Mitral Valve Basal Chordae: Comparative Anatomy and Terminology

Alexandra A. Degandt, Patricia A. Weber, Hashim A. Saber and Carlos M.G. Duran

The online version of this article, along with updated information and services, is located on the World Wide Web at:

Mitral Valve Basal Chordae: Comparative Anatomy and Terminology

Alexandra A. Degandt, MD, Patricia A. Weber, DrPH, Hashim A. Saber, PhD, and Carlos M.G. Duran, MD, PhD

The International Heart Institute of Montana Foundation at Saint Patrick Hospital and Health Sciences Center, and Department of Mathematics, The University of Montana, Missoula, Montana

Background. Recent awareness of the importance of the mitral valve's basal chordae stimulated a comparative anatomic study of these chordae in 11 human, 10 ovine, and 10 porcine hearts.

Methods. The basal chordae were defined as the chordae that arise from the papillary muscles and insert into the ventricular aspect of the leaflets.

Results. All leaflet insertions of the basal chordae were close to the annulus, except at the anterior mitral leaflet, where insertion was at the junction of the smooth and rough zones. The number of basal chordae was 24.6 ± 4.21 in the porcine, 19.7 ± 2.90 in ovine, and 18.81 ± 3.54 in the human hearts. At least two anterior basal chordae were present in each half of the anterior leaflet in 70% of ovine and porcine and in 100% of human hearts. At least two basal chordae were present in each half of the middle scallop of the posterior mitral leaflet in 80% of ovine, 70% of porcine, and 63.6% of humans. Among them, only the two principal or strut chordae were identified as the longest and thickest.

Conclusions. The basal chordae of the mitral valve follow a definite pattern in each of the three species studied. A new and logical terminology that should facilitate identification of specific basal chordae is suggested.

(Ann Thorac Surg 2007;84:1250–5)
© 2007 by The Society of Thoracic Surgeons

The study of functional mitral valve regurgitation, where an apparently normal valve is regurgitant, has highlighted the importance of the mitral valve's basal chordae, which were mostly ignored until very recently. A significant number of clinical and experimental studies have implicated the basal chordae as an essential component of not only the mitral valve but also the left ventricle [1–3]. These findings have assumed that the basal chordae are similar across different species studied. In addition, the absence of a clear terminology makes it difficult to interpret which specific chordae were studied or sectioned. These facts led us to:

1. undertake a detailed anatomic study of the mitral valve basal chordae in ovine, porcine, and human hearts;
2. attempt to define a simple and standard terminology consistent with our findings;
3. search for landmarks that would help the surgeon identify each basal chorda in all three species; and
4. provide information on interspecies differences that might prove useful when analyzing the results of experimental manipulation of the basal chordae.

Material and Methods

We studied 10 ovine, 10 porcine, and 11 human hearts. The porcine and ovine hearts were obtained from a local abattoir (Hamilton Packing, Inc, Hamilton, MT). The pigs were of a variety of breeds, approximately 7 to 10 months of age, and weighed 110 to 164 kg at the time of slaughter. The sheep were primarily the Suffolk breed, 8 to 10 months of age, and weighed 54 to 68 kg. The human hearts (4 male, 7 female, aged 41 to 95 years) were obtained from the Centre du Don du Corps (Faculté de Médecine, Paris, France) and dissected at the Institute d'Anatomie (Paris Cedex 06, France). Consultation with the Saint Patrick Hospital and Health Sciences Center Institutional Review Board and the University of Montana Institutional Animal Care and Use Committee concluded that no approval for this study was necessary. All specimens were nonfixed and examined early after collection.

Terminology

The different components of the mitral valve were classified according to the terminology described by Kumar and colleagues [4], which is familiar to surgeons and echocardiographers [5] (Fig 1). This terminology was based on the principle that the mitral valve is basically a paired structure determined by its two papillary muscles.

