CLINICAL SCIENCES

STUDY OF THE TRACTION RESISTANCE OF MITRAL VALVE CHORDAE TENDINEAE

Frederico Lafraia Lobo, Flávio Roberto Takeda, Carlos Manuel de Almeida Brandão, Domingo Marcolino Braile, Fabio Biscegli Jatene, Pablo Maria Alberto Pomerantzeff

Lobo FL, Takeda FR, Brandão CM de A, Braile DM, Fabio Biscegli Jatene, Pomerantzef PMA. Study of the traction resistance of mitral valve chordae tendineae. CLINICS. 2006;61(5):395-400.

OBJECTIVE: To determinate the extension and the resistance of the primary mitral valve chordae tendineae when submitted to traction. The importance of keeping the integrity of papillary muscle, chordae tendineae, and mitral valve cuspid when the replacement of this valve occurs is clear, but the knowledge of the maximum resistance that a primary tendinea chorda can withstand is not known.
METHODS: Eight hearts were dissected, and one hundred and thirty two primary human chordae tendineae were measured (length and thickness) and submitted to traction under controlled conditions so that the absolute resistance, resistance relative to thickness (relative resistance), and elongation could be measured.
RESULTS: The correlation between the elongation at the moment of rupture and the thickness was equal to 1.54 + 17.02 x thickness ($P = 0.026$); and to absolute resistance was equal to 0.95 + 1.42 x resistance ($P < 0.001$); and to the resistance relative to thickness (relative resistance) was equal to 1.95 + 0.08 x relative resistance ($P = 0.009$). The correlation between the absolute resistance and the thickness was equal to 0.26 + 14.53 x thickness ($P < 0.001$).
CONCLUSION: The resistance of primary mitral valve chordae tendineae is associated with its thickness and elongation at the moment of rupture, but is not associated with the length. The elongation at the moment of rupture shows a relationship with the resistance relative to thickness (relative resistance) and with the thickness of the primary chordae tendineae, but not with the length of the chordae tendineae.

KEYWORDS: Chordae Tendineae. Mitral Valve. Left Atrioventricular Apparatus. Elongation. Stretching Resistance.

INTRODUCTION

The left atrioventricular apparatus is located between the left atrium and the left ventricle, and consists of the following: mitral ring, anterior and posterior cusps, chordae tendineae, and papillary muscles.[1] The transmitral pressure exerted on mitral valve leaflets causes full closure during systole,[2] thus producing the strain in the chordae tendineae, which are inserted in the different cusp areas. The force exerted by the cusps on the chordae tendineae is directly proportional to the transmitral pressure gradient and to the area covered by the cusps.[3] These forces are transmitted to the papillary muscles, which are located in the posterior wall of the left ventricle.

During systole, a change occurs in the mitral ring configuration, with its eccentric size reduction.[4] Thus, the left ventricle motion produces a displacement of the papillary muscle base. The subsequent contraction and motion of the papillary muscle, per se, affect the distances between portions of the papillary muscles and the mitral ring plane, which is a normal aspect of the movement.[5]

Since the publication of the study conducted by Lillehei et al[6] in 1964, it has become known how important it is to maintain the integrity of the papillary muscle, chordae tendineae, and mitral valve cusp, preserving the conical shape

Heart Institute (InCor), Hospital das Clínicas, São Paulo University Medical School - São Paulo/SP, Brazil.
Email: frede_lobo@yahoo.com.br
Received for publication on January 16, 2006.
Accepted for publication on May 30, 2006.

of the left ventricle when this valve is replaced. More recent studies[7-14] have confirmed and justified this preservation of the left ventricular function, as proposed by Lillehei et al[6].

Nevertheless, the maximum stretch that the chordae tendineae can sustain has not been quantified, despite a study carried out on porcine chordae tendineae[15] in 2001. Therefore, it is necessary to establish the individual maximum resistance of the chordae tendineae to stretching, which will enable the prediction of resistance during the left ventricular systole.

OBJECTIVE

The objective of this study was to determine the elongation and stretching resistance of human mitral valve chordae tendineae, taking their thickness into account and establishing the relative resistance of each primary chorda tendinea.

