HEMODYNAMIC FACTORS DETERMINING IMMEDIATE RESPONSE OF LEFT ATRIAL PRESSURE REDUCTION ATTRIBUTED TO BALLOON MITRAL VALVOTOMY.

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Abstract

Rheumatic mitral stenosis is a chronic cardiac disease that results in considerable anatomical and functional alternations. Mitral stenosis (MS) is associated with elevated left atrial pressure (LAP). Balloon Mitral Valvuloplasty (BMV) is a proven modality in the treatment of mitral valve stenosis. The purpose of this study was to assess the success of balloon mitral Valvotomy via the measurements of LAP and PAP before and after procedures and to determine the hemodynamic factors that may influence reduction in mean LAP in patients with adequate relief of mitral valve obstruction after BMV.

Twenty seven patients with moderate to severe mitral stenosis underwent cardiac catheterization. Hemodynamic measurements were recorded at pre-valvuloplasty and after balloon valvuloplasty. All patients were submitted to an echocardiography before BMV and the test was performed after the procedure to measure the mitral valve area. The results presented in this study were based on analysis of changes in mean left atrial pressure (LAP) attributed to BMV procedure quartiles in a sample of 27 patients with MS. The study subjects were categorized into ordered categories based on resulting quartiles of LAP change. The group with highest change included those in whom LAP was (≤ 18) mmHg after BMV, the second group with average response included those in whom LAP was (17) to (7) mmHg after BMV, and third group with lowest response included those in whom LAP was (≥ 6) mmHg after BMV. The changes in mean LAP attributed to procedure showed a statistically significant linear correlation with mean (LAP) before BMV ($r = -0.712$, $p<0.001$), and mean pulmonary artery pressure (PAP) before BMV had a statistically significant linear correlation with changes in mean LAP attributed to procedure ($r = -0.68$, $p < 0.001$). By using receiver operator characteristic curve (ROC) can distinguish the best homodynamic measurements before BMV that can be efficiently determine change in mean LAP attribute to BMV procedure. The (mean LAP and mean PAP) before the procedure (pre-treatment) are an important contributing factors for determine the reduction in mean LAP attributed to BMV procedure.

Keywords: Mitral stenosis, Balloon mitral Valvotomy, Left atrial pressures.

Introduction

Balloon mitral valvuloplasty (BMV) has become the procedure of choice for isolated uncomplicated mitral stenosis (MS) with favorable morphology, BMV is widely performed for relief of symptoms in patients with pure mitral stenosis, [1]. The fundamental hemodynamic feature of mitral stenosis (MS) is increased left atrial pressure due to restriction of normal outflow. The elevated LA pressure in turn raises pulmonary venous and capillary pressures, resulting in extertional dyspnea. The development of pulmonary is a common and important sequala in patients with advanced mitral stenosis and is associated with hemodynamic and clinical decompensation. However, the influence of BMV on patients with reactive pulmonary hypertension has seldom been evaluated, [2].

Our objectives were first, to probe into the immediate effects of BMV on patients with MS complicated by reactive pulmonary hypertension, second: to assess the success of BMV via the measurements of left atrial pressure before and after procedure, and to examine the magnitude of immediate response in mean left atrial pressure (LAP) attributed to BMV procedure predicted by selected hemodynamic parameters (before the procedure).

Methods

From July 2008 to February 2009, a series of 27 patients with moderated to severe isolated mitral valve stenosis who where eligible for BMV, at Ibn Al-Bitar hospital for cardiac surgery. All 27 patients had severe symptomatic mitral stenosis with no other significant valvular or myocardial disease. Their mean age 35 ± 10.8 (range 21-58) years. The majority of them (74.1%) were women and (25.9%) were men.

Echo-Doppler evaluation: A 2-dimentional echo Doppler study was performed in each patient before the procedure. Diagnosis was confirmed by two-dimensional area, [3]. The degree of mitral regurgitation was used by echo Doppler before and after the procedure, [4]. Mitral valve morphology was evaluated by calculating the echocardiographic score, as defined by Wilkins et al, [5]. Mitral valve scoring proposed by wilkins depends on (valve thickness, rigidity, calcification, and subvalvular apparatus).

Patients with a favorable morphology were selected and a Transesophageal echocardiography was performed to excluded left atrial thrombus, [6].

All patients gave fully informed written consent before entering the study, and the procedures were in accordance with the ethical guidelines.

