 3.7 mm. The longest length of tendon was seen in tendons connecting septum to PM and was supported by study of Luetmer PH et al., [9]. Embryologically, inner muscle layer of the primitive heart may give rise to false tendons [28]. Left ventricular tendons were further classified by Philip S et al., according to the width and histopathology of tendon studied, as fibrous (1.4 mm, 44.4%), fibromuscular (1.5-2.4 mm, 50.7%), and muscular type (>2.5 mm, 5.3%) [7]. In the present study, fibrous, fibromuscular, muscular were of 53%, 4%, 1%, respectively and histopathology was not done. This difference in paediatric and adult age group could be partially explained as a process elongation of tendon as the heart enlarges and some amount of resorption could take place as the age progresses.

Limitation(s)

Heart specimens of less than 18 years of age were not obtained in the present study period and corresponding clinical echocardiographic data on LV tendon was not available for correlation study.

CONCLUSION(S)

Association of left ventricular tendons with various clinical conditions and in otherwise normal patients, emphasises the necessity for an awareness of these anatomic variants when evaluating patients for left ventricular pathology. It is relatively benign in nature but may confuse with clinical conditions having similar echocardiographic appearance, but it may cause functional murmur. Recognition of this entity by cadaveric exposition is important to know the morphology for clinical correlation and also to avoid false diagnosis. Keeping in mind the ever evolving and yet unexplored facts of this subject, the present study was undertaken to shed more light on this topic of left ventricular tendons.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Oct 08, 2021
- Manual Googling: Dec 01, 2021
- iThenticate Software: Dec 28, 2021 (7%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Oct 06, 2021**
Date of Peer Review: **Oct 21, 2021**
Date of Acceptance: **Dec 02, 2021**
Date of Publishing: **Feb 01, 2022**