METHODS

Eight human hearts were obtained from the Forensic Department of Verification of Deaths of the the City of São Paulo from 8 corpses of individuals aged 29 to 83 years (mean age 57.7 years; standard deviation, 15.3 years and median age, 57.5 years). Five corpses (62.5%) were male. Six corpses (75%) were caucasian, and the other 2 (25%) were black. Four of the deceased (57.1%) were smokers, and 2 (28.6%) had systemic hypertension (SH). No valvulopathy or positive serology for HIV was found. The body mass index (BMI) of these corpses ranged from 15.6 kg/sq m to 29.8 kg/sq m (mean value of 22.9; standard deviation, 4.9 and median, 23.8). The measurements were performed between 12 to 35 hours after death (mean, 18.3 hours, standard deviation, 7.5 hours, and median, 16.1 hours).

From these 8 hearts, 145 chordae tendineae were evaluated, with the results shown on Table 1. Once obtained, each heart was dissected in the Anatomic Surgery Laboratory of the Heart Institute of the São Paulo University Medical School, with the mitral valve system (papillary muscle, chordae tendineae, and anterior and posterior cusps) being exposed (Figure 1).

Figure 1 - Primary human tendinae chordae of mitral valve after dissected

After the dissection of the 8 mitral valve systems, the primary chordae tendineae were separated, but part of the papillary muscle and of the valve edges of each primary chorda tendinea were left connected to the chordae, thus providing 145 chordae tendineae. Each specimen was washed in running water and stored dry in plastic polyethylene bags, which, in turn, were sealed and stored in a container filled with water, covered, and kept in a freezer at - 6 ºC.

Once the individual chordae tendineae were frozen and stored in a thermal container, the material was transported to Braile Biomédica, located in the city of São José do Rio Preto/SP, so that stretching could be performed in the MTS Q Test/1L equipment (Figure 2). For the calculation of resistance relative to thickness (relative resistance, kg/m^2), a Mitutoyo 0.01 mm micrometer was used to measure the thickness of each set of chordae tendineae and, indirectly, the transverse-section area of each chorda tendinea. Yhis was done by considering the chorda tendinea to be a perfect cylinder.

At the time of stretching, each edge of the chorda tendinea was fixed by metal claws designed for this purpose.

Table 1 - Mean values, standard deviation, median, minimum, and maximum measurements performed on the chordae tendineae

Variable	N	Mean value	Standard deviation	Median	Minimum	Maximum
Length (cm)	145	1.4	0.38	1.39	0.08	2.36
Thickness (cm)	145	0.05	0.02	0.05	0.02	0.11
Resistance (kg)	132	1	0.63	0.91	0.08	3.43
Relative resistance (kg/mm^2)	132	4.9	4.31	3.3	0.58	27
Elongation at the time of the rupture (mm)	103	2.39	1.44	2.16	0.27	7.12

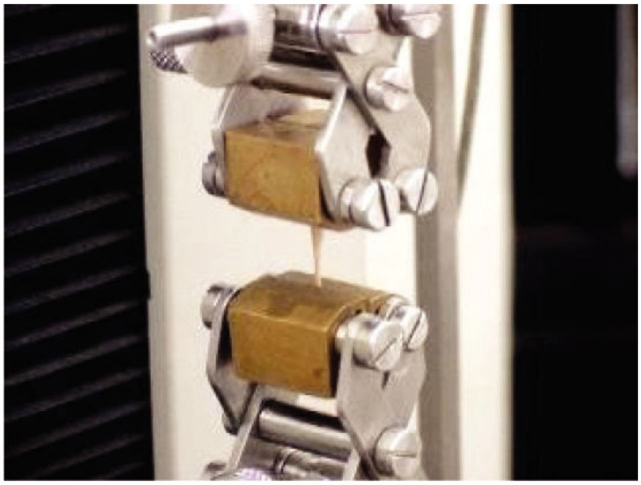

Figure 2 - Primary human tendinae chordae of mitral valve during traction

The chordae tendineae were exposed between the two claws, and the papillary muscle and the cusp were fixed with part of the chorda tendinea to the claw. The described procedure made it possible to stretch only the chorda tendinea, not the elements connected to it (papillary muscle and anterior or posterior cusps).

The resistance to stretch was assessed by the load (kg) applied at the time of rupture, and the resistance relative to the thickness of the chordae tendineae (relative resistance) was calculated as kg/m^2. Elongation was represented by the increase in the percent of the specimen length under stretch at the time of rupture. [16]

For the purpose of determining correlations between elongation and other measurements (thickness, absolute resistance, relative resistance, and length), linear regression models were built. The correlation between resistance, thickness, and length was also assessed.

At first, all the variables were analyzed in a descriptive manner. For the quantitative variables, this analysis was made through the observation of the minimum and maximum values, and of the calculation of mean and standard deviation values. For the qualitative variables, the absolute and relative frequencies were calculated.