BMV was performed using the Inoue method, [7]. The procedure was performed under local anesthesia using the stepwise Inoue balloon technique with the antegrade transvenous approach. Left atrial pressure,and pulmonary artery pressure were measured, before and after balloon mitral Valvotomy at the same cardiac catheterization.

The pulmonary vascular bed gradient (mmHg) was calculated as:

mean PAP – mean LAP.

To confirm the final result, a repeat 2-dimentional echo Doppler study was performed within 24 hours of the procedure to evaluate the final mitral valve area and to assess the degree of residual mitral regurgitation. Only patients with successful outcomes after BMV (defined as a final mitral valve area > 1.5 cm^2 or an increase > 25% relative to baseline values) were finally included. Exclusion criteria were: patients with an echocardiographic score >11, [5].

Doppler-echocardiographic study was repeated at 48 to 96 hours after the procedure to evaluate the final mitral valve area and to assess the degree of residual mitral regurgitation.

The presence or absence of a left-to-right shunt was assessed with two-dimensional echocardiography and Doppler studies.

Statistical Analysis

All statistical analysis were performed using SPSS version 15. (Statistical package for social sciences) Frequency distribution for selected variables was done first. All the quantitative outcome dependent variables tested in the presented study, were normally distributed. These variables are conveniently described by the mean, standard deviation (SD) and standard error (SE). The parametric statistical test were used namely ANOVA to test the significance of difference in mean between more than two groups.

The statistical significance, direction and strength of linear correlation between two quantitative normally distributed variables is measured by person's linear correlation coefficient. All comparisons were considered to be statistically significant if the p-value was < 0.05.

Discrete data between the two groups (male and female) were compared by Fisher's exact test. Performance characteristics of a test or criteria, was analyzed by ROC (Receiver Operating Characteristic Curve) which include, among others: sensitivity, specificity, positive predictive value and negative predictive value. The receiver–operating characteristics curves were chosen as the preferable method of analysis, because they allow an easy way of choosing the optimal cutoff point, and because they allow a quantitative comparison of all tested by comparing the area under the curve.

Results

Twenty seven patients with moderate to severe mitral stenosis (MS) and an appropriate echocardiographic score who underwent BMV, all patients had a successful outcome and constitute the present study group.

Patients had a moderated to severe mitral stenosis with a mean echocardiographic score was (5.8 ± 1.9). Overall, left ventricular function was normal (ejection fraction = (61 ± 8) %, range (33 to 74) %.

All hemodynamic parameters-before procedure of study group shown in Table (1).

Table (1)
Hemodynamic parameters-before procedure for study group.

Homodynamic parameters	*Range*	*Mean*	*SD*	*SE*	*NO*
Mitral valve area (cm) 2)	(0.8 to1.39)	1	0.2	0.04	27
Mean LAP (mmHg) – before procedure	(8 to 40)	25.7	7.5	1.45	27
PVBG(mmHg) – before procedure	(–1 to 54)	16.7	9.4	1.81	27
Mean LVP (mmHg) –before procedure	(6 to 15)	10.9	3	0.58	27
Mean PAP (mmHg) –before procedure	(12 to 70)	42.5	13.6	2.62	27
Balloon volume	(24 to 30)	26.5	1.2	0.26	22

SD: Standard deviation

SE: Standard error

NO: Number of patients

PAP: *pulmonary artery pressure*, ***LAP***:*left atrial pressure*,***LVP***: *left ventricular pressure.*

PVBG: *pulmonary vascular bed gradient*

The results presented in this study were based on the analysis of changes in mean LA pressure (LAP) attributed to procedure-quartiles in a sample of 27 patients with mitral stenosis.

Change in LAP attributed to procedure=
Mean LAP (after) – mean LAP (before) = (–) (reduction) mmHg.

After BMV, there was a significant change (reduction) in mean left atrial pressure in study group, indicating successful dilation in all patients (Table (2)).

Table (2)
Mean LAP before and after BMV – procedure for all study group.

LAP-mean	*Before procedure*	*After procedure*	*Changes attributed to procedure*	*p-value*
Range	(8 to 40)	(7 to 30)	(-25 to 0)	≤0.05
Mean	25.7	12.8	-12.9	
SD	7.5	5.7	7.4	
SE	1.45	1.09	1.43	
N	27	27	27	

The study subjects were categorized into **ordered categories** based on resulting quartiles of LAP change. The first group with highest change or highest response (first quartile) included those in whom LAP was (≤ 18) mmHg after BMV. The second group with average response (second quartile) included those in whom LAP was (17) to (7) mmHg after BMV. The third group with lowest response (third quartile) included those in whom LAP was (≥ 6) mmHg after BMV.

