HEMODYNAMIC PROFILE OF MITRAL STENOSIS. CORRELATION WITH VALVE AREA

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Thirty-eight patients with isolated rheumatic mitral stenosis were studied by cardiac catheterization to assess the severity of mitral valve obstruction. Mitral valve area varied from 0 5 to 1.7 cm² (0 96 ± 0 35 cm, mean ± SD). Cardiac index was normal in hall of the patients (2 82 ± 0 64 L/min/m²). Most of the patients had increased pulmonary artery pressure and resistance and all but three had elevated pulmonary capillary wedge pressure (PCWP). Mitral valve area correlated best with cardiac index (r = 0 74). The correlation of mitral valve area with PCWP, mitral diastolic gradient and pulmonary artery systolic pressure was poor. Several patients with critical stenosis had normal pressure values. Pressure-flow curves for different mitral valve areas were obtained, but some individuals could not fit in them probably because left atrial compliance varied from patient to patient. Patients with mitral stenosis have been shown to have impaired left ventricular contractility and/or compliance and this may be the reason for the different behavior between PCWP and mitral valve gradient.

It is concluded that the severity of mitral stenosis is best assessed by calculation of the mitral valve area. Cardiac index correlates well with the severity of stenosis, but pressure data may often give misleading information.

Rheumatic mitral stenosis is an acquired heart disease for which surgical treatment is indicated when the mitral obstruction is of such degree as to cause significant hemodynamic changes that impair normal physical activity. Patients in NYHA functional class I and II are usually treated medically and those in class III and IV are treated surgically [1]. The assessment of functional impairment of patients with mitral stenosis is frequently a problem when one relies only on subjective information [2-5]. Due to the fact that physical disability is gradual and slowly progressive in this disorder some patients my misinterpret or even be unaware of limiting symptons[6]. Sedentary individuals my be a prototype of asymptomatic patient with severe mitral valve obstruction.

On the other hand, objective non-invasive tests as phonocardiography, echocardiography and stress exercise have been less than ideally reliable in assessing the severity of mitral stenosis [7-11].

Therefore, cardiac catheterization remains as the most important examination in the assessment of the severity of mitral valve' obstruction. The mitral valve area calculated from invasive hemodynamic data based on Gorlin Gorlin's formula [12] is the most reliable parameter of the severity of mitral stenosis. It has been established that a mitral valve area equal to or less than 1.0 cm² can be considered critical stenosis, because most of the tine it produces hemodynamic derangements that will place a patient in function class III or IV 2,13,14, requiring probable surgical management.

The present study was undertaken in order to correlate the mitral valve area with the hemodynamic parameters obtained during complete right and left cardiac catheterization and to determine if any of these parameters could substitute the calculated mitral valve area in the assessment of severity of mitral stenosis.

MATERIAL AND METHODS

Thirty-eight patients, 10 males and 28 females between 20 one 58 (mean of 35 2 ± 9 8) years of age, with clinical, electrocardiographic and radiologic findings consistent with isolated mitral valve stenosis, underwent right and left cardiac catheterization and angiography. The patients were studied in the post absorptive state by either brachial or femoral artery approach. Fluid-filled catheters were connected to

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two strain-gauge transducers, which were placed mid chest for zero level. Pressures curves were registered on photographic paper at a speed of 25 or 100 mm/sec (the latter for transvalvular gradients). Transmitral diastolic gradient was obtained by planimetry using simultaneous pulmonary capillary wedge and left ventricular pressure curves. The left ventricular diastolic filling period was measured at the diastolic crossings of these two curves and the heart rate was determined at this moment. Cardiac output was obtained by the thermodilution technique [15] in 24 patients, by the Fick Method [16] in eleven and by the cineangiographic method [17] in two mitral valve area was calculated using the modified Gorlin Gorlin's equation [18] in 37 patients. One patient had his mitral valve area measured directly at surgery. The pulmonary vascular resistance was obtained according to Poiseuille's equation, where

$$\text{Resistance} = \frac{\text{Pressure gradient x 80}}{\text{Cardiac - output}} \quad \text{dynes-see-cm-}^{5}.$$