In order to evaluate the correlation between the two variables, Pearson's correlation coefficient[17] and the linear regression model[17] were used.

The significance level used for the tests was of 5%.

RESULTS

From the 145 chordae tendineae prepared for stretching, 13 broke before stretching or were not fixed properly to the claws. Therefore, 132 chordae tendineae were satisfactorily stretched, of which 29 did not have data points for the variable, elongation at the time of the rupture (mm), which is calculated by the stretching machine, coincident with strain peak described in the results as the resistance (kg), at the point at which the chordae tendineae were considered ruptured; consequently 103 chordae tendineae were included in the results for the variable, elongation at the time of the rupture (mm).

The correlation between the elongation and thickness was equal to 1.54 + 17.02 x thickness ($P = 0.026$) as shown in Figure 3; the correlation between elongation and length was equal to 2.86 - 0.33 x length ($P = 0.361$); the correlation between elongation and absolute resistance was equivalent to 0.95 + 1.42 x resistance ($P < 0.001$); and the correlation between elongation and relative resistance was equal to 1.95 + 0.08 x relative resistance ($P = 0.009$) as shown in Figure 4. Therefore, we found positive and significant correlations between elongation and thickness, resistance, and relative resistance, but not between elongation and length.

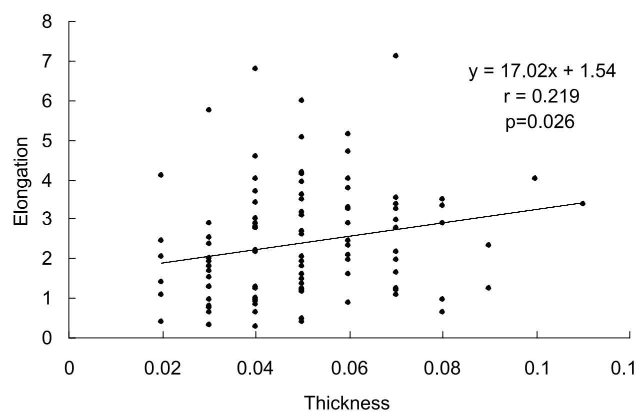

Figure 3 - Correlation between elongation and thickness

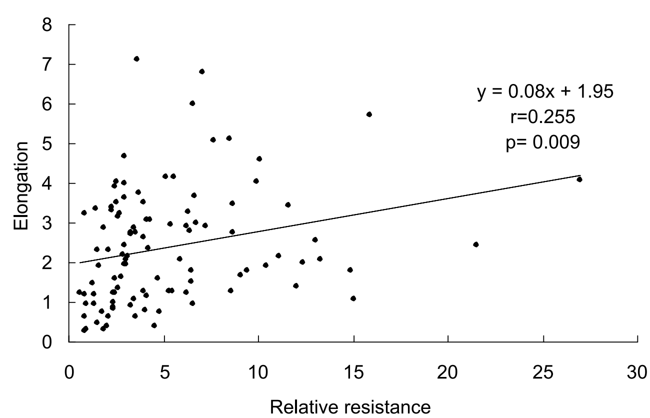

Figure 4 - Correlation between elongation and relative resistance (resistance relative to thickness)

We found that the correlation between absolute resistance and thickness was equal to 0.26 + 14.53 x thickness ($P < 0.001$), which is positive and significant, as shown in

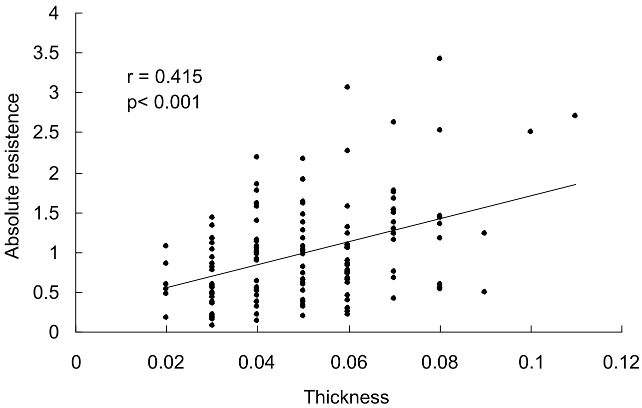

Figure 5 - Correlation between absolute resistance and thickness.

Figure 5, and that there was no significant correlation between resistance and length (Table 2).