Age (years) and BMI (Kg/m^2) showed no statistically significant difference between the three quartiles groups Table (3).

Table (3)
The relation between age, body mass index, and changes in mean LAP after BMV in study group.

		Changes in Mean LAP Attributed to Procedure-quartiles			
		First quartile (Highest response) (≤18 mmHg) (No = 8)	**Second quartile Average response (17 to 7 mmHg) (No = 14)**	**Third quartile (lowest response) (≥6 mmHg) (No = 5)**	**P-Value (ANOVA)**
Age in years	Range	(21 – 46)	(26 – 58)	(24 – 49)	0.36 [NS]
	Mean ± SE	33 ± 3.16	38.1 ± 3.1	31 ± 4.81	
BMI (Kg/m^2)	Range	(19.6 – 26)	(22.2 – 26)	(24.2 – 25.5)	0.19 [NS]
	Mean ± SE	23.2 ± 0.87	24 ± 0.35	25 ± 0.28	

***No:** number of patients.*
***SE:** Standard Error, BMI = body mass index.*
***NS:** Not Significant.*

As shown in Table (4) the baseline mean LAP was significantly higher among subjects with highest response quartile (≤ 18 mmHg) and lowest response quartile (≥ 6mmHg), P(ANOVA) = 0.002.

Mean PAP (before procedure) was obviously higher among subjects with highest response quartile. PVBG(pulmonary vascular bed gradient) (before procedure) showed no statistically significant difference between lowest and highest quartile group. P(ANOVA) = 0.17 [NS]. mitral valve area (before procedure) showed statistically significant between lowest and highest quartile group. P(ANOVA) = 0.012.

Table (4)
Hemodynamic parameters (pre –treatment) in three quartiles groups of LAP response attributed to BMV procedure.

Reduction in mean LAP attributed to procedure-quartiles				
	First quartile (Highest response) (≤ 18 mmHg) (No = 8)	**Second quartile(average response) (17 to 7 mmHg) (No = 14)**	**Third quartile (Lowest response) (≥ 6 mmHg) (No = 5)**	**P (ANOVA)**
mean PAP (before procedure)				0.002
Range	(50 – 60)	(20 – 70)	(12 – 50)	
Mean ± SE	53.8 ± 1.57	40.8 ± 3.15	29.2 ± 6.89	
mean LAP (before procedure)				<0.001
Range	(28 – 40)	(15 – 30)	(8 – 30)	
Mean ± SE	32 ± 1.77	25.4 ± 0.98	16.8 ± 4.53	
PVBG (before procedure)				0.17[NS]
Range	(20 – 27)	(5 – 45)	(–1 – 25)	
Mean ± SE	21.8 ± 0.98	15.4 ± 2.95	12.4 ± 4.18	
mitral valve area (cm^2) (before procedure)				0.012
Range	(0.8 – 1.05)	(0.88 – 1.1)	(0.88 – 1.39)	
Mean ± SE	0.9 ± 0.05	1 ± 0.03	1. ± 0.1	
mean LVP (before procedure)				0.014
Range	(6 – 12)	(8 – 15)	(8 – 10)	
Mean ± SE	9.5 ± 0.73	12.4 ± 0.84	8.8 ± 0.49	
systolic AoP (before procedure)				0.049
Range	(100 – 140)	(120 – 160)	(100 – 135)	
Mean ± SE	113.8 ± 5.96	131.4 ± 3.9	125 ± 6.32	

SE: *Standard Error,* ***p<0.05*** *(significant),* ***AoP****: aortic pressure,*

PAP: *pulmonary artery pressure****, LAP****:left atrial pressure,****LVP****: left ventricularpressure.* ***PVBG:*** *pulmonary vascular bed gradient.* ***MVA****:mitral valve area.* ***PVBG (mmHg):*** *mean PAP(mmHg) - mean LAP(mmHg).*

The correlation between reduction in mean LAP attributed to BMV procedure and selected (pre-treatment) hemodynamic parameters as shown in Table (5).

The mean PAP (before procedure) had a strong and statistically significant negative linear correlation with changes reductions) in mean LAP attributed to procedure (r = –0.687, P < 0.001).