No patient in this study had other valvular lesions as assessed by left ventriculography, aortography and pressure curve analysis. The majority of the patients had a history consistent with rheumatic heart disease and were In NYHA functional class II or III. Thirty-three patients were in sinus rhythm and the remaining were in atrial fibrillation. The heart rate at the tine of the study ranged between 55 and 127 (mean 870 ± 177) bpm. The data are expressed as mean standard deviation. Analysis of differences among groups was made by the Student's t test Regression equation and correlation coefficient were obtained by standard formulas. Probability less than 5% ($p < 005$) was considered significant.

RESULTS

Mitral valve area ranged from 05 to 1-7 (mean 096 ± 035) cm^2 and was below the so called critical level (1,0 cm2) in 24 of the 38vpatients. The cardiac index ranged from 18 to 45 (mean 2.82 -4 0.64) L/minx/m2, being abnormally low (less than 2-8 L/min/ m^2) in eighteen of the 37 patients. The mitral valve diastolic blood flow ranged from 83 to 272 (mean 143.3 ± 42.4) ml/s. The pulmonary artery systolic pressure ranged between 28 and 90 (mean 50.0 ± 166) mmHg and was abnormally elevated (higher than 35 mmHg) in 29 of the 38 patients. The pulmonary arteriolar vascular resistance ranged between 15 and 1090 (mean 23.07 ±- 214.1) dynes-see-cm-^{5} and was abnormally elevated (higher than 90 dynes-sec-cm-5) in 29 of 37 patients. The mean pulmonary capillary wedge pressure varied from 8 to 36 (mean 23.0 ± 7.5) mmHg, but was normal (equal to or less than 12 mmHg) in only three patients. The transmitral mean diastolic gradient ranged between 7 and 34 (mean 16.8 ± 6.9) mmHg, and the trans-pulmonary mean pressure gradient (mean pulmonary artery pressure less mean pulmonary capillary wedge pres. sure) ranged between 1 and 45 (mean 11.0 ± 8.5 mmHg.

The relationship between the mitral valve area and pulmonary capillary wedge pressure is shown in figure 1. This relationship has a low correlation coefficient (r = -0.46) because of scattering of data. One can see that for a given mitral orifice a wide range of pulmonary capillary pressure values is possible and that even a slight abnormal value can occur with a critical mitral valve area.

The relationship between mitral valve area and

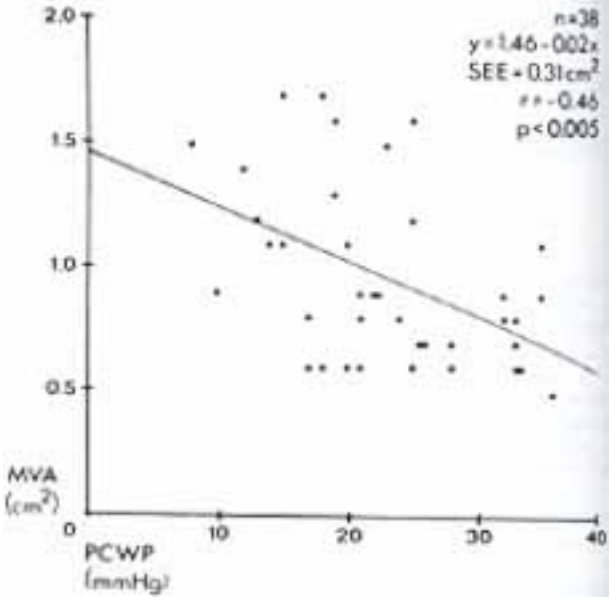

Fig.1 - Relationship between mitral area (MVA) and pulmonary capillary wedge pressure (PCWP) in patients with mitral stenosis.