Table 2 - Values of the correlation coefficient between resistance, thickness, and length

	Thickness	Length
r	0.415	-0.163
p	< 0.001	0.062

DISCUSSION

There are no studies in the medical literature worldwide addressing or testing the resistance of human primary chordae tendineae. The only studies with similar interest to ours deal with the force exerted by the papillary muscle,[2,3,5,15] with the importance of the position of the chordae tendineae in the proper hemodynamics of the left ventricle[4,15] and with the importance of preserving the left subvalvar system in valvuloplasty and in the mitral valve replacement.[6-14, 18]

Echocardiographic examinations can yield the pressure exerted by the left ventricular chamber in each type of subvalvar system disease, such as rheumatic fever and myxomatous degeneration. As our investigation proceeds, we will be able to obtain the average resistance of the chordae tendineae in each of these diseases, and discuss the preservation or not of chordae tendineae in each condition affecting the chordae tendineae.

The method employed in the dissection and traction of chordae tendineae was designed to avoid, to the maximum possible extent, the degeneration of the material under investigation. Notwithstanding the precaution taken, we should reconsider, for the continuation of our study, the following aspects of our method: should the chordae tendineae be preserved dry or in saline solution, should we preserve them until the time of stretching in regular freezers (temperature of approximately -6ºC) or in liquid nitrogen (lowest temperature of -196ºC), and should we store them in separate plastic polyethylene bags or in any other container type that is less reactive with the research material.

The purpose of this study was to start the investigation on the resistance of primary chordae tendineae; it was not designed to establish the final mean value of that resistance. This line of research will certainly continue, but using other methods for the preservation of the chordae tendineae, eg. liquid nitrogen. There is also great interest in the future analysis of chordae tendineae from corpses with valvular diseases of different etiologies.

CONCLUSION

The results presented show that the resistance of human primary mitral valve chordae tendineae is related to their thickness and elongation at the time of rupture during stretching, with no relation to their length. The thickness-related resistance shows a positive and significant correlation with elongation at the time of rupture.

ACKNOWLEDGMENTS

The authors wish to thank Rosangela Monteiro and Aristides T. Correa, from the Anatomic Surgery Laboratory of the Heart Institute of Hospital das Clínicas - FMUSP [Medical School Hospital of the University of São Paulo], for their assistance in obtaining the hearts and having them dissected, and to Dr. Vladimir Ramirez and Solange de Oliveira Dourado, from Braile Biomédica, who helped perform the stretching of the chordae tendineae.

RESUMO

Lobo FL, Takeda FR, Brandão CM de A, Braile DM, Fabio Biscegli Jatene, Pomerantzef PMA. Estudo da resistência à tração das cordas da valva mitral. CLINICS. 2006;61(5):395-400.

OBJETIVO: Determinar o alongamento e a resistência à tração das cordas tendíneas primárias humanas da valva mitral cardíaca. Sabe-se da importância de se manter a integridade do músculo papilar, corda tendínea e cúspide da valva mitral, quando da substituição desta valva, mas não se tem conhecimento da resistência máxima que uma corda tendínea primaria pode sofrer resistência máxima que uma corda tendínea apresenta.

MÉTODO: Foram dissecados 8 corações que permitiram a tração de cento e trinta e duas cordas tendíneas primárias humanas. Foram dissecados 8 corações que permitiram a tração de cento e trinta e duas cordas tendíneas primárias humanas, as quais foram medidas (comprimento e espessura) e submetidas a trações em condições controladas, e assim a resistência absoluta, a resistência relativa a espessura (resistência relativa) e o alongamento puderam ser medidos.

RESULTADOS: A correlação entre alongamento no momento da ruptura e espessura foi igual a 1,54 + 17,02*espessura (p=0,026); e à resistência absoluta foi igual a 0,95 + 1,42*resistência (p<0,001); e à resistência relativa à espessura foi igual a 1,95 + 0,08*resistência relativa (p=0,009). A correlação entre resistência absoluta e espessura foi igual a 0,26 + 14,53*espessura (p<0,001).

CONCLUSÃO: A resistência da corda tendínea primaria humana da valva mitral está relacionada com sua espessura e com o alongamento no momento da ruptura à tração, não estando relacionada ao seu comprimento; e que o alongamento no momento da ruptura apresenta correlação com a resistência relativa à espessura e com a espessura da corda tendínea primaria humana, não estando relacionada com o comprimento da mesma.

UNITERMOS: Cordoalha. Corda Tendinea. Valva Mitral. Aparelho atrio-ventricular. Resistência. Alongamento.

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