Statistically significant linear correlation between MVA and changes in mean LAP attributed to BMV procedure (r = 0.61, P = 0.006), Table (5).

The changes in mean LAP attributed to procedure showed a statistically significant strong negative linear correlation with mean LAP (before procedure) ($r = -0.712$, $p < 0.001$).

Statistically significant negative linear correlation between PVBG and changes in mean LAP attributed to BMV procedure ($r = -0.425$, $P = 0.027$).

Mean LVP (before procedure) showed no important or statistically significant linear correlation with changes in mean LAP attributed to BMV procedure. ($r = -0.063$, $P = 0.75$) [N.S].

Table (5)
The correlations between change in immediate response in mean LAP after BMV and hemodynamic parameters before BMV.

	Reduction in mean LAP attributed procedure	
	r–value	***P-value***
mean PAP(mmHg) **(before procedure)**	–0.687	< 0.001
MVA (cm^2) **(before procedure)**	0.61	0.006
PVBG (pulmonary vascular bed pressure gradient)(mmHg) **(before procedure)**	–0.425	0.027
mean LAP(mmHg) **(before procedure)**	–0.712	< 0.001
mean LVP(mmHg) **(before procedure)**	–0.063	0.75 [NS]

[NS]: *Not significant, AoP: aortic pressure,* ***PAP:*** *pulmonary artery pressure,* ***LAP:*** *left atrial pressure.* ***LVP:*** *Left ventricular pressure,* ***PVBG:*** *Pulmonary vascular bed gradient.*

As shown in table (6):

Balloon volume showed no statistically significant differences between the three quartiles groups of LAP response. P(ANOVA) = 0.5 6 [NS].

A weak negative and statistically insignificant linear correlation between balloon volume and changes in mean LAP attributed to BMV procedure ($r = -0.22$, $P = 0.32$ [NS]).

Table (6)
The relation between Balloon volume and change in mean LAP attributed to procedure.

	Reduction in mean LAP attributed to procedure-quartiles			
	First quartile (Highest response) (≤ 18 mmHg) (No. = 8)	***Average (-17 to 7 mmHg) (No. = 14)***	***(Lowest response) quartile (≥ 6 mmHg) (No. = 5)***	***P(ANOVA)***
Balloon volume				0.56 [NS]
Range	(26 – 28)	(24 – 30)	(26 – 26)	
Mean±SE	26.3±0.29	26.7±0.49	26±0	

[NS]: *not significant*
SE: *standard error.*

The results in Table (7), showed that the eight female had highest response in mean LAP attributed to procedure, 40%.

Table (7)
The association between change in mean LAP attributed to procedure and gender (male and female).

	Total	***Highest response in LAP-mean attributed to procedure (≤ 18)***	
Gender	***No***	***No***	***%***
Female	20	8	40
Male	7	0	0

P (Fisher's exact) = 0.045.

Determinant parameters of changes in mean left atrial pressure-attributed to procedure

As shown in Table (8):

- To identify the factors that determine the highest response of mean LAP-attributed to BMV (immediately after BMV), we used 6 pre-procedure parameters including (PAP, LAP, PVBG, AoP, LVP, and balloon volume) in the Receiver operator characteristic curve (ROC) analysis. Such analysis permits to organize the parameters according to the ROC area that can occupy and if such occupation is significant or not.
- The ROC analysis revealed that the value of tested baseline parameter in predicting highest response in LAP shown in descending order was as follows: (PAP = 0.921, mean LAP = 0.895, PVBG = 0.78, AoP = 0.76).

The test of parameters (Baseline mean LVP, Balloon volume) failed to occupy a significant ROC area, Table (6).

Table (8)
Receiver operator analysis (ROC) for the prediction of the best hemodynamic parameters before procedure can predict changes in mean LAP after BMV procedure.

	Area	***P - value***
mean PAP **(before procedure)-**	0.921	< 0.001
mean LAP **(before procedure)**	0.895	< 0.001
PVBG (Pulmonary vascular bed pressure gradient) mmHg	0.78	< 0.024
Systolic AoP **(before procedure)**	0.76	0.036
mean LVP **(before procedure)**	0.648	0.23[NS]
Balloon volume	0.538	0.78[NS]
mitral valve area (cm^2) **(before procedure)**	0.721	0.15[NS]

NS: *not significant (P>0.05).*

AOP: *aortic pressure.*

LAP: *left atrial pressure.*

LVP: *left ventricular pressure. PAP: pulmonary artery pressure.*

P < 0.05 *= Significant.*

P < 0.001 *= highly Significant.*

Table (9)
Validity of selected cutoff value of hemodynamic parameters (mmHg) before BMV in prediction of immediate reduction in mean LAP after BMV procedure.

