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MORPHOLOGIC STUDIES

Incidence and Distribution of Left Ventricular False Tendons: An Autopsy Study of 483 Normal Human Hearts

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The incidence and distribution of left ventricular false tendons were studied in a series of 483 autopsy specimens of human hearts from subjects evenly distributed by sex and age. False tendons were observed in 265 specimens (55%), and their incidence was greater in hearts from male than from female subjects (61 versus 49%; $p < 0.01$). Neither the incidence nor the location of false tendons varied appreciably with age. Of the 265 specimens containing false tendons, 100 (38%) exhibited 2 or more, such that the total number of false tendons identified was 414. Of these 414, 272 (66%) were located between the posteromedial papillary muscle and the ventricular septum, 49 (12%) between the two papillary muscles, 47 (11%) between the anterolateral papillary muscle and the ventricular septum, 38 (9%) between the free wall and the septum and 3 (< 1%) between two aspects of the free wall; 5 (1%) had three or more points of insertion and formed weblike structures.

False tendons are common anatomic variants of the normal human left ventricle which may be detected by two-dimensional echocardiography and should not be misinterpreted as pathologic structures such as flail mitral chordae tendineae or mural thrombi.

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False tendons of the left ventricle may be a source of confusion or misinterpretation by two-dimensional echocardiography (1–5). The present study was undertaken to investigate the incidence and distribution of this anatomic variant in an autopsy population of normal hearts.

Methods

Study cases. From the collection of normal human hearts in the tissue registry at our institution (6), we selected for study only those hearts that had been dissected by the inflow-outflow method (7), because identification of left ventricular false tendons would have been difficult in specimens dissected by other methods. Normal hearts were chosen because it was not clear whether pathologic conditions such as endocardial fibrosis or mural thrombosis might encase and mask the false tendons and thereby produce a lower incidence than actually exists.

From this group of specimens, we randomly selected 25 hearts from male subjects and 25 hearts from female subjects for each of the first nine age decades. From the 10th age decade, appropriately dissected specimens were available from only 12 male subjects and 21 female subjects. Therefore, the study group comprised 483 hearts.

Pathologic examination. Each specimen was examined for left ventricular false tendons. These were defined as discrete, cordlike fibromuscular structures that crossed the ventricular cavity and had no attachment to the mitral valve leaflets. Structures greater than 3 mm in diameter tended to be primarily muscular and are the subject of another investigation at our institution; hence, they are not included in the present study. Shallow apical trabeculations are also the subject of another investigation and similarly were disregarded.

The location of each false tendon was described according to its points of attachment and to its base-apex level. Furthermore, each false tendon was characterized according to length, diameter, the presence of grossly visible muscular tissue and the angle subtended by the long axis of the false tendon relative to the direction of systolic blood flow (Fig. 1). Histologic examination was not performed.

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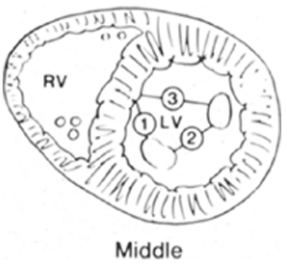
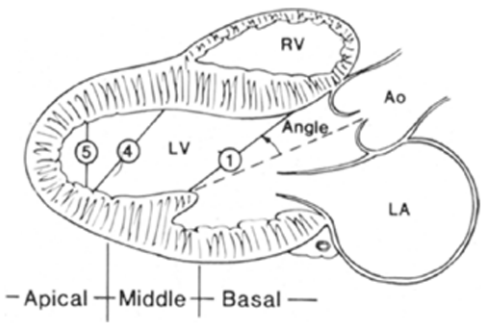
Key	Location	Apical	Middle	Basal	Total No.	%
1	PMPM-VS	15	79	178	272	66
2	ALPM-PMPM	5	43	1	49	12
3	ALPM-VS	14	30	3	47	11
4	LVFW-VS	23	14	1	38	9
5	LVFW-LVFW	3	0	0	3	1
-	Other	1	3	1	5	1





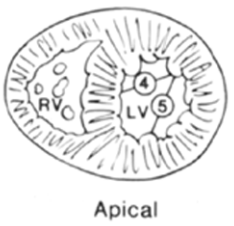


Figure 1. Incidence and distribution of 414 left ventricular false tendons in a study of 265 normal human hearts. ALPM = anterolateral papillary muscle; Ao = aorta; LA = left atrium; LV = left ventricle; LVFW = left ventricular free wall; PMPM = posteromedial papillary muscle; RV = right ventricle; VS = ventricular septum.