All structures supported by the anterolateral papillary muscle were identified with the numeral 1; those supported by the posteromedial papillary muscle were identified with the numeral 2. Therefore, the half of the
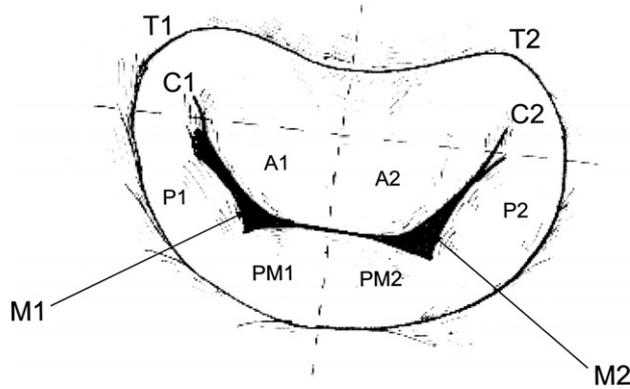
Fig 1. Terminology superimposed on an atrial view of the mitral valve. (T1 = left trigone; T2 = right trigone; C1 = anterolateral commissure; C2 = posteromedial commissure; A1 and A2 = anterior leaflet; P1 and P2 = posterior leaflet lateral scallops; PM1 and PM2 = anterolateral and posteromedial segments of the posterior leaflet mid-scallop; M1 = anterolateral papillary muscle; M2 = posteromedial papillary muscle.)

Fig 3. A ventricular view of the posterior mitral leaflet outlines the posterior strut chordae. (PS1 = posterior strut chorda arising from anterolateral papillary muscle; PS2 = posterior strut chorda arising from posteromedial papillary muscle.)

anterior mitral leaflet and chordae supported by the anterior papillary muscle (called "M1") were identified as A1, the commissure as C1, and the anterolateral scallop of the posterior leaflet as P1.

The other half of the anterior leaflet, commissure, and posteromedial scallop supported by the posterior papillary muscle (called "M2") were identified as A2, C2, and P2. Because it is supported by chordae from both papillary muscles (M1 and M2), the posterior middle scallop (PM), was divided into PM1 and PM2. The two trigones were identified as T1 for the left and T2 for the right.

Similar with previously published classifications, the mitral chordae were divided into marginal (first order) when inserted into the leaflet's free edge and basal (second order) when inserted into the ventricular aspect of the body of the leaflets [6–8]. All chordae were identified by their insertion into the anterior leaflet (A1 and A2) and posterior mitral leaflet (P1, PM1, PM2, and P2). The two constant and thick anterior (AS) and posterior (PS) strut chordae were identified as AS1 and AS2 for the anterior and PS1 and PS2 for the posterior. The other

basal chordae located lateral to the AS and PS were termed AB1 and AB2 for the anterior, and PMB1 and PMB2 for the middle scallop of the posterior leaflet (Fig 2 and Fig 3). For the purpose of this study, pure (or marginal) basal chordae were defined as those with no other type of chordae arising from them; they were labeled "mixed" when the chordae had both basal and marginal branches.

Measurements

Before examination of each heart, the aorta and pulmonary artery were resected 1 cm above the valve commissure, and each heart was weighed. To verify the absence of mitral regurgitation, each valve was inspected through the left atrium while saline was pressure-injected through the aorta. The aortic and mitral valve annulus diameters were measured with Hegar probes. The heart was then sectioned vertically through the right coronary sinus of Valsalva, interventricular septum, and right ventricular free wall to allow a ventricular view of the
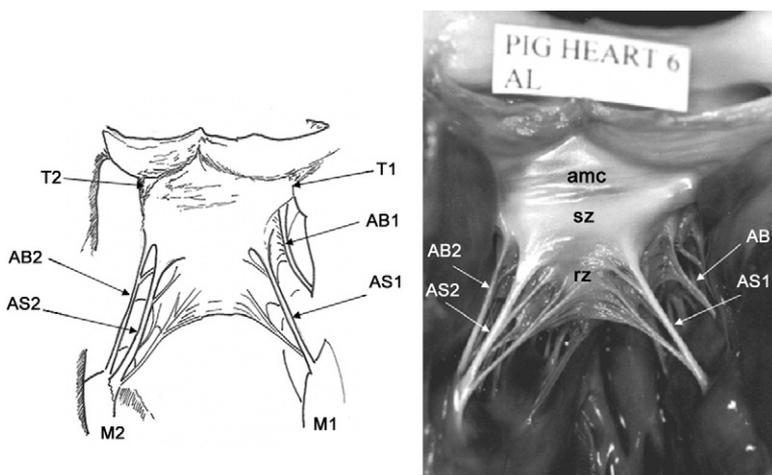
Fig 2. A diagram and photograph of the ventricular aspect of the anterior mitral leaflet show the anterior basal chordae. (Tl = left trigone; T2 = right trigone; AB1 = anterolateral basal chorda; AB2 = posteromedial basal chorda; AMC = aortomitral curtain; AS1 = anterolateral strut chorda; AS2 = posteromedial strut chorda; M1 = anterolateral papillary muscle; M2 = posteromedial papillary muscle; Rz = rough zone; Sz = smooth zone.)