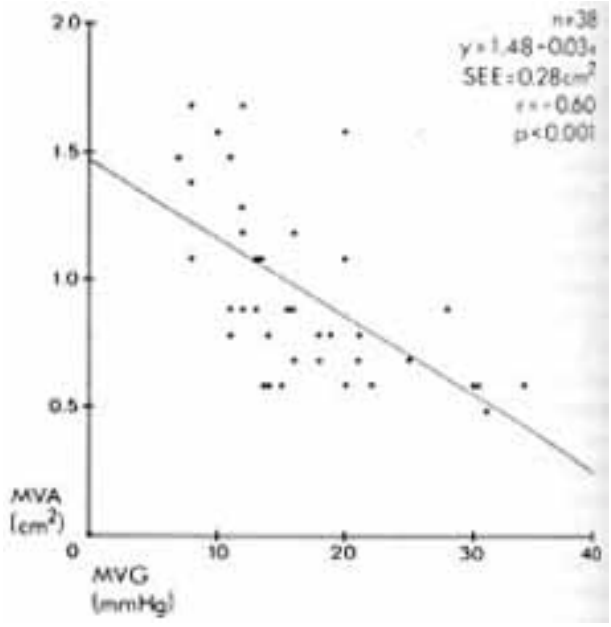

Fig.2 - Relationship between mitral valve area (MVA) and transmitral mean diastolic gradient (MVG) in patients with mitral stenosis.

cardiac index is depicted in figure 4. This relationship is linear with am acceptable correlation coefficient (r = 0.74), demonstrating that the cardiac index follows

closely the mitral valve area. However, it can be seen that a normal cardiac index is still possible with severe mitral stenosis.

The relationship between the mitral valve area and transmitral flow is shown in figure 5. This relationship also has an acceptable correlation coefficient (r = 0.78). Similar to the cardiac index, the valve area accompanies a narrow range of mitral flow.

The relationship between transmitral mean diastolic gradied and pulmonary capillary wedge pressure is presented in figure 6. This relationship has an acceptable correlation coefficient (r = 0.77). However, it can be seen that the greater the pulmonary capillary wedge pressure the wider is the range of mitral valve gradient, indicating that the augmentation of these two pressure parameters in mitral stenosis may not have the same causes.

The relationship between transmitral flow and pulmonary capillary wedge pressure is shown in figure 7. There is no correlation between these two parameters. One cam see that almost all patients with mitral valve areas greater than 1.0 cm^2 had mitral flaw greater than 150 ml/diastolic sec, while almost all patients with valve areas less than 1.0 cm^2 had flows smaller than 150 ml/diastolic sec.

No significant correlation was found between heart rate and pulmonary capillary wedge pressure (figure 8), although it may be seen that the pulmonary capillary wedge pressure has a tendency to increase as the heart rate increases. However, this varied from patient to patient.

The separate analysis of the five patients with atrial fibrillation indicated that these patients all had mitral valve areas under 1.0 cm^2 (mean 0.76 ± 0.11), cardiac indices less than 2.8 L/min/m^2 (mean 2.37 ± 0.21), mitral blood flow below 150 ml/diastolic sec (mean 122.0 ± 11.3), pulmonary capillary wedge. Pressure above 20 mmHg (mean 274 ± 5.0), transmitral diastolic gradient greater than 13 mmHg (mean 17.2 ± 2.8) and pulmonary artery systolic pressure greater than 40 mmHg (mean 51.8 ± 12.6). The mean age was 46.8 ± 2.4 years and all but one were females. Comparing these date with those of the patients with sinus rhythm, the mitral valve areas, cardiac indices and mitral blood flows were less, while the pressure values and the age were greater, the differences, however, were not reach statistically significant.