Results

General features. Of 483 specimens, 265 (55%) had one or more false tendons. Among those with false tendons, 100 (38%) contained more than one, such that the total number of false tendons identified was 414. Among the 237 hearts from male subjects, 145 (61%) contained false tendons, whereas in 246 hearts from female subjects, only 120 (49%) contained false tendons ($p < 0.01$; chi-square test). There was no appreciable age-related difference in incidence or location.

Location. False tendons most frequently were located between the posteromedial mitral papillary muscle and the ventricular septum (66%). These were usually characterized by thin fibrous bands that arose near the apex of the papillary muscle and traversed the ventricular cavity in a basal direction to insert just beneath the membranous septum (Fig. 1 and 2A; Table 1).

Second in frequency (12%) were false tendons between the two papillary muscles (Fig. 2B). Because the specimens had been dissected by the inflow-outflow method, which involved opening the left ventricular free wall between the two mitral papillary muscles, false tendons in this location were difficult to assess, and their incidence may be greater than 12%.

False tendons between the anterolateral papillary muscle and the ventricular septum accounted for 11% of the structures (Fig. 2C). They generally cut across the ventricular cavity and formed an angle of 45° or greater relative to the direction of systolic blood flow.

Fourth in frequency (9%) were false tendons between the left ventricular free wall and the ventricular septum (Fig. 2D). These false tendons arose medially to the anterolateral papillary muscle and inserted on the ventricular septum, most often in the apical region.

False tendons connecting two points of the free wall (Fig. 2E) were uncommon (< 1%). These tendons were located exclusively in the apical region and traversed the ventricular cavity perpendicular to the base-apex axis.

Five false tendons (1%) had three or more regions of insertion and formed weblike structures (Fig. 2F). They were thicker than most other false tendons observed in our study and ranged from 1 to 3 mm in diameter. However, they were not grossly muscular.

Discussion

Left ventricular false tendons, also referred to as pseudotendons or bands (1–4), were first described by Turner (8) nearly a century ago. Their recognition and possible misinterpretation by two-dimensional echocardiography have led to renewed interest in these anatomic variants.

Incidence. The reported incidence of false tendons detected at echocardiography varies greatly (Table 2). This variability may be due in part to improvements in imaging resolution, different criteria for diagnosis, different population selection (for example, normal versus abnormal hearts) and different numbers of echocardiographic views examined. Moreover, in most cases, because neither operation nor autopsy was performed, there was little opportunity for anatomic confirmation of the echocardiographic findings.