Table 1. Human, Porcine, and Ovine Mitral Valve General Measurements[a]

Measurement	Human	Porcine	Ovine
Heart weight (g)	309.54 ± 80.63	466 ± 107.5	271 ± 54.9
Aortic annulus diameter (mm)	21.90 ± 1.86	21 ± 2.10	18.9 ± 1.37
Mitral annulus diameter (mm)	29.54 ± 2.54	28.1 ± 3.54	24.7 ± 3.46
Intertrigonal distance (mm)	27.45 ± 4.13	27.7 ± 5.2	20.76 ± 3.49
T1-M1 (mm)[b]	14.98 ± 4.25	25.2 ± 2.06	22.2 ± 2.68
T2-M2 (mm)[c]	18.21 ± 4.60	28.6 ± 3.05	24.64 ± 2.38

[a] Measurements are presented as mean ± standard deviation. [b] T1-M1 is the distance from anterior papillary muscle tip to left trigone. [c] T2-M2 is the distance from posterior papillary muscle tip to right trigone.

anterior basal chordae (Fig 3). The left ventricle was then sectioned vertically from the apex to the middle point of the posterior mitral annulus to expose the posterior basal chordae. Finally, the atrial and ventricular myocardium was excised, leaving the mitral annulus, leaflets, chordae, and papillary muscles. Under transillumination, the height of each leaflet (free edge to annulus), length of the rough and smooth zones, and the mitral annulus perimeter were measured with calipers (data not shown).

The number, distribution, length, and thickness of all anterior and posterior basal chordae were measured. The origin from each papillary muscle was recorded as low, middle, or high according to whether the basal chorda originated at the base, body, or tip of the papillary muscle. Photographs and drawings were taken of each specimen.

All data are reported as mean ± the standard deviation. Data were compared using a *t* test for paired observations, with the level of significance set at $p < 0.05$ for statistical comparison within a species. Interspecies comparisons of basal chorda number were done using

Table 2. Length of Anterior and Posterior Strut Chordae and Other Basal Chordae[a]

Chordae[b]	Human	Porcine	Ovine
Anterior mitral leaflet			
AS	18.08 ± 3.60	25.91 ± 3.29	21.79 ± 3.06
AS1	17.02 ± 3.09	24.91 ± 3.14	21.36 ± 2.57
AS2	19.14 ± 3.89	26.92 ± 3.29	22.21 ± 3.57
AB	16.95 ± 3.9	21.49 ± 4.26	18.18 ± 3.29
AB1	15.46 ± 2.42	18.77 ± 2.53	17.41 ± 2.75
AB2	18.45 ± 4.59	24.54 ± 3.74	19.18 ± 3.87
Posterior mitral leaflet			
PS	18.86 ± 3.52	21.11 ± 4.21	18.75 ± 3.21
PS1	18.47 ± 3.49	21.73 ± 4.59	19.39 ± 2.09
PS2	19.24 ± 3.84	20.49 ± 3.94	18.10 ± 4.05
PB	16.63 ± 2.85	18.22 ± 4.62	14.62 ± 3.05
PB1	16.94 ± 3.43	17.83 ± 4.15	14.87 ± 3.29
PB2	16.32 ± 2.43	18.62 ± 5.24	14.40 ± 2.97

[a] Values are in mm and are presented as mean ± standard deviation. [b] The numeral 1 designates all chordae inserted into left mitral hemivalve. The number 2 designates all chordae inserted into right hemivalve.