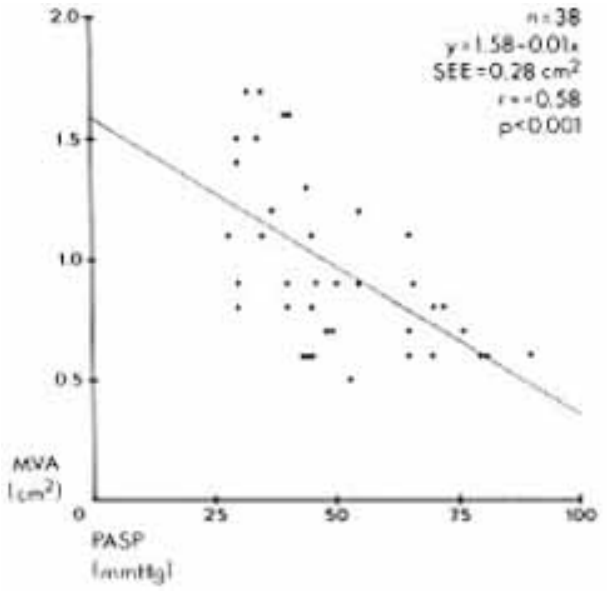

Fig.3 - Relationship between mitral valve area (MVA) and pulmonary artery systolic pressure(PASP) in patients with mitral stenosis.

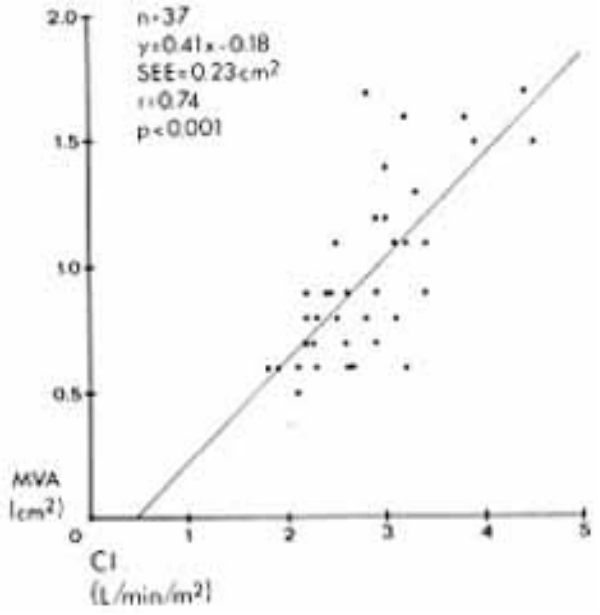

Fig.4 - Relationship between mitral valve area (MVA) and cardiac index (CI) in patients with mitral stenosis.

DISCUSSION

Cardiac catheterization has been performed throughout the world for the past 30 years, with limitations in many laboratories. One of these is the inability to measure cardiac output. This data has vital importance in patients with valvular heart disease and is essential for calculation of stenotic valve areas and/or regurgitant fractions. These laboratories either obtain a cardiac output based on assumed oxygen consunption, obviously introducing variable degrees of error in its data, or do not calculate it at all. In the latter case the assessment of severity of valvular stenosis is based on pressure data and the degree of valvular insufficiency is based on subjective angiographic examinations Braunwald et al [19] expressed the idea that the mitral valve gradient is the fundamental hemodynamic manifestation of mitral stenosis, but further studies have demonstrated this parameter to be less important [5,20-22]. The initial works of Gorlin and Gorlin [12] and Wood [13] introduced the concept of assessing the severity of mitral stenosis by the calculation of mitral valve area from catheterization data. This has been proven to be valid by

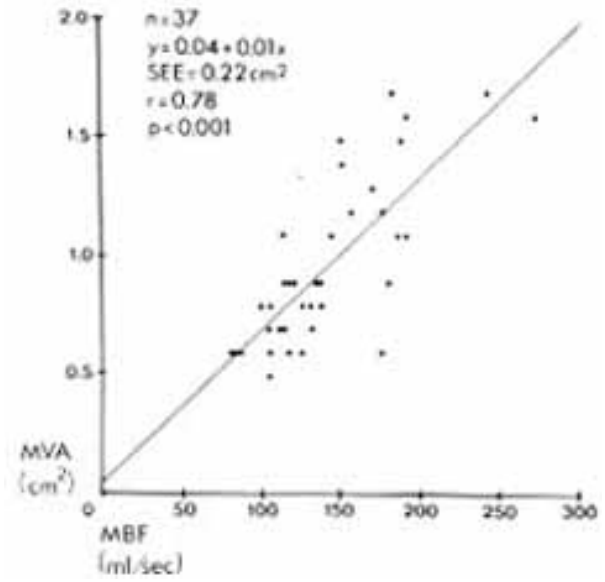

Fig.5 - Relationship between mitral valve area (MVA) and transmitral blood flow (MBF) in patients with mitral stenosis.

