**Left ventricle geometry, atrial strain, ventricle strain and hemodynamics across aortic valve before and after transcatheter aortic valve replacements**

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The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Abstract**

Background: Transcatheter Aortic Valve Replacements (TAVR) has become widespread throughout the world. To date there are no echocardiographic study of TAVR patients from Southeast Asia (SEA). We sought to evaluate 1) changes in echocardiographic and strain values pre and post TAVR 2) relationship between aortic stenosis (AS) severity and strain values, 3) left ventricle geometry in severe AS 4) relationship of flow rate to dimensionless index (DVI) and acceleration time (AT) and 5) effect of strains on outcome.

Methods: Retrospective study of 112 TAVR patients in our center from 2009 to 2020. The echocardiographic and strain images pre (within 1 months), post (day after) and 6 months post TAVR were analyzed by expert echocardiographer.

Results: The ejection fraction (EF) increased at 6 months (53.02 ± 12.12% to 56.35 ± 9.00%) (p=0.044). Interventricular septal thickness in diastole (IVSd) decreased (1.27 ± 0.21cm to 1.21 ± 0.23cm) (p=0.038) and left ventricle internal dimension in diastole (LVIDd) decreased from 4.77 ± 0.64cm to 4.49 ± 0.65cm (p = 0.001). No changes in stroke volume index (SVI pre vs 6 months p =0.187), but the flow rate increases (217.80 ± 57.61mls/s to 251.94 ± 69.59mls/s, p<0.001). Global Longitudinal Strain (GLS) improved from -11.44 ± 4.23% to -13.94 ± 3.72% (p <0.001), Left Atrial Reservoir strain (Lar-S) increased from 17.44 ± 9.16% to 19.60 ± 8.77% (p=0.033). 8 patients (7.5%) had IVSd < 1.0cm, and 4 patients (3.7%) had normal left ventricle (LV) geometry. There was linear relationship between IVSd and mean PG (r=0.208, p=0.031), between GLS to aortic valve area (AVA) and aortic valve area index (AVAi) (r = – 0.305, p=0.001 and r= – 0.316, p = 0.001). There was also relationship between AT (r=-0.20, p=0.04) and DVI (r=0.35, p< 0.001) with flow rate. Patients who died late (after 6 months) had lower GLS at 6 months. (Alive; -13.94 ± 3.72% vs Died; -12.43 ± 4.19%, p= 0.001)

Conclusion: At 6 months TAVR cause reverse remodeling of the LV with reduction in IVSd, LVIDd and improvement in GLS and LAr-S. There is linear relationship between GLS and AVA and between IVSd and AVA.

**Key words**

Echocardiography, Aortic Stenosis, Transcatheter Aortic Valve Replacement, Global Longitudinal Strain, Southeast Asia

**INTRODUCTION**

Since it was first performed in 2002 by Alan Cribier and his team, transcatheter aortic valve replacement (TAVR) for severe aortic stenosis (AS) has become widespread worldwide1. Its usage has expanded rapidly from the inoperable to intermediate and most recently to low-risk patients2–4. Echocardiography is one of the main tools for assessment of patients with severe AS either in general or pre and post TAVR. As far as we are aware, there is no published data from Southeast Asian (SEA) patients with most studies from this region coming from South Korea and Japan5-7. With the advent of speckle tracking strain analysis, there were few publications from western countries looking at the changes in strain parameters pre and post TAVR and again there are no published data from SEA countries8–10. In this study of multi-racial patients in a single center, Institut Jantung Negara (National Heart Institute), Kuala Lumpur, Malaysia, we sought to evaluate 1) immediate and 6 months changes in traditional echocardiographic and strain parameters 2) relationship between these echocardiographic and strain parameters with AS severity 3) pattern of left ventricle wall thickness and geometry pre TAVR 4) whether acceleration time (AT) and dimensionless index (DVI) is affected by flow rate and finally 5) relationship of echocardiography and strain parameters to mortality.

**MATERIALS AND METHODS**

This is a single center retrospective study of patients with severe AS who underwent TAVR in our institution from 2009 to 2020.