AB = basal chordae located lateral to the anterior strut chordae; AS = anterior strut chorda; PB = basal chordae located lateral to the posterior strut chordae; PS = posterior strut chordae.

analysis of variance (ANOVA), with Bonferroni correction using XLSTAT 2007 software (Addinsoft SARL, Paris, France).

Results

The heart weights, aortic and mitral annulus diameters, and the measured distances are summarized in Table 1. There were no differences in mitral orifice diameter between measurements with a Hegar dilator or measuring the mitral perimeter in the open heart.

The basal chordae were easily identified by their triangular-shaped insertion into the ventricular aspect of the leaflets. The total number of basal chordae was 18.81 ± 3.54 in the human, 24.6 ± 4.21 in the porcine, and 19.4 ± 2.98 in the ovine valves. A statistically significant difference was found between the number of basal chordae in the human and porcine valves but not in the human and ovine valves (ANOVA, Bonferroni corrected significance level, $p = 0.0167$).

The leaflet insertion of the basal chordae into the undersurface of the anterior leaflet was at the junction of the smooth and rough zones (Fig 2). The anterior leaflet smooth zone height varied considerably between individual valves: mean 10.78 ± 3.20 mm in porcine (range, 5 to 15.88 mm); 6.46 ± 1.66 mm in ovine (range, 5 to 9.7 mm), and 10.22 mm ± 1.71 in humans (range, 6.77 to 12.01 mm). The leaflet insertion of the basal chordae into the posterior leaflet and commissural areas was always close to the annulus in all three species (Fig 3). In fact, except for the anterior leaflet, all basal chordae were inserted around the annulus (Fig 4).

The AS and PS chordae were easily identified in all three species as the most medial basal chordae and could
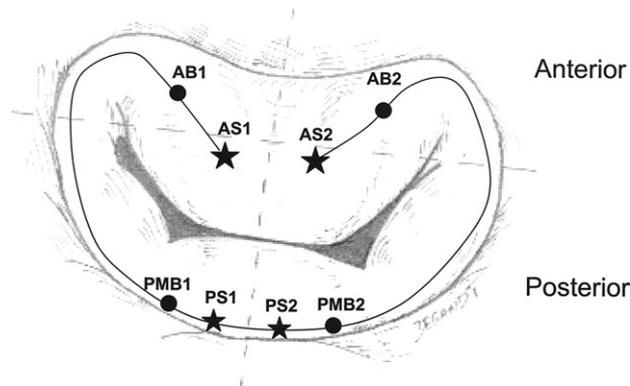

Fig 4. Left atrial view of the mitral valve. The continuous line represents basal chorda insertions into leaflets. Large stars represent the insertion of the anterior strut chordae. Smaller stars represent the insertion of the posterior strut chordae. Dots correspond to insertions of basal chordae. (AS1 and AS2 = anterior strut chordae; AB1 and AB2 = lateral anterior basal chordae; PS1 and PS2 = posterior strut chordae; PMB1 and PMB2 = lateral posterior basal chordae.)

CARDIOVASCULAR

Table 3. Thickness of Anterior and Posterior Strut Chordae and Other Basal Chordae[a]

Chordae[b]	Human	Porcine	Ovine
Anterior mitral leaflet			
AS	0.99 ± 0.07	1.06 ± 0.24	0.85 ± 0.33
AS1	1.04 ± 0.28	1.00 ± 0.16	0.80 ± 0.28
AS2	0.94 ± 0.27	1.13 ± 0.29	0.91 ± 0.37
AB	0.76 ± 0.25	0.95 ± 0.11	0.57 ± 0.30
AB1	0.71 ± 0.16	0.97 ± 0.07	0.67 ± 0.18
AB2	0.81 ± 0.33	0.93 ± 0.14	0.64 ± 0.26
Posterior mitral leaflet			
PS	0.69 ± 0.03	0.82 ± 0.36	0.66 ± 0.21
PS1	0.65 ± 0.2	0.79 ± 0.23	0.58 ± 0.30
PS2	0.73 ± 0.16	0.85 ± 0.46	0.58 ± 0.23
PB	0.64 ± 0.19	0.92 ± 0.37	0.59 ± 0.23
PB1	0.69 ± 0.26	1.05 ± 0.43	0.64 ± 0.27
PB2	0.60 ± 0.08	0.79 ± 0.25	0.55 ± 0.21

[a] Values are in mm and are presented as mean ± standard deviation.   [b] The numeral 1 designates all chordae inserted into left mitral hemivalve. The number 2 designates all chordae inserted into right hemivalve.

