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RESEARCH ARTICLE

CORRELATION OF PULMONARY CAPILLARY WEDGE PRESSURE CALCULATED BY ECHO-DOPPLER WITH INVASIVE MEASUREMENT BY SWAN GANZ CATHETER IN POST CORONARY ARTERY BYPASS GRAFT PATIENTS

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Abstract

The present study was conducted to correlate PCWP estimated by Doppler Echocardiography with that obtained by Swan-Ganz catheter in patients with post coronary artery bypass graft surgery and to evaluate the feasibility and accuracy of Doppler Echocardiographic data. The present study provides evidence that in patients with coronary artery disease who underwent elective CABG surgery, PCWP can be reliably and accurately estimated by combining Doppler Echocardiographic variables of mitral flow and Tissue Doppler imaging and the relationship between E/Ea ratio and measured PCWP by Swan Ganz catheter was the strongest of all Doppler variables determined.

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Introduction:-

Introduced in clinical practice more than 30 years ago, the pulmonary artery catheter remains the most popular means for continuous monitoring of cardiac index, mixed venous oxygen saturation, pulmonary artery pressure and pulmonary capillary wedge pressure (PCWP). However, its insertion is an invasive procedure associated with iatrogenic complications, that may compromise the final outcome.

The Swan-Ganz catheter can be placed at the bedside within few minutes even in critically ill patients. Although placement of these catheters is not difficult, some training and experience are required to avoid complications and for proper interpretation of the haemodynamic data.

In non-sedated, spontaneously breathing cardiac patients, doppler indices derived from mitral and pulmonary venous flows obtained using transthoracic Echocardiography have been shown to be acceptable estimation of pulmonary capillary wedge pressure. More recently, the flow propagation velocity of early mitral inflow measured by Color M-mode Doppler and the ratio between the early mitral inflow measured by conventional doppler and the displacement of the mitral annulus measured by Tissue Doppler imaging have been shown to accurately reflect PCWP in cardiac patients. Therefore, a non-invasive technique that could simply and reliably predict filling pressures would be invaluable not only in the diagnosis, but more importantly in tailoring therapy.

The present study therefore is aimed to assess, whether pulmonary capillary wedge pressure measured from a pulmonary artery catheter (Swan-Ganz) could be accurately predicted using Echocardiographic indices derived from transthoracic conventional Doppler and Tissue Doppler imaging in a series of post coronary artery bypass graft surgery patients.

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Objectives of the study:-

To study the correlation of pulmonary capillary wedge pressure calculated by Echo-Doppler with invasive measurement by Swan Ganz catheter in post CABG patients.

To determine the relationship between different Echocardiographic indices and pulmonary capillary wedge pressure by invasive measurement by Swan-Ganz catheter.

Methodology:-

Present study was done at P.D.Hinduja National Hospital and Research Centre, Mumbai – 400 016 from July 2008 to June 2010. 35 patients, who were diagnosed as multi-vessel coronary artery disease on coronary angiography and underwent elective coronary artery bypass grafting, were selected for this study.

Each of the patients included in the study underwent pulmonary artery catheter (Swan-Ganz) placement before the surgery for haemodynamic measurement.

Inclusion Criteria

Patients diagnosed with multi-vessel coronary artery disease.

Patients underwent elective coronary artery bypass grafting.

Exclusion Criteria

1. The patients with inadequate acoustic window for echocardiography.
2. Patients in atrial fibrillation, flutter and multiple frequent VPC's etc.
3. Patients with associated valvular heart disease (i.e. mitral stenosis, severe aortic and mitral regurgitation, post mitral valvuloplasty).
4. Patients with prosthetic valves.
5. Patients with pacemakers.
6. Patients with pericardial diseases and cardiomyopathies.
7. Patients undergoing Redo-CABG or CABG along with other surgeries like valve replacement or pericardiectomy.

Investigations

1. Routine haemogram
2. Urine – R and M
3. Renal profile
4. Lipid profile
5. X-ray Chest PA view
6. ECG
7. Cardiac enzymes
8. Blood sugar – F and PP

Detailed Echocardiographic study

M-Mode Echo

Cardiac chamber dimensions

LV volumes

Flow propagation velocity (FVP)

2D Echo

1. Cardiac chambers sizes
2. Septae
3. Cardiac valves
4. Regional wall motion abnormality
5. LV systolic function
6. RV systolic function
7. Any clot/vegetation/mass
8. Any pericardial pathology

Colour M-Mode doppler measurements were recorded at the horizontal sweep speed of 100mm/seconds. Different parameters (ratios) and PCWP calculated by using different formulas from the literature as follows:

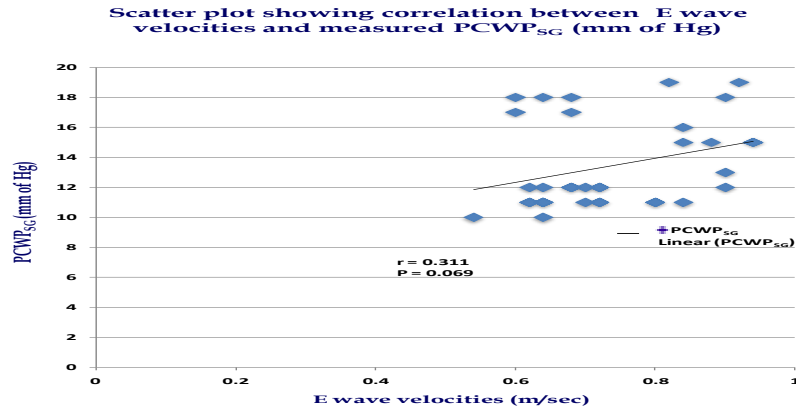
1. E/E a Ratio
2. E/FVP Ratio
3. Equation 1 : $PCWP_{Ea} = 0.97 E/E_a + 4.34$
4. Equation 2 : $PCWP_{vp} = 3.91 E/E_{vp} + 4.92$
5. Equation 3 : Gonzalez –Viklez formula = $PCWP = [1000/2 IVRT + FPV] \times 4.5 - 9$

Statistical Analysis

The numerical data obtained from this study was analyzed and significance of differences was estimated by using statistical methods. Results are reported as frequencies, percentages, means and standard deviations (SD) as applicable. Pearson correlation co-efficient was used to measure the relationship between catheter derived PCWP and Echocardiographic variables. Stepwise multiple linear regression analysis was used to estimate the relation between parameters obtained by Doppler Echocardiography examination and PCWP. The graphical representations, correlation tests and Pearson correlation coefficient were employed to establish the relationship between catheters derived PCWP.

Correlation of E wave velocities with pulmonary capillary wedge pressure by Swan Ganz catheter (PCWP_{SG})

| No. | E wave velocities (m/sec) | PCWP _{SG} (mm of Hg) |
|-----|---------------------------|-------------------------------|
| 1 | 0.62 | 11 |
| 2 | 0.80 | 11 |
| 3 | 0.64 | 10 |
| 4 | 0.84 | 11 |
| 5 | 0.90 | 13 |
| 6 | 0.72 | 12 |
| 7 | 0.94 | 15 |
| 8 | 0.68 | 12 |
| 9 | 0.70 | 11 |
| 10 | 0.94 | 15 |
| 11 | 0.84 | 15 |
| 12 | 0.84 | 16 |
| 13 | 0.64 | 11 |
| 14 | 0.68 | 18 |
| 15 | 0.64 | 11 |
| 16 | 0.88 | 15 |
| 17 | 0.68 | 12 |
| 18 | 0.72 | 11 |
| 19 | 0.92 | 19 |
| 20 | 0.82 | 19 |
| 21 | 0.70 | 12 |
| 22 | 0.68 | 12 |
| 23 | 0.64 | 18 |
| 24 | 0.90 | 17 |
| 25 | 0.54 | 10 |
| 26 | 0.72 | 11 |
| 27 | 0.68 | 17 |
| 28 | 0.80 | 11 |
| 29 | 0.64 | 11 |
| 30 | 0.72 | 12 |
| 31 | 0.90 | 12 |
| 32 | 0.64 | 18 |
| 33 | 0.62 | 11 |
| 34 | 0.60 | 18 |
| 35 | 0.62 | 12 |

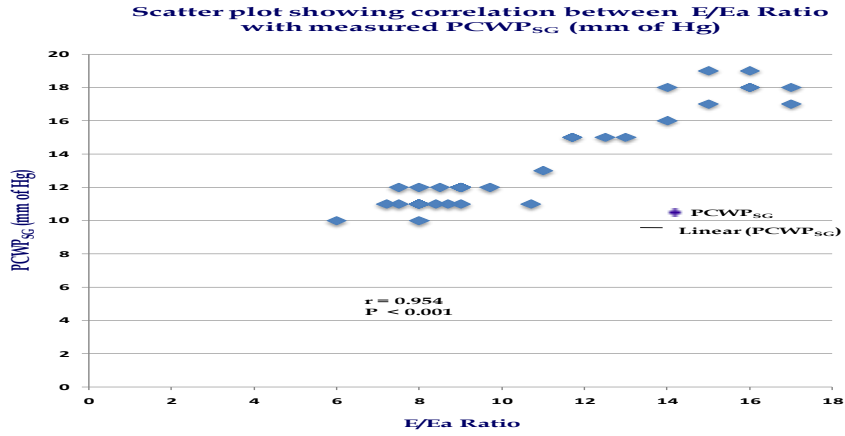


| Correlation | | | |
|---|---------------------|-------------------|--------------------|
| | | E wave velocities | PCWP _{SG} |
| E wave velocities | Pearson Correlation | 1 | .311(**) |
| | Sig. (2-tailed) | | .069 |
| | N | 35 | 35 |
| ** Correlation is non significant at the 0.01 level (2-tailed). | | | |