	Sensitivity	*Specificity*	*Accuracy ٪*	*PPV*
mean PAP- positive if ≥ cut-off value				
≥ 48 mmHg	100.0	84.2	88.9	86.4
mean LAP-positive if ≥ cut-off value				
≥35 mmHG	25.0	100.0	77.8	100.0
PVBG (Pulmonary vascular bed pressure gradient)-positive if ≥ cut-off value				
≥17.5 mmHG	100.0	63.2	74.1	73.1
systolic AoP-positive if < cut-off value				
<115 mmHg	75.0	94.7	88.9	93.4

PPV: *Positive predictive value.*

As shown in Table (9):

- The most important finding in Table (7) was a subject with a ne mean PAP(before procedure) of 48 and above would predict a high response (highest reduction) in mean LAP immediately after procedure with 100% sensitivity, 84% specificity and 88.9٪ accuracy.
- At this cut-off value testing positive would predict high response with 86.4% confidence at a pretest probability of 8/27=27% (prevalence of high response in studied sample).
- As shown in table using the cutoff of 17.5 mmHg for pulmonary vascular resistance revealed that a patient with a positive value (equal to /or greater than 17.5 mmHg at a sensitivity of 100 ٪ and specificity of 63.2 ٪.

Discussion

Several investigators [8, 9, 10] have measured the reduction in mean left atrial pressure after the BMV treated of mitral stenosis. In our study, we divided our patients according to change or reduction in mean LAP into three quartiles and compared the findings in these three groups.

Reactive pulmonary hypertension occurs when left atrial pressure chronically ≥20 mmHg, specially a pressure gradient across the pulmonary vascular bed > 12 mmHg [11]. Pulmonary hypertension is present when mean pulmonary artery pressure exceeds 25 mmHg at rest or 30 mmHg with exercise, [12].

Our patients have reactive pulmonary hypertension (PVBG = 21.8 ± 0.98 mmHg for first quartile, 15.4 ± 2.95 mmHg for second quartile and 12.4 ± 4.18 mmHg for third quartile).They achieve a greater absolute gain in terms of improvement in LAP after BMV. This finding agree with previous observations where it was found that BMV in patients with severe pulmonary hypertension show immediate benefit after BMV [13], [14], [15].

In our study, we found that reduction of mean-LAP attributed to procedure in patients with mitral stenosis and reactive pulmonary hypertension could be predicted by hemodynamic characteristics before BMV.

The most interesting finding is the strong and significant relation between change (reduction) in mean LAP attributed to BMV and mean PAP **(before procedure)**, ($r = -0.687$, $P < 0.001$).

The ROC analysis showed that the factor predict a decrease in mean LAP – attributed to BMV was the mean PAP before BMV (area under the curve = 0.92, $p < 0.001$).

This result may be explained by the fact that: in mitral stenosis, pulmonary hypertension due to left atrial hypertension (passive retrograde transmission of elevated left atrial pressure), pulmonary arteriolar constriction (reactive pulmonary arteriolar vasoconstriction), and pulmonary vascular disease [16], [17].

The first two factors are reversible [18]. The first immediately after BMV and the second much latter [19].

Left atrial hypertension related to pulmonary artery hypertension regress immediately after BMV [8], [20].

The rationale behind using ROC analysis is to define the ability of the cardiac catheterization parameters pre-BMV procedure to distinguish the highest response in mean LAP, post BMV for the subject with mitral stenosis, i.e., to define the (prediction accuracy).

Presenting the accuracy of these hemodynamic parameters before BMV procedure in diagnostic the highest response in mean LAP after BMV in term ROC curve have many advantages:

The area under the curve gives an idea about the usefulness of the test and helps in comparing into other test. The closer the area to one (ideal test) the more valid it is in present study the test proved very useful, since the area for mean PAP was 0.92,and for other hemodynamic parameters, (mean LAP, PVBG and systolic AOP)were 0.895, 0.78, and 0.76 respectively.

There were significantly different from the 0.5 area (represent an equivocal test, in which the gain in sensitivity equal to the loss in specificity from each unit decrease in cut off values. The larger the area under the curve (closer to one) the more valid the test, since there is great in sensitivity for minimal losses in specificity.