AB = basal chordae located lateral to the anterior strut chordae;   AS = anterior strut chorda;   PB = basal chordae located lateral to the posterior strut;   PS = posterior strut chordae.

be identified in 100% of the specimens. The two anterior strut chordae (AS1 and AS2) were inserted in the central part of the anterior leaflet at the junction of smooth and rough zones. The posterior strut chordae (PS1 and PS2) were inserted into a single fibrous band located close to central portion of the posterior annulus (Fig 4).

The insertion of the basal chordae into the papillary muscles was semicircular. The insertion of both anterior strut chordae (AS1 and AS2) into the papillary muscles was the lowest of all chordal insertions in 100% of the porcine and ovine hearts. In humans, the AS1 insertion was the lowest in only 63.64% of the hearts and AS2 in 90.91%. In these hearts, the chorda inserted at the lowest point of the papillary muscle was a very thin marginal chorda.

The PS insertions showed a greater variability in their papillary muscle insertion. In the porcine heart, PS1 and PS2 were inserted at the highest point of both papillary muscles (M1 and M2) in 30% of the cases. In the ovine heart, PS1 insertion was the highest in 40% and PS2 in 30%. In humans, the PS chordae were always inserted in an intermediate position of both papillary muscles and never at the lowest point of the papillary muscles in all hearts.

The AS and PS lengths and thicknesses are presented in Tables 2 and 3. Although the lengths of the anterior and posterior basal chordae were significantly different in the ovine hearts, no statistical difference was found in the human and porcine hearts. Again, the lengths of the AS and PS were different in the porcine ($p < 0.0005$) and ovine ($p < 0.0005$) hearts but not in human hearts. No significant differences were found between the lengths of AS1 and AS2 and PS1 and PS2 in all three species.

The thickness of the strut chordae (measured at their middle segment) was higher in the AS than in the PS in the three species (porcine and ovine, $p < 0.05$; human, $p < 0.005$). The AS chordae were thicker than the adjacent basal chordae in the human hearts ($p < 0.05$). No significant difference in thickness was found between the PS chordae and their adjacent basal chordae in the three species.

Pattern of Distribution of the Basal Chords

Evaluation of the basal chorda distribution showed that at least two chordae (ie, one strut and its adjacent basal chorda) were present in each half of the anterior leaflet in 70% of porcine and ovine (7/10) and in 100% of human hearts (11/11). At least two basal chordae were present in each half of the middle scallop of the posterior leaflet in 70% of porcine (7/10), 80% of ovine (8/10), and 63.63% of humans hearts (7/11).

Marginal or rough zone chordae usually arose from the basal chordae. The marginal and corresponding basal chordae formed triangular structures found all around the mitral valve. Pure marginal chordae (ie, arising directly from a papillary muscle without connection with basal chordae) were infrequent (1 to 6 per valve).

Comment

The anatomy of the mitral valve leaflets, commissures, and annulus has been extensively studied [9–11]. The subvalvular apparatus and the basal chordae, in particular, have received far less attention. In fact until recently, the basal chordae have been practically ignored. Among these chordae, Lam and colleagues [12] identified two particularly thick anterior chordae that he termed "strut chordae" (also known as principal chordae). In a porcine beating-heart endoscopic study, van Rijk-Zwicker and colleagues [13] identified the two anterior strut chordae but also noted the presence of two posterior basal chordae. They further described how these four strut chordae remained taut during the entire cardiac cycle.

In a subsequent anatomic study, we confirmed the individuality of these four strut chordae [4]. Because of their thickness and strategic location, we postulated that they must be essential in maintaining the geometry of the mitral valve and probably of the left ventricle. Contrary to "strut," which means a structure designed to resist compression, we suggest they should be called "stay" chordae, which implies a support or steadying function [14]. Lomholt and colleagues [15] have shown in a sheep model that the anterior stay chordae sustain approximately three times more tension than the corresponding marginal chordae.