**Echocardiographic data**

All the echocardiographic images from pre (Up to one month pre-procedure), immediately (one day post procedure) and at 6 months post procedure were analyzed. These duration for echocardiography is applied routinely for patients undergoing TAVR in our center. We excluded those with incomplete images or those not suitable for interpretation (3 patients excluded due to inadequate baseline images). For traditional echocardiographic parameters of left ventricle, we analyzed interventricular septal thickness at diastole (IVSd), left ventricle internal dimension at diastole (LVIDd), posterior wall thickness at diastole (PWTd), biplane Simpsons’ ejection fraction (EF) and relative wall thickness (RWT). For aortic valve we calculated aortic valve area (AVA), aortic valve area index (AVAi) from continuity equation, peak velocity (Vmax), mean gradient (meanPG), acceleration time (AT), acceleration time/ejection time (AT/ET) and dimensionless index (DVI) across aortic valve. Lastly, we calculated the stroke volume index (SVi), flow rate (stroke volume/ejection time across left ventricular outflow tract), peak tricuspid regurgitation gradient (TRpeak PG), systolic pulmonary artery pressure (s-PAP) and left atrial volume index (LAVI).

**Strain analysis**

We analyzed strain by using Tom Tec software retrospectively by using apical 4 chamber view, apical 3 chamber view, apical 2 chamber view for global longitudinal strain (GLS), Apical 4 chamber view for left atrial reservoir strain (LAr-S), left atrial conduit strain (LAc-S), left atrial booster strain (LAbooster-S). For right ventricle free wall strain (RVFW-S), we used right ventricle focused apical 4 chamber views.

**Statistical analysis**

The categorical variables were presented as percentage and the continuous variables were presented in terms of mean and standard deviations. Repeated measures ANOVA were used to compare differences between groups at different times points with a Greehouse-Geisser correction and post hoc analysis of Bonferroni correction where applicable. The linear association between variables were determined using Pearson correlation coefficients. P values < 0.05 were considered statistically significant. Statistical analysis was performed using SPSS ver. 27.0 (SPSS, Chicago, IL, USA).

**RESULTS**

There was n=112 patients included in the study (female;57 and male; 55). The average age was 77.97 ± 5.01 years old. 45.5% (n=51) were Malay, 22.3% (n=25) were Chinese, 22% (n=19.6) were Indian, 5.4% (n=6) were of other races from Malaysia and 7.1% (n=8) were patients from other countries. The procedures were done with both self-expandable and balloon expandable TAVR valves. There are 2 procedure failures, and both are cause by left ventricle (LV) perforations. Overall, 6 (5.4%) patients died in hospital and 7 (6.3%) patients died within 6 months of procedure (Total 6 months mortality was 13 patients,11.6%). 34 (30.4%) patients died after 6 months, and 64 (57.1%) patients are still alive. 1 patient was lost to follow-up after the procedure. Therefore, they were 98 patients that have complete echocardiographic and strain data until 6 months post procedure (34 who died after 6 months plus 64 that is still alive). 12 (10.7%) patients need pacemaker implantations. Pre procedure, most patients are in NYHA Ⅱ (48.2%) and Ⅲ (28.6%) and at 1 months, majority of patients are in NYHA Ⅰ (83.9%). Immediately post procedures majority of patients have mild paravalvular (83.9%) and mild transvalvular (86.6%) regurgitation (Table 1).

At 6 months post TAVR, AVA increased from 0.68 ± 0.19cm2 to 2.02 ± 0.73cm2 (p<0.001), peak aortic velocity went down from 4.45 ± 0.64 m/s to 2.06 ± 0.59 m/s (p<0.001) and mean PG came down from 49.94 ± 13.53 mmHg to 9.49 ± 6.09 mmHg (p<0.001). Interestingly, there were no significant changes in SVi (46.42 ± 13.71 mls/m2 to 49.00 ± 13.95 mls/m2; p=0.187) although the flow rate increased significantly to upper limit of normal (217.80 ± 57.61 mls/s to 251.94 ± 69.59 mls/s; p<0.001). (Table 2)

For other echocardiographic parameters at 6 months, EF increased from 53.02 ± 12.12% to 56.35 ± 9.00% (p=0.004). Both IVSd and LVIDd reduced significantly (IVSd; 1.27 ± 0.21 cm to 1.21 ± 0.23 cm, p=0.022 and LVIDd; 4.77 ± 0.64 cm to 4.49 ± 0.65 cm, p<0.001). As expected, AT decreased from 120.00 ± 26.33 ms to 75.98 ± 16.82 ms (p<0.001) and DVI increased from 0.21 ± 0.06 to 0.60 ± 0.17 (p<0.001). There were no significant changes in PWTd (p=0.136), RWT (p=0.831), LAVI (p=0.183) and s-PAP (p=0.772) immediately and at 6 months. (Table 2)