Correlation of E/Ea ratio with pulmonary capillary wedge pressure by Swan Ganz catheter (PCWP_{SG})

| No. | E/Ea Ratio | PCWP _{SG} (mm of Hg) |
|-----|------------|-------------------------------|
| 1 | 10.7 | 11 |
| 2 | 9 | 11 |
| 3 | 8 | 10 |
| 4 | 8.4 | 11 |
| 5 | 11 | 13 |
| 6 | 9 | 12 |
| 7 | 11.7 | 15 |
| 8 | 9.7 | 12 |
| 9 | 8.7 | 11 |
| 10 | 11.7 | 15 |
| 11 | 13 | 15 |
| 12 | 14 | 16 |
| 13 | 8 | 11 |
| 14 | 17 | 18 |
| 15 | 8 | 11 |
| 16 | 12.5 | 15 |
| 17 | 7.5 | 12 |
| 18 | 7.2 | 11 |
| 19 | 15 | 19 |
| 20 | 16 | 19 |
| 21 | 9 | 12 |
| 22 | 8.5 | 12 |
| 23 | 16 | 18 |
| 24 | 15 | 17 |
| 25 | 6 | 10 |
| 26 | 8 | 11 |
| 27 | 17 | 17 |
| 28 | 8 | 11 |
| 29 | 8 | 11 |
| 30 | 8 | 12 |
| 31 | 9 | 12 |

| | | |
|----|-----|----|
| 32 | 16 | 18 |
| 33 | 7.5 | 11 |
| 34 | 14 | 18 |
| 35 | 9 | 12 |



| Correlation | | | |
|-------------|---------------------|------|--------------------|
| E/Ea | | E/Ea | PCWP _{SG} |
| | Pearson Correlation | 1 | .954(**) |
| | Sig. (2-tailed) | | < 0.001 |
| | N | 35 | 35 |

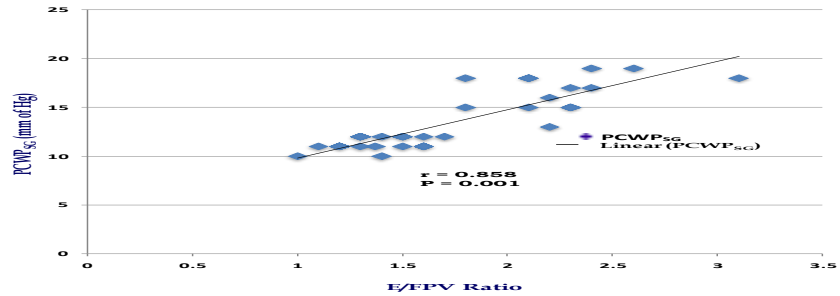
** Correlation is significant at the 0.01 level (2-tailed).

Correlation of E/FVP Ratio with pulmonary capillary wedge pressure by Swan Ganz catheter (PCWP_{SG})

| No. | E/FVP Ratio | PCWP _{SG} (mm of Hg) |
|-----|-------------|-------------------------------|
| 1 | 1.37 | 11 |
| 2 | 1.6 | 11 |
| 3 | 1.4 | 10 |
| 4 | 1.6 | 11 |
| 5 | 2.2 | 13 |
| 6 | 1.7 | 12 |
| 7 | 2.3 | 15 |
| 8 | 1.5 | 12 |
| 9 | 1.5 | 11 |
| 10 | 2.3 | 15 |
| 11 | 2.1 | 15 |
| 12 | 2.2 | 16 |
| 13 | 1.1 | 11 |
| 14 | 3.1 | 18 |
| 15 | 1.2 | 11 |
| 16 | 1.8 | 15 |
| 17 | 1.3 | 12 |
| 18 | 1.2 | 11 |
| 19 | 2.6 | 19 |
| 20 | 2.4 | 19 |
| 21 | 1.4 | 12 |
| 22 | 1.3 | 12 |
| 23 | 2.1 | 18 |
| 24 | 2.4 | 17 |
| 25 | 1 | 10 |
| 26 | 1.3 | 11 |
| 27 | 2.3 | 17 |

| | | |
|----|-----|----|
| 28 | 1.6 | 11 |
| 29 | 1.2 | 11 |
| 30 | 1.3 | 12 |
| 31 | 1.5 | 12 |
| 32 | 2.1 | 18 |
| 33 | 1.2 | 11 |
| 34 | 1.8 | 18 |
| 35 | 1.6 | 12 |