Increasing evidence is now available on the importance of these stay chordae. Recent experimental and clinical studies have shown their role in the genesis of functional ischemic mitral regurgitation [1–3]. The lateral and apical displacement of the ischemic posterior papillary muscle pulls the anterior leaflet downward, making the valve incompetent. The inextensible anterior stay chordae that connect the papillary muscle to the anterior

leaflet are responsible for this tenting effect. A logical consequence of this mechanism led Messas and colleagues [16] to suggest cutting the anterior stay chordae as a surgical treatment of ischemic regurgitation. However, further experimental studies have questioned the wisdom of this technique because of the negative effect it might have on left ventricular function [17, 18].

These facts stimulated the present work, which was primarily designed to obtain a detailed knowledge of the mitral basal chordae in ovine, porcine, and human hearts. These species were selected because most experimental studies have been performed in ovine and porcine models expecting that the results could be transferred to the human heart. The present study shows that the number of basal chordae in the human was similar to the ovine but not the porcine valves. Also, although the origin of the anterior stay chordae in the papillary muscles was the lowest in the ovine and porcine hearts, it was only in 77.30% of the human specimens. From a clinical point of view, this easily identified landmark, although useful in the animal, is unreliable in the human heart. A more reliable reference point to identify the anterior and posterior stay chordae is their location as the most medial of all basal chordae in 100% of all three species. This method of identification can easily be done through a standard atriotomy.

The significant difference in the height of the rough and smooth zones of the anterior mitral leaflet within the same species (10 mm in porcine and 5 mm in ovine and human hearts) should alert the surgeon when performing an anterior leaflet basal incision to increase or reduce its area [20, 21]. This incision should not inadvertently section the stay chordae. It is also interesting that although the length of the anterior and posterior stay chordae is similar in the humans, the posterior stay chordae were shorter than the anterior in the ovine and porcine specimens. This geometric difference, which might be due to humans being bipedal, must be taken into consideration when data from animal studies are assumed to apply to human subjects.

In all cases, the anterior stay chordae were thicker than the posterior. This finding suggests that the anterior stay chordae sustain higher tension during the cardiac cycle. We have shown in an acute sheep model that the sectioning of these two anterior stay chordae induced an immediate increase in the aorta-mitral angle formed by the aortic and mitral annulus planes [22]. The apex of this angle is directly connected to the anterior stay chordae through the aortic curtain. Integrity of the heart's basal plane has been shown to be essential for left ventricular pumping action [20].

Soon after initiating the present anatomic study, we were overwhelmed by the difficulty in describing our findings. The classic descriptions of the mitral basal chordae were limited to mentioning their presence in the anterior and posterior leaflets and of two thicker anterior strut or principal chordae. A more precise terminology was obviously needed.

Application of Carpentier's well-known terminology [23] was difficult because it is based on three anterior (A1, A2, A3) and three posterior (P1, P2, P3) leaflet areas. This is a very simple and practical classification for the surgeon when dealing at the leaflet level but insufficient when attempting to describe all marginal and basal chordae. For instance, the anterior marginal and basal chordae cannot be classified into three groups (A1, A2, or A3) because anatomically there are clearly two groups defined by their papillary muscle origin. Similarly, the chordae of the posterior middle scallop (P2) are separated into two groups according to their origin from two papillary muscles. A more rational method is to classify all chordae according to their papillary muscle origin. This method considers the mitral valve as being formed by two symmetrical hemivalves supported by two papillary muscles.

It is hoped that this anatomic study of the basal chordae will increase the awareness of their importance, question the concept of their section as innocuous, and stimulate new mitral valve repair techniques.

The main limitation of this study is the small number of specimens. In addition, the measurements were performed under static, nonphysiologic conditions in an excised heart. However, because of the care undertaken to avoid deformations, the identification and location of the different chordae should not have been affected. Of more concern is the method used to measure their length and thickness with calipers. Aware of the possibility of interoperator error with this limitation, all measurements were performed by a single observer. Comparison between species in terms of difference in lengths and thickness of the basal chordae cannot be made because of the differences in weights of the hearts. Also the number and location of the chordae within a species should not be age-dependent.