From analysis of speckle tracking strain, both GLS and LAr-S had significant overall improvement at 6 months (GLS; from -11.44 ± 4.23% to -13.94 ± 3.72%, p<0.001 and LAr-S from 17.44 ± 9.16% to 19.60 ± 8.77%, p=0.033). This was interesting as LAVI did not change significantly post-TAVR. There were no significant changes in Left Atrial Conduit Strain (LAc-S, p=0.326), Left Atrial Booster Strain (LA booster, p=0.562) and RVFW-S (p=0.543). There was greater relative increase in GLS compared to EF (21.85% vs 6.28%) and relative increases in LAr-S were more than relative to decreases in LAVI (12.39% vs 5.38%). Patients who died after 6 months had lower GLS at 6 months (-12.43 ± 4.19% vs -13.94 ± 3.72%, p=0.001). (Table 3, Table 4).

We performed linear regression analysis to evaluate relationship between pre-TAVR IVSd and strain with AS severity. IVSd had moderate but significant direct relationship with MeanPG (r=0.208, p=0.031) and AVA (r=0.239, p=0.013). GLS had stronger and significant inverse relationship with AVA (r=-0.305, p=0.001) and AVAi (r=-0.316, p=0.001) while RVFW-S had weak but significant inverse relationship with AVAi (r=-0.179, p=0.041) (Table 5, Figure 1a to 1d). AT had significant inverse relationship with flow rate (r=-0.199, p=0.040) and DVI had significant direct relationship with flow rate (r=0.347, p<0.001) (Table 6, Figure 2). We also found 4 patients (3.74%) to have had normal LV geometry followed by eccentric hypertrophy, n=13 (12.15%) and concentric remodeling, n= 23 (21.5%). Majority had concentric hypertrophy=67 (62.62%) (Figure 3). 8 patients (7.5%) had IVSd < 1.0cm while 13 patients (12.1%) had PWTd < 1.0cm (Figure 4 and Figure 5).

**DISCUSSION**

This study involved 112 severe AS patients from different ethnicities in Malaysia, a country in SEA where there is no existing published data about echocardiographic and strain parameters pre and post TAVR procedures. As expected, the AVA increased while peak aortic velocity and meanPG decreased significantly, at immediate and at 6 months post TAVR. In term of EF, our patients showed significant improvements post TAVR, like previous publications involving patients of different races11–15.Next, we analyzed the changes in IVSd, LVIDd and PWTd pre and post TAVR. Like TAVR, there are echocardiographic studies in surgical aortic valve replacement (SAVR) patients showing significant regression of these parameters16,17. For TAVR patients however, most of the studies utilize cardiac magnetic resonance imaging rather than echocardiography to demonstrate reverse remodeling18–20. In this study, there were significant reductions in IVSd and LVIDd at 6 months post TAVR but there were no differences in PWTd and RWT. Flow (volume of blood ejected in a single heartbeat per body surface are) and flow rate (volume of blood ejected per second) are different parameters. There is one prior study that illustrates how TAVR improves stroke volume index21, but we could not find any publication looking at flow rate post TAVR. In our study, we found that the SVi did not increase significantly but flow rate increased almost 16% from baseline.

Prior studies tend to look at a single aspect of strain, but in this study, we analyzed almost all aspects of strain. There were many prior publications showing improvement in GLS after TAVR procedures, thus suggesting that baseline GLS can be predictive of outcome8–10,22. Our study showed no improvement in GLS immediately post TAVR, but significant improvement (21.9%) at 6 months post TAVR. The relative improvements in GLS were much higher than in EF (21.85% vs 6.28%). There was no difference in baseline GLS between those who died after 6 months versus those who did not, but patients who were still alive exhibited higher GLS at 6 months post TAVR. Studies on LAr-S, LAc-S and LAbooster-S in TAVR are rare but published data did show improvement in LAr-S post TAVR23,24. In our study LAr-S did not increase immediately but only improved at 6 months post TAVR (relative increase of 12.4%). There was no significant difference in LAc-S and LAbooster-S post TAVR. Lastly, there are many different parameters of RV function, but RVFS-S have been suggested as single best parameter for right ventricle assessment and is predictive of mortality25,26. However, there was no significant improvement and no difference in baseline RVFW-S between those who were alive and those who died in our study at 6 months post TAVR.