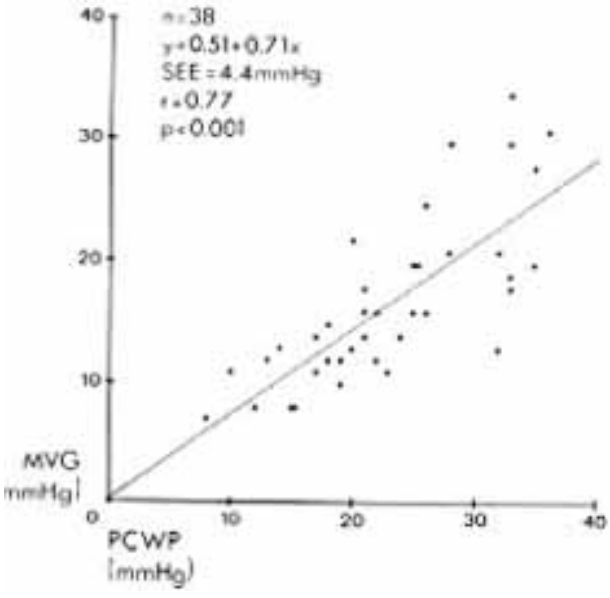

Fig.6 - Relationship between transmitral mean diastolic gradient (MVG) and pulmonary capillary wedge pressure (PCWP) in patients with mitral stenosis.

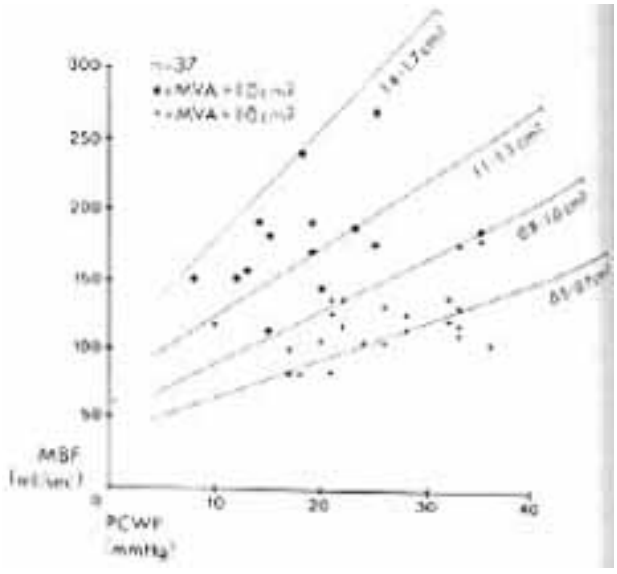

Fig.7 - Relationship between transmitral blood flow (MGF) and pulmonary capillary wedge pressure (PCWP) in patients with mitral stenosis. The straight lines separate pressure-flow bands for the various mitral valve areas (MVA).

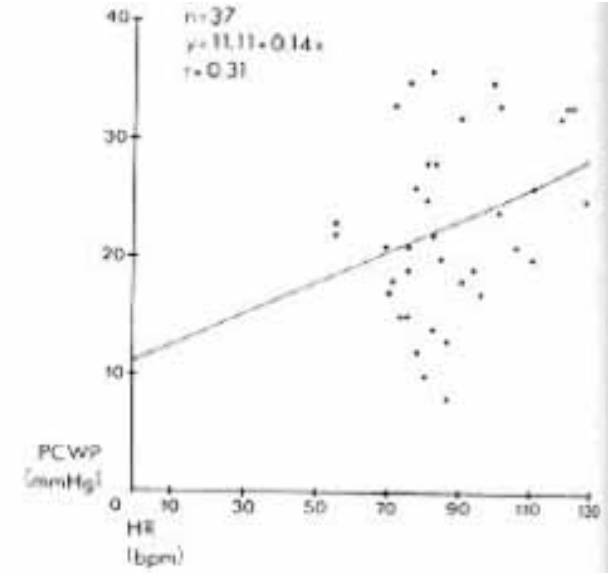

Fig.8 - Relationship between pulmonary capillary wedge pressure (PCWP) and heart rate (HR) in patients with mitral stenosis.