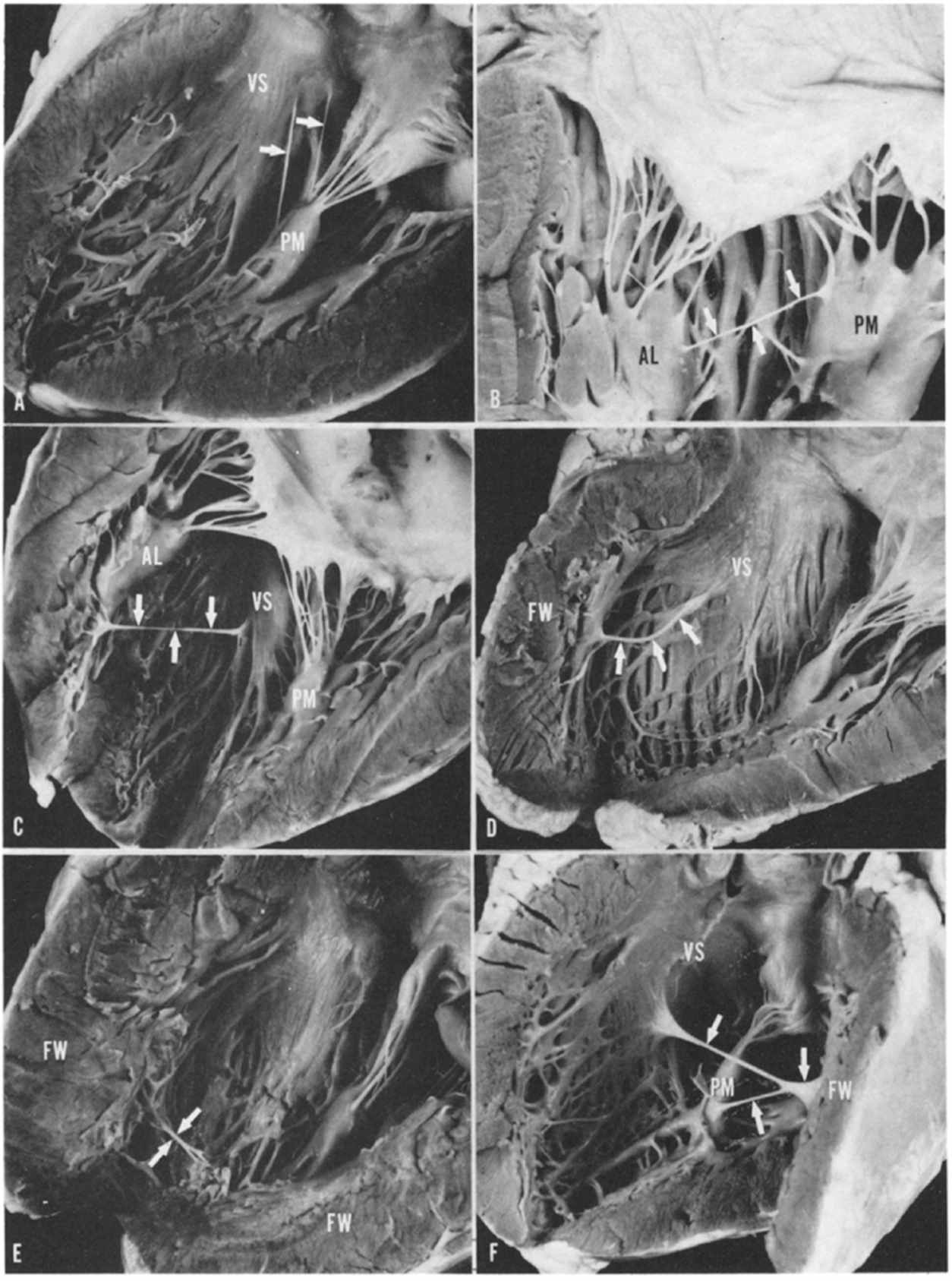


Figure 2. Various locations of left ventricular false tendons. **A**, Two false tendons **(arrows)** from posteromedial mitral papillary muscle (PM) to ventricular septum (VS). **B**, False tendon **(arrows)** between anterolateral (AL) and posteromedial mitral (PM) papillary muscles. **C**, False tendon **(arrows)** between anterolateral (AL) papillary muscle and ventricular septum (VS). **D**, False tendon **(arrows)** between left ventricular free wall (FW) and ventricular septum (VS). **E**, False tendon **(arrows)** between two aspects of left ventricular free wall (FW). **F**, Complex branching false tendon **(arrows)** with origin from left ventricular free wall (FW) and insertions into ventricular septum (VS) and base of posteromedial mitral papillary muscle (PM).

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Table 1. Characteristics of Left Ventricular False Tendons

Location	Length (mm)		Gross Appearance (%)		Angle >45° (%)
	Range	Mean	Fibrous	Muscular	
PMPM-VS	10 to 35	20	92	8	6
ALPM-PMPM	7 to 25	10	100	0	94
ALPM-VS	10 to 35	20	91	9	74
FW-VS	8 to 30	15	92	8	60
FW-FW	10 to 15	12	100	0	100

ALPM = anterolateral papillary muscle; FW = free wall; PMPM = posteromedial papillary muscle; VS = ventricular septum.

Of approximately 12,300 hearts examined by echocardiography (2,9–17), pathologic correlation was obtained in only 39 cases, 35 of which came from one study (16).