Aortic stenosis causes increase in afterload and therefore increase in LV wall thickness. There were studies previously showing that it was possible to have normal LV wall thickness and normal LV geometry in severe AS6,18. This was seen in small group of our patients who have normal LV geometry (n=4; 3.74%) and wall thickness < 1.0cm (IVSd n=8;7.5% and PWTd n=13;12.1%). There are not many studies looking at relationship between IVSd, PWTd, strain parameters and AS severity527. There is moderate direct relationship between IVSd and AS severity (meanPG and AVA), moderate inverse relationship between GLS and AS severity (AVA and AVAi) and finally weak inverse relationship between RVFW-S and AS severity (AVAi).

Acceleration time (AT) and dimensionless index (DVI) are echocardiographic parameters that was initially utilized for prosthetic aortic valve dysfunction assessment but recently has also been studied in native aortic valve patients6,9,10,21. In this study, we wanted to see whether these parameters were related to flow rate and indeed we found that AT had moderate but inverse relationship with flow rate whereas DVI had stronger and direct relationship with flow rate. Therefore, flow rate should be considered when using these parameters.

**Conclusions**

Our study of multi-racial patients in a single center showed that TAVR improved EF, IVSd, LVIDd, GLS and LAr-S at 6 months. Both IVSd and GLS have linear relationship with AS severity and the AT and DVI were significantly affected by flow rate.

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Table 1. Demographics, TAVR Patient Characteristics and Outcomes.

|  |  |
| --- | --- |
| Variables | TAVR (N = 112) |
| Age, Mean ± SD | 77.97 ± 5.01 |
| Female, n (%) | 57 (50.89%) |
| Race Group |  |
| Malay | 51 (45.54%) |
| Chinese | 25 (22.32%) |
| Indian | 22 (19.64%) |
| Other Malaysian | 6 (5.36%) |
| Foreigner | 8 (7.14%) |
| Valve Type |  |
| Corevalve | 37 (33.04%) |
| Corevalve Evolut-R | 26 (23.21%) |
| Edwards Sapien | 13 (11.61%) |
| Edwards Sapien 3 | 23 (20.54%) |
| Edwards Sapien Xt | 10 (8.93%) |
| Myval | 3 (2.68%) |
| Outcomes |  |
| In-Hospital DEATH | 6 (5.40%) |
| DEATH ≤ 6 MONTHS | 7 (6.30%) |
| DEATH > 6 MONTHS  LOST TO FOLLOW-UP  ALIVE | 34 (30.4%)  1 (0.9%)  64 (57.1%) |
| PACEMAKER IMPLANTATION | 12 (10.7%) |
| NYHA PRE PROCEDURE |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NYHA Pre- Procedure | Ⅰ | Ⅱ | Ⅲ | Ⅳ |
| Number (Percentage) | 17 (15.2%) | 54 (48.2%) | 32 (28.6%) | 9 (8.0%) |
| NYHA Post-Procedure at 1 months | Ⅰ | Ⅱ | Ⅲ | Ⅳ |
| Number (Percentage) | 94 (83.9%) | 7 (6.3%) | 1 (0.9%) | 0 (0%) |
| Post-procedure paravalvular regurgitation | none | mild | moderate | severe |
| Number (Percentage) | 14 (12.5%) | 94 (83.9%) | 3 (2.7%) | 1 (0.9%) |
| Post-procedure transvalvular regurgitation | none | mild | moderate | severe |
| Number (Percentage) | 14 (12.5%) | 97 (86.6%) | 1 (0.9%) | 0 (0%) |