This study addresses a largely ignored anatomic component of the mitral valve. We present information on the presence, type, and location of the different basal chordae and in particular the anterior and posterior strut chordae. This nomenclature for the basal chordae will facilitate the recording of findings as well as new chordal surgical procedures. It is hoped that this effort will bring nearer the biblical statement that "Now the whole earth *had* one language and a common speech" (Genesis 11:1–1).

References

1. Obadia JF, Casali C, Chassignolle JF, Janier M. Mitral subvalvular apparatus. Different functions of primary and secondary chordae. Circulation 1997;4;96:3124–8.
2. Nielsen SL, Timek TA, Green GR, et al. Influence of anterior mitral leaflet second order chordae tendinae on left ventricular systolic function. Circulation 2003;108:486–91.
3. Goetz WA, Lim HS, Pekar F, et al. Anterior mitral leaflet mobility is limited by the basal stay chords. Circulation 2003;17;107:2969–74.

4. Kumar N, Kumar M, Duran CMG. A revised terminology for recording surgical findings of the mitral valve. J Heart Valve Dis 1995;4:70–5.
5. Shah PM, Raney AA, Duran CMG, Oury JH. Multiplane transesophageal echocardiography: A roadmap for mitral valve repair. J Heart Valve Dis 1999;8:625–9.
6. Tandler J. Anatomie des Herzens: Handbuch der Anatomie des Menschen, band III; part 1. Jena, Germany: Gustav Fischer; 1913:84–88.
7. Acar C, Deloche A. Anatomie et physiologie des valves mitrale et tricuspide. In: Acar J, ed. Cardiopathies valvulaires acquises. Paris, France: Flammarion; 1985:3–20.
8. He S, Weston MW, Lemmon J, Jensen M, Levine RA, Yoganathan AP. Geometric distribution of chordae tendinae: An important anatomic feature in mitral valve function. J Heart Valve Dis 2000;9:495–501.
9. Ranganathan N, Lam JHC, Wigle ED, Silver MD. Morphology of the human mitral valve. II. The valve leaflets. Circulation 1970;41:459–67.
10. Williams WR PL, ed. Gray's anatomy. 35th ed, (British). Philadelphia, PA: WB Saunders Company; 1973:599–15.
11. Yacoub M. Anatomy of the mitral valve chordae and cups. In: Kalmanson D, ed. The mitral valve. A pluridisciplinary approach. London: Edward Arnold; 1976:15–20.
12. Lam JHC, Ranganathan N, Silver MD. Morphology of the human mitral valve. I. Chordae tendineae: a new classification. Circulation 1970;41:449–58.
13. van Rijk-Zwikker GL, Delemarre BJ, Huysmans HA. Mitral valve anatomy and morphology: relevance to mitral valve replacement and valve reconstruction. J Card Surg 1994; 9(2 suppl):255–61.
14. Webster's unabridged dictionary. New York, NY: Random House Value Publishing, Inc; Barnes & Noble, Inc; 1996:1863.
15. Lomholt M, Nielsen SL, Hansen SB, Andersen NT, Hasenkam JM. Differential tension between secondary and primary mitral chordae in an acute in-vivo porcine model. J Heart Valve Dis 2002;11:337–45.
16. Messas E, Pouzet B, Touchot B, et al. Efficacy of chordal cutting to relieve chronic persistent ischemic mitral regurgitation. Circulation 2003;9;108(suppl 1):II111–5.
17. Goetz WA, Lansac E, Lim HS, Stevens SA, Weber PA, Duran CMG. Kinking of the atrioventricular plane during the cardiac cycle. Asian Cardiovasc Thorac Ann 2006;14:394–8.
18. Rodriguez F, Langer F, Harrington KB, et al. Importance of mitral valve second-order chordae for left ventricular geometry, wall thickening mechanics, and global systolic function. Circulation 2004;110(suppl II):II115–22.
19. Alam M, Rosenhamer G. Atrioventricular plane displacement and left ventricular function. J Am Soc Echocardiogr 1992;5:427–33.
20. Acar C, de Ibarra JS, Lansac E. Anterior leaflet augmentation with autologous pericardium for mitral repair in mitral valve insufficiency. J Heart Valve Dis 2004;13:741–6.
21. Duran CMG. Surgical techniques for the repair of anterior mitral leaflet prolapse. J Cardiac Surg 1999;14:471–81.
22. Goetz WA, Lim HS, Lansac E, Weber PA, Birnbaum DE, Duran CMG. The aortomitral angle is suspended by the anterior mitral basal "stay" chords. Thorac Cardiovasc Surg 2003;51:190–5.
23. Carpentier AF, Lessana A, Relland JYM, et al. The "physio-ring": an advanced concept in mitral valve annuloplasty. Ann Thorac Surg 1995;60:1177–86.