Recently, Gerlis et al. (17) reported a morphologic study of false tendons in 55 normal cardiac specimens from children less than 15 years of age and in 50 diseased cardiac specimens from adults ranging in age from 19 to 77 years. The incidence of false tendons was 46 and 57%, respectively. Our findings were similar and demonstrated false tendons in 265 (55%) of 483 specimens from a normal population spanning 10 age decades; they also demonstrated that false tendons were more common in hearts from male than from female subjects (61 versus 49%; $p < 0.01$) and that there was no appreciable correlation between patient age and incidence of false tendons. These two studies indicate that false tendons are common anatomic variants in the left ventricle.

Echocardiographic interpretation. False tendons in the outflow tract between the posteromedial papillary muscle and the ventricular septum (66% of all false tendons identified in our study) have been misinterpreted echocardiographically as obstructions of the left ventricular outflow tract (such as membranous or fibromuscular discrete subaortic stenosis), hypertrophic cardiomyopathy, aneurysms of the membranous septum, flail aortic or mitral valve, mitral valve vegetations, congenital mitral anomalies or pedunculated mural thrombi (1–4). Choo et al. (3) suggested that misinterpretations can be avoided by analysis of the timing of the echo in the cardiac cycle, by the appearance of the echo and the apparent points of attachment to the myocardium and by corroboration with the clinical history.

In an effort to establish the reliability of two-dimensional echocardiography for recognizing left ventricular false tendons, Keren et al. (16) correlated preoperative echocardiographic findings with postoperative morphologic findings in 35 patients undergoing cardiac transplantation. Left ventricular false tendons were correctly identified by two-dimensional echocardiography in 11 of the 13 hearts, but four false positive diagnoses also were made (sensitivity 85%; specificity 82%).

Associated systolic murmurs. Although recent studies of false tendons have been concerned primarily with avoid-

Table 2. Incidence of Left Ventricular False Tendons in Various Studies

Year	Authors	Age of Patients (yr)	No. of Hearts	Status of Hearts	Method of Detection	Incidence of False Tendons (%)
1981	Okamoto et al. (9)	All ages	132	Diseased	2D echo	46.2
1981	Nishimura et al. (10)	All ages	1,000	Diseased	2D echo	0.5
1983	Perry et al. (11)	≤15	3,847	Diseased	2D echo	0.8
1984	Sethuraman et al. (12)	>12	1,012	Diseased	2D echo	0.4
1984	Ryssing et al. (13)	All ages	2,000	Diseased	2D echo	0.2
1984	Vered et al. (2)	All ages	2,079	Diseased	2D echo	2.0
1984	Suwa et al. (14)	All ages	1,117	Diseased	2D echo	6.4
1984	Brenner et al. (15)	≤18	100	Diseased	2D echo	61.0
1984	Keren et al. (16)	≥15	35	Diseased	2D echo	42.9
					Autopsy	37.1
1984	Gerlis et al. (17)	≤18	179	Diseased	2D echo	21.7
		>18	800	Diseased	2D echo	0.4
		<15	581	Diseased	Autopsy	47.8
		≥19	50	Diseased	Autopsy	52.0
		<15	55	Normal	Autopsy	46.0
1986	Present study	All ages	483	Normal	Autopsy	54.9

2D echo = two-dimensional echocardiography.

ing misinterpretation of these structures by echocardiography, they also have shown that false tendons may be associated with systolic musical murmurs (11,13,18,19) and rate-dependent premature ventricular contractions (11,14). However, as postulated by Gerlis et al. (17), this latter association may be a chance phenomenon related to the high incidence rate of false tendons.

In 1969, Roberts (18) reported a transient precordial systolic musical murmur associated with a false tendon in a 68 year old man during exacerbation of congestive heart failure. Roberts postulated that the increased diameter of the left ventricle rendered the false tendon taut and created localized turbulence, vibrations and a murmur. Subsequently, Ryssing et al. (13) reported four cases of systolic murmur associated with false tendons. In one case, oscillations of the false tendon were demonstrated by echophonocardiographic study; these oscillations were of the same frequency as the murmur. Their study, similar to echophonocardiographic studies of leaflet flutter (20), support Roberts' hypothesis. In the case reported by Roberts, the false tendon was perpendicular to the direction of systolic blood flow, and we postulate that the likelihood of vibration and murmur production may increase as the angle approaches 90°. In our study, 122 (29%) of 414 false tendons formed an angle of 45° or greater. However, the relation between systolic musical murmurs and false tendons is still debated (2,10,11).

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