Table 2. Echocardiographic Parameters Pre, Post Immediate and Post 6 months after TAVR\*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics | Pre | Post Immediate | Post 6 months | Overall p value | p value post-hoc analysis | | | % Mean Difference  (Pre-to 6-month) |
| Pre-to-post | Post-to-6 month | Pre-to 6-month |
| IVSd | 1.27 ± 0.21 | 1.26 ± 0.19 | 1.21 ± 0.23 | 0.022 | 1.000 | 0.174 | 0.038 | -4.72% |
| PWTd | 1.19 ± 0.24 | 1.17 ± 0.22 | 1.12 ± 0.20 | 0.136 |  |  |  | -5.88% |
| LVIDd | 4.77 ± 0.64 | 4.60 ± 0.58 | 4.49 ± 0.65 | <0.001 | 0.044 | 0.288 | 0.001 | -5.87% |
| RWT | 0.51 ± 0.14 | 0.52 ± 0.12 | 0.51 ± 0.11 | 0.831 |  |  |  | 0.00% |
| EF | 53.02 ± 12.12 | 56.64 ± 11.31 | 56.35 ± 9.00 | 0.004 | 0.004 | 1.000 | 0.044 | 6.28% |
| AVA | 0.68 ± 0.19 | 2.07 ± 0.73 | 2.02 ± 0.73 | <0.001 | <0.001 | 1.000 | <0.001 | 197.06% |
| AVAi | 0.42 ± 0.12 | 1.28 ± 0.44 | 1.25 ± 0.47 | <0.001 | <0.001 | 1.000 | <0.001 | 197.62% |
| Peak velocity | 4.45 ± 0.64 | 1.98 ± 0.50 | 2.06 ± 0.59 | <0.001 | <0.001 | 0.463 | <0.001 | -53.71% |
| Mean PG | 49.94 ± 13.53 | 8.57 ± 4.51 | 9.49 ± 6.09 | <0.001 | <0.001 | 0.226 | <0.001 | -81.00% |
| SVi | 46.42 ± 13.71 | 46.34 ± 13.54 | 49.00 ± 13.95 | 0.187 |  |  |  | 5.56% |
| AT | 120.00 ± 26.33 | 73.74 ± 16.86 | 75.98 ± 16.82 | <0.001 | <0.001 | 1.000 | <0.001 | -36.68% |
| AT/ET | 0.35 ± 0.07 | 0.25 ± 0.05 | 0.24 ± 0.05 | <0.001 | <0.001 | 1.000 | <0.001 | -31.43% |
| Flow Rate | 217.80 ± 57.61 | 249.32 ± 69.75 | 251.94 ± 69.59 | <0.001 | <0.001 | 1.000 | <0.001 | 15.67% |
| DVI | 0.21 ± 0.06 | 0.62 ± 0.18 | 0.60 ± 0.17 | <0.001 | <0.001 | 0.851 | <0.001 | 185.71% |
| TR Peak PG | 30.44 ± 14.34 | 29.59 ± 12.41 | 29.10 ± 10.62 | 0.806 |  |  |  | -4.40% |
| s-PAP | 34.96 ± 16.37 | 34.46 ± 14.42 | 33.29 ± 12.12 | 0.772 |  |  |  | -4.78% |
| LAVI | 52.96 ± 15.29 | 51.93 ± 16.74 | 50.11 ± 17.42 | 0.183 |  |  |  | -5.38% |

\*Data from 98 patients with complete echo for the duration of study

Table 3. Strain Analysis Pre, Post Immediate and Post 6 months after TAVR\*

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics | Pre | Post Immediate | Post 6 months | Overall p value | p value post-hoc analysis | | | % Mean Difference  (Pre-to 6-month) |
| Pre-to-post | Pre-to-post | Pre-to-post |
| GLS | -11.44 ± 4.23 | -11.65 ± 5.13 | -13.94 ± 3.72 | <0.001 | 1.000 | 0.003 | <0.001 | 21.85% |
| LAr-S | 17.44 ± 9.16 | 16.69 ± 7.98 | 19.60 ± 8.77 | 0.033 | 1.000 | 0.041 | 0.203 | 12.39% |
| LAc-S | 10.17 ± 6.56 | 8.96 ± 5.26 | 10.07 ± 6.28 | 0.326 |  |  |  | -0.98% |
| LA booster | 10.85 ± 5.90 | 11.24 ± 5.57 | 12.01 ± 6.02 | 0.562 |  |  |  | 10.69% |
| RVFW-S | -19.01 ± 6.88 | -18.26 ± 6.75 | -19.27 ± 6.44 | 0.543 |  |  |  | 1.47% |