several subsequent studies [20,23,25] Gorlin's original formula for the mitral valve area has been revised and the equation modified for left heart catheterization data [18]. Since the works of Gorlin and Wood, few studies have been performed to obtain a hemodynamic profile of mitral, stenosis, by correlating the mitral valve area with other catheterization data and to determine the validity of other hemodynamic data for assessing the severity of mitral stenosis [5,19-21,25,26].

Our study shown that the pulmonary capillary wedge pressure is an inadequate parameter for assessment of severity of mitral stenosis (fig.1). Patients with non-critical valve area (more than 10 cm^2) may have important pressure elevations in the pulmonary capillary bed as well as patients with severe stenosis (less than 10 cm^2) may have almost normal pressure values. It is known that the pulmonary capillary pressure is dependent on several factors, namely the mitral orifice size, the mitral flow (which in turn depends on the heart rate and blood volume), thc, diastolic filling period (which depends on the heart rate alone), the left ventricular diastolic pressure and left atrial compliance [19,21,27]. These many factors night explain the poor correlation of the pulmonary capillary pressure with the mitral valve area, a fact that has been also found by other authors [5,20,21,28].

Although no correlation could be found between pulmonary capillary wedge pressure and mitral blood flow, we were able to reproduce the theoretical pressure-flow curves for different valve areas proposed by Gorlin-Gorlin [12] (fig 7). They had proposed that different patients with similar valve areas could modify their left atrial pressure in a predictable fashion according to the mitral blood flow. Our pressure flow "bands" comprised most of the patients with similar valve areas, although some of them were noted to fall in a neighboring band. This probably resulted from a non-homogeneous bahavior of pressure, as it depends on several factors. We feel that left atrial compliance may be one of these factors making the pressure response to flow sometimes different from patient to patient with similar valve areas.

This finding does not invalidate Gorlin's hypothesis that the left atrial pressure in mitral stenosis in highly dependent on mitral flow in a given patient. It has been demonstrated that with exercise or pacing a patient will increase his left atrial pressure in a predictable fashion [12,19,27].

On the other hand, figure 8 shows that the heart rate itself bears no relationship to the pulmonary capillary wedge pressure. Different patients with similar valve areas and heart rates can have a wide range of pulmonary capillary wedge pressures. This indicates that the heart rate, in general, is not a very important factor in the genesis of pulmonary venous hypertension in a patient with mitral stenosis and that other factors (left atrial compliance, for example) are probably more important. This finding does not mean that an increase in the heart rate of a patient with mitral stenosis would not increase the pulmonary capillary wedge pressure in a predictable way, as it has been demonstrated previously [12,19,22,27,40].

Carman et al [29] has shown distinct behaviour o the pulmonary capillary wedge pressure (PCWP) in patients with critical mitral stenosis when correlate with cardiac index (CI). He demonstrated three possible combinations of data: low CI/high PCWP (88% of cases), normal CI/high PCWP (7%) and low CI/normal PCWP (5%), postulating that the last two groups represent situations in which potent flow-regulating factors operate independently of the obstructive lesions. Although these authors did not comment on the pressure-flow curves of Gorlin Gorlin, we feel that their data demonstrate the fact that pressure in not always dependent only on flow in mitral stenosis.

The transmitral diastolic gradient was shown in our study to be slightly more accurate than the pulmonary capillary wedge pressure in assessing the severity of mitral stenosis (fig. 2). Small gradient (less than 15 mmHg) were seen in patients with critical and non-critical mitral orificies, but large gradients (greater than 25 mmHg) were seen only in critical valve areas.

It should be remembered that, as pressure varies inversely to the square of the area, the pressure gradient required to maintain an adequate blood flow would be excessively high, especially for critical stenosis.