INVITED COMMENTARY

Mitral valve anatomy has been studied extensively since Vesalius first gave the valve its name 500 years ago. Despite this, a growing realization that mitral repair durability is not as robust as was once believed has stimulated surgeons to analyze valve structure with a more quantitative eye. Toward this end, Degandt and colleagues [1] report a simple, yet well done study describing comparative basal chord anatomy.

Theoretical studies have shown leaflet curvature to be an important determinant of leaflet stress and leaflet stress a potential determinate of repair durability [2, 3]. In addition, recent studies by our group using real-time three-dimensional echocardiography (rt3DE) have revealed mitral leaflet curvature to be much more complex than previously believed (unpublished data). A particularly interesting result of these early rt3DE studies has been to show the mid-posterior leaflet (P2) to be a region of dense curvature heterogeneity. Such spatially dense surface curvature changes have been correlated with an increased stress distribution in aortic aneurysms [4]. This may explain why the P2 region is the most common location for valve disruption in patients with myxomatous degeneration.

Complex leaflet geometry is, at least in part, a function of the intricate chordal insertion pattern that this article describes thoroughly for the first time. The results of this study should not be underestimated. The information provided will not only be helpful in interpreting 3D valve imaging, but it will facilitate the development of more accurate computer models of functional valve anatomy. As these models evolve they will ultimately be used to develop, optimize, and evaluate repair techniques. Such a tool will allow the surgeon to quantitatively plan a mitral valve repair operation before he or she enters the operating room.

Joseph H. Gorman III, MD

University of Pennsylvania School of Medicine
313 Stemmler Hall
36th and Hamilton Walk
Philadelphia, PA   19104-4283
e-mail: gormanj@uphs.upenn.edu

References

1. Degandt AA, Weber PA, Saber HA, Duran CMG. Mitral valve basal chordae: comparative anatomy and terminology. Ann Thorac Surg 2007;84:1250–5.
2. Salgo IS, Gorman JH 3rd, Gorman RC, et al. Effect of annular shape on leaflet curvature in reducing mitral leaflet stress. Circulation 2002;106:711–7.
3. Arts T, Meerbaum S, Reneman R. Stresses in the closed mitral valve: a model study. J Biomech. 1983;16:539–47.
4. Sacks MS, Vorp DA, Raghavan ML, Federle MP, Webster MW. In vivo three-dimensional surface geometry of abdominal aortic aneurysms. Ann Biomed Eng 1999;27:469–79.

CARDIOVASCULAR

Mitral Valve Basal Chordae: Comparative Anatomy and Terminology

Alexandra A. Degandt, Patricia A. Weber, Hashim A. Saber and Carlos M.G. Duran

Updated Information & Services	including high-resolution figures, can be found at: http://ats.ctsnetjournals.org/cgi/content/full/84/4/1250
References	This article cites 18 articles, 2 of which you can access for free at: http://ats.ctsnetjournals.org/cgi/content/full/84/4/1250#BIBL
Citations	This article has been cited by 1 HighWire-hosted articles: http://ats.ctsnetjournals.org/cgi/content/full/84/4/1250#otherarticles
Subspecialty Collections	This article, along with others on similar topics, appears in the following collection(s): **Valve disease** http://ats.ctsnetjournals.org/cgi/collection/valve_disease
Permissions & Licensing	Requests about reproducing this article in parts (figures, tables) or in its entirety should be submitted to: http://www.us.elsevierhealth.com/Licensing/permissions.jsp or email: healthpermissions@elsevier.com.
Reprints	For information about ordering reprints, please email: reprints@elsevier.com

THE ANNALS OF
THORACIC SURGERY