\*Data from 98 patients with complete echo for the duration of study

Table 4. Relationship between echo and strain parameters with mortality\*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics | Pre | Post  Immediate | Post  6 months | % Mean Difference  (Pre-to-6-month) | p value1 | p value2 | p value3 |
| LAr-S |  |  |  |  |  |  |  |
| Overall | 17.44 ± 9.16 | 16.69 ± 7.98 | 19.60 ± 8.77 | 12.39% | 0.563 |  |  |
| Alive | 16.90 ± 8.12 | 16.93 ± 7.17 | 20.12 ± 7.51 | 19.00% |  | 0.898 | 0.405 |
| Death | 18.52 ± 11.07 | 16.21 ± 9.56 | 18.58 ± 10.98 | 0.31% |  |
| GLS |  |  |  |  |  |  |  |
| Overall | -11.44 ± 4.23 | -11.65 ± 5.13 | -13.94 ± 3.72 | 21.80% | 0.001 |  |  |
| Alive | -11.53 ± 4.29 | -11.84 ± 5.31 | -14.69 ± 3.25 | 27.48% |  | 0.206 | 0.246 |
| Death | -11.28 ± 4.19 | -11.25 ± 4.84 | -12.43 ± 4.19 | 10.19% |  |
| RVFW-S |  |  |  |  |  |  |  |
| Overall | -19.01 ± 6.88 | -18.26 ± 6.75 | -19.29 ± 6.44 | 1.48% | 1.000 |  |  |
| Alive | -18.98 ± 7.45 | -18.85 ± 6.66 | -20.89 ± 6.34 | 10.09% |  | 0.067 | 0.051 |
| Death | -19.06 ± 5.73 | -17.06 ± 6.90 | -16.07 ± 5.45 | -15.68% |  |

\*Data from 98 patients with complete echo for the duration of study

p values1 suggested any statistically significance of value differences at % difference pre to post 6 months, p values2 suggested any statistically significance of value differences between groups regardless different time points and p values3 suggested any statistically significance of possible interaction of value differences between groups and different time points

Table 5. Relationship between IVSd, strains with mean PG with AVA and AVAi\*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Mean PG | AVA | AVAi |
| IVSd | Correlation coefficient, r | 0.208 | 0.239 | 0.173 |
|  | p value | 0.031 | 0.013 | 0.075 |
| GLS | Correlation coefficient, r | - 0.060 | - 0.305 | - 0.316 |
|  | p value | 0.537 | 0.001 | 0.001 |
| Lar-S | Correlation coefficient, r | 0.160 | 0.095 | 0.093 |
|  | p value | 0.099 | 0.330 | 0.343 |
| RVFW-S | Correlation coefficient, r | - 0.172 | - 0.151 | - 0.197 |
|  | p value | 0.076 | 0.122 | 0.041 |

\*Data from all 112 patients from their pre-procedure echocardiogram and strains

Table 6. Relationship between DVI/AT and Flow rate\*

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | AT | DVI |
| Flow Rate | Correlation coefficient, r | - 0.199 | 0.347 |
|  | p value | 0.040 | <0.001 |

\*Data from all 112 patients from their pre-procedure echocardiogram and strains

**Figure Legends**

**Figure 1 (a).** **Relationship between pre IVSd with pre mean PG, pre-AVA and pre AVAi**

In pre TAVR patients, IVSd have moderate but significant direct relationship with meanPG and AVA but not AVAi

**Figure 1 (b). Relationship between pre GLS with pre mean PG, pre-AVA and pre AVAi**

In pre TAVR patients, GLS have strong and significant inverse relationship with AVA and AVAi but not meanPG

**Figure 1 (c). Relationship between pre-LAr-S with pre mean PG, pre-AVA and pre AVAi**

In pre TAVR patients, LAr-S have no significant relationship with AS severity

**Figure 1 (d). Relationship between pre RVFW-S with pre mean PG, pre-AVA and pre AVAi**

In pre TAVR patients, RVFW-S have weak but significant inverse relationship with AVAi only

**Figure 2. Relationship between DVI/AT and Flow rate**

Both AT and DVI have significant linear relationship with flow rate. The relationship is stronger between DVI and flow rate

**Figure 3. Left Ventricle Geometry**

There are 4 patients (3.74%) with normal LV geometry. The most common LV geometry is concentric hypertrophy

**Figure 4. Pre-TAVR IVSd**

There are 8 patients (7.5%) pre-TAVR with IVSd < 1.0cm

**Figure 5. Pre-TAVR PWTd**

There are 13 patients (12.1%) pre-TAVR with PWTd < 1.0cm