The gradient, similar to pulmonary capillary pressure, is influenced by the mitral valve orifice size, blood flow, left atrial compliance and diastolic filling period but not by the left ventricular diastolic pressure [19;27,30]. This probably explains the better correlation of mitral valve area with transmitral diastolic gradient, as compared to the pulmonary capillary pressure, confirming previous studies [5,20,21].

Pulmonary artery systolic pressure behave similarly to the pulmonary capillary wedge pressure in its correlation with the mitral valve area (fig 3). Although the majority of patients had pulmonary artery hypertension, it was noted that pressure levels less than 50 mmHg were compatible with critical and non-critical mitral stenosis. The analysis of these patients showed that the behaviour of the pulmonary vascular bed was variable, some with increased and others with normal or decreased pulmonary vascular resistance, thus explaining the wide scatter seen in pressure levels below 50 mmHg. On the other hand, levels above 50 mmHg were almost always associated with severe mitral stenosis and all had increased pulmonary vascular resistance less than half of the patients had an increased mean pulmonary artery mean pulmonary capillary wedge pressure gradient, which is a measurement of the reactivity of the pulmonary arteriolar bed to chronic congestion, as seem in important mitral stenosis (active or reactive pulmonary hypertension). However, several of our patients with critical stenosis had normal gradients through the pulmonary vascular bed, indicating that the vascular reactivity is not always dependent on the degree of stenosis.

Previous studies have also found poor correlation between the pulmonary artery pressure and resistance and the mitral valve area [5,21].

The cardiac index was found to be best hemodynamic parameter to correlate with the severity of mitral stenosis (fig 4), behaving similar to the mitral blood flow (fig. 5), a finding previously seem by other authors [21,29,31]. It was seen that a cardiac index of less than 2 8 L/min/m^2 was almost always indicative of severe mitral stenosis, although levels above that figure could be found is some critically tight valves. This close relationship is not surprising since the hydraulic formula for fixed valve orifices, from which the Gorlin-Gorlin formula for calculation of mitral valve area was derived [12], had the flow rate (or cardiac output) as its sole factor for the numerator.

Although Carman and Lange [29] found only 7% of patients with critical mitral stenosis to have a normal cardiac index, Hugenholtz et al [5] demonstrated a poor correlation between cardiac index and mitral valve area (r = 0407), a finding for which there has been no explanation.

The relationship between mitral valve gradient and pulmonary capillary wedge pressure as seen in figure 6 was less significant than we expected to find, since the latter is directly dependent on the former However, left atrial pressure depends not only on the degree of mitral stenosis, the blood flow, the left atrial compliance and the heart rate (as the gradient), but also on the level of left ventricular diastolic pressure (unlike the gradient). Thus if left ventricular overload or dysfunction is present for some reason, an increased left ventricular end-diastolic pressure would lead to an increased left atrial pressure, regardless of the degree of mitral valve obstruction [28]

Recent studies [32,34] have demonstrated that patients with pure rheumatic mitral stenosis have normal or slightly decreased left ventricular end diastolic volume and moderately increased left ventricular endsystolic volume consequently decreased ejection fraction, characterizing impaired left ventricular function. The inappropriately normal or even elevated left ventricular end-diastolic pressure found at rest in these patients [5,35,36] may result from impaired ventricular compliance [35,36] and/or contractility [32,34,37,38] and may thus explain the less than optional correlation between mitral gradient and left atrial pressure found in our study and in a previous paper by Samet et al [39]

The mitral valve areas, as measured by Gorlin-Gorlin's formula, have a few sources for error. On of these is the presence of mitral regurgitation. None of our patients had mitral insufficiency as assessed by left ventriculography. The other is the measurement of the left ventricular diastolic filling period in all of our cases, this was done simultaneously with recordings of the left ventricular and the pulmonary capillary wedge pressures. It can be said that the calculated mitral valve area in the present work is as close as possible to the true valve crosseccional area, although no direct measurement at surgery or autopsy was made. Possible differences between our results and prior studies may be due to the fact that many of these studies lacked complete and up-todate information regarding cardiac catheterization, such as: performance of aortic and left ventricular angiography (to rule out associated valvular regurgitation), measurement of left ventricular diastolic pressure (to calculate the mitral gradient and the diastolic filling period), calculation of mitral valve area by the Gorlin-Gorlin equation [41].