One can select a typical cutoff value which results in a highly valid test (highly specific with reasonably high sensitivity) from the ROC curve.

Our results shows that eight females 40٪ had highest response in mean LAP attributed to procedure table (5). This finding agree with previous observations [21], [22], [23], [24], [25], where it was found that there are gender difference in the pathophysiology of mitral stenosis with a 3:1 female preponderance for the condition. Calcification of the valves tends to occur later in women than in men, providing a longer time window in which balloon valvuloplasty can be performed, and perhaps explaining why 82٪ of all mitral balloon valvuloplasty candidates are women [26].

Conclusions

BMV is an effective procedure in patients with MS and reactive pulmonary hypertension.

Mean PAP before BMV is the best hemodynamic parameter in predicting highest response in mean LAP after BMV procedure.

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الخلاصة

تضيق الصمام الإكليلي الروماتيزمي هو احد أمراض القلب المزمنة التي تنتج عنها تغيير تشريحي و وضيفي للصمام الإكليلي، وتضييق هذا الصمام يؤدي إلى ارتفاع ضغط الأذين الأيسر وأحدى طرق علاج تضيق الصمام الإكليلي هي توسيع الصمام باستخدام البالون في عملية القسطرة القلبية [Balloon Mitral Valvatomy (BMV)] يرتكز البحث على مدى نجاح عملية توسيع الصمام الاكليلي من خلال قياس ضغط الأذين الايسر قبل وبعد العملية و تحديد العوامل الهيموداياناميكية التي قد تؤثر في انخفاض ضغط الأذين الأيسر لمرضى تضيق الصمام الإكليلي بعد إجراء عملية توسيع الصمام الإكليلي (BMV).

شملت الدراسة 27 مريضا عانوا من تضيق الصمام الاكليلي، خضعوا لعملية القسطرة القلبية حيث تتراوح شدة المرض بين المتوسط الى الشديد (moderate to sever) وتم اخذ القياسات الهيموديناميكية لكل مريض قبل وبعد عملية توسيع الصمام (BMV). كما تم استخدام تصوير القلب الصدوي ثنائي البعد (2-D echocardiograph) لجميع المرضى قبل وبعد توسيع الصمام (BMV) وذلك لقياس مساحة الصمام الإكليلي.

النتائج المقدمة في هذه الدراسة هي حول تحليل التغير الحاصل في ضغط الأذين الأيسر بعد عملية توسيع الصمام، تم تقسيم المرضى الى ثلاثة مجاميع اعتماداً على مقدار الانخفاض الآني في ضغط الاذين الايسر او الاستجابه لعملية التوسيع. المجموعه الاولى هي المجموعه الاكثر استجابه او الاكثر انخفاض في ضغط الاذين الأيسر حيث كان ضغط الأذين الأيسر لديهم (اقل أويساوي 18 ملم زئبق)، والمجموعة الثانية ذات الانخفاض المتوسط، حيث كان ضغط الذين الأيسر لديهم من [(17) إلى (7) ملم زئبق] والمجموعة الثالثة التي أظهرت اقل استجابة وانخفاض في ضغط الاذين الأيسر حيث كان ضغط الذين الأيسر لديهم (اكبر أو يساوي 6 ملم زئبق) بعد عملية توسيع الصمام.

هذه الدراسة بينت ان معدل التغير في ضغط الاذين الايسر نتيجة لعملية توسيع الصمام يرتبط ارتباط قوي مع ضغطي الشريان الرئوي والاذين الايسر قبل التوسيع. و حيث إن العوامل المشمولة بالدراسة (ضغط الاذين الايسر والشريان الرئوي) هي عوامل وثيقة الصلة ببعضها البعض.

تم استخدام التحليل الاحصائي (ROC curve) للتمييز بين اي عامل من العوامل المقاسة قبل توسيع الصمام يكون الاكثر ارتباطا بانخفاظ ضغط الاذين الايسر بعد التوسيع من خلال معرفة المساحة تحت المنحني لكل عامل من العوامل المذكورة انفا. حيث تبين من خلال هذه الاجراءات الاحصائيه ان قيمة ضغط الشريان الرئوي قبل اجراء عملية التوسيع هما من العوامل الاساسيه في تحديد مدى الاستجابة اوالانخفاض في ضغط الاذين الايسر بعد اجراء عملية توسيع الصمام الاكليلي (BMV).