The presence of chronic atrial fibrillation in patients with rheumatic mitral stenosis has been associated with severe hemodynamic derangement, enlarged left atrium, the extent of fibrosis of the atrial myocardium and the age of the patient [42-45]. Our paper shows that patients with rheumatic mitral stenosis who are in chronic atrial fibrillation always have a critically stenosed valve with a low cardiac index and elevated pulmonary and arterial venous pressures; they are older than those with sinus rhythm. We feel that the extent of myocardial sear ring and chronic inflammation in long standing rheumatic disease plays as important a role as the severity of the obstruction of the mitral valve in the genesis of atrial fibrillation in these patients [42]

It can be concluded that although mitral stenosis produces well-defined hemodynamic derangements that cam be observed through catheterization of the right and left chambers, such abnormalities are not present in all patients and are not even constant in the same patient. Assessment of the severity of mitral stenosis by pressure curve analyses, namely of the left atrial (or pulmonary capillary wedge) and the pulmonary artery pressures and of transmitral diastolic gradient are less than accurate and may lead to gross under or overestimation of severity. The cardiac index has a good correlation with the mitral valve area, although normal values have been seen with severe mitral stenosis. The finding of atrial fibrillation is indicative of i -critically stenosis mitral valve and low cardiac output. It must be stressed that the mitral valve area calculated from Gorlin-Gorlin's equation remains the most reliable measure for assessing the severity of mitral stenosis. Thus cardiac output may be measured accurately in all such patients.

RESUMO

Trinta e oito pacientes portadores de estenose mitral reumática pura foram estudados por cateterismo cardíaco para avaliar a gravidade da obstrução valvar. A idade média foi de 35,2 ± 98 anos e 28 eram mulheres. A maioria dos pacientes estava em classe funcional II e III. A área valvular mitral foi calculada pela equação de Gorlin-Gorlin em 37 casos e medido na cirurgia em um, e variou de 0,5 a 1,7 cm^2 (0,96 ± 0,35). O índice cardíaco estava normal na metade dos pacientes (2,82 ± 0,64 L/min/m^2). Muitos dos pacientes tinham elevação da pressão e resistência arterial pulmonar e a maioria tinha aumento da pressão capilar pulmonar. A área valvular mitral se correlaciona melhor com o índice cardíaco (r = 0,74) apesar de que valores normais deste foram vistos com áreas valvares iguais ou menores que 1 cm^2. Muitos pacientes com estenose mitral crítica tinham fluxo transversal menor que 150 ml/s diastólico. A correlação da área valvular mitral com a pressão capilar pulmonar, pressão sistólica de artéria pulmonar e gradiente transvalvular mitral foi fraca. Vários pacientes com estenose mitral critica tinham valores pressóricos normais. Curvas de pressão-fluxo para diferentes áreas valvares foram construídas para indivíduos deferentes mas alguns não se, ajustavam nas mesmas provavelmente porque a complacência atrial esquerda variou entre os pacientes. O comportamento da pressão capilar pulmonar foi um pouco deferente do gradiente transversal mitral; apesar de que aquele depende deste, o gradiente não é influenciado pela

pressão diastólica final do ventrículo esquerdo.

Pacientes com estenose mitral reumática multas vezes apresentam alterações da contratilidade e/ou da complacência ventricular esquerda e esta pode ser a razão para o diferente comportamento entre a pressão capilar pulmonar e o gradiente transvalvar.

Fibrilação atrial só foi encontrada em pacientes com estenose mitral crítica. Conclui-se que a gravidade da estenose mitral é melhor avaliada pelo cálculo da área valvar. O índice cardíaco se correlaciona bem com a área valvar porém os dados press6ricos podem ser desorientadores em muitas situações.

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