Scatter plot showing correlation between E/FPV Ratio and measured PCWP_{SG} (mm of Hg)



| Correlation | | | |
|-------------|-------------------------------------|-------|--------------------|
| E/FPV | Pearson Correlation Sig. (2-tailed) | E/FPV | PCWP _{SG} |
| | | 1 | .858(**) |
| | N | 35 | .001 |
| | | | 35 |

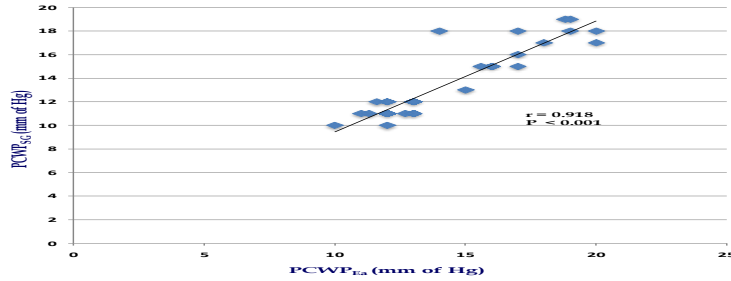
** Correlation is significant at the 0.01 level (2-tailed).

Correlation of PCWP_{Ea} (0.97 E / Ea + 4.34) with PCWP (SG) by Swan Ganz catheter

| No. | PCWP _{Ea} (mm of Hg) | PCWP _{SG} (mm of Hg) |
|-----|-------------------------------|-------------------------------|
| 1 | 13 | 11 |
| 2 | 13 | 11 |
| 3 | 12 | 10 |
| 4 | 12 | 11 |
| 5 | 15 | 13 |
| 6 | 13 | 12 |
| 7 | 15.6 | 15 |
| 8 | 13 | 12 |
| 9 | 12.7 | 11 |
| 10 | 16 | 15 |
| 11 | 17 | 15 |
| 12 | 17 | 16 |
| 13 | 12 | 11 |
| 14 | 20 | 18 |
| 15 | 12 | 11 |
| 16 | 16 | 15 |
| 17 | 11.6 | 12 |
| 18 | 11.3 | 11 |
| 19 | 18.8 | 19 |
| 20 | 19 | 19 |
| 21 | 13 | 12 |
| 22 | 12 | 12 |
| 23 | 14 | 18 |
| 24 | 18 | 17 |
| 25 | 10 | 10 |
| 26 | 12 | 11 |

| | | |
|----|----|----|
| 27 | 20 | 17 |
| 28 | 12 | 11 |
| 29 | 12 | 11 |
| 30 | 12 | 12 |
| 31 | 13 | 12 |
| 32 | 19 | 18 |
| 33 | 11 | 11 |
| 34 | 17 | 18 |
| 35 | 13 | 12 |

Scatter plot showing correlation between PCWP_{SG} (mm of Hg) measured and estimated by Equation 1 (PCWP_{Ea})



| Correlation | | | |
|--------------------|---------------------|--------------------|--------------------|
| | | PCWP _{Ea} | PCWP _{SG} |
| PCWP _{Ea} | Pearson Correlation | 1 | .918(**) |
| | Sig. (2-tailed) | | <0.001 |
| | N | 35 | 35 |

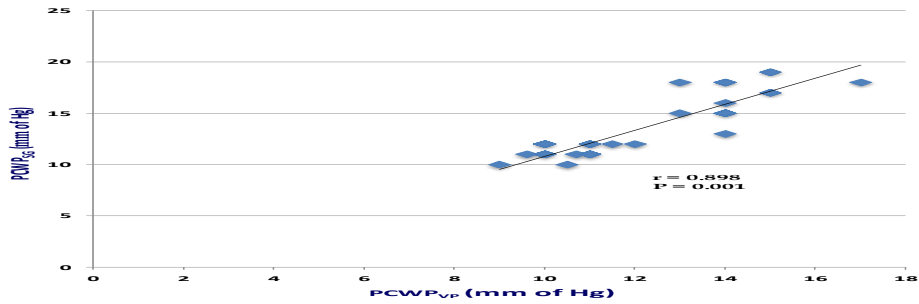
** Correlation is significant at the 0.01 level (2-tailed).

Co-relation of PCWP_{VP} (3.91 x E/VP + 4.92) with PCWP_{SG} by Swan Ganz Catheter

| No. | PCWP _{VP} (mm of Hg) | PCWP _{SG} (mm of Hg) |
|-----|-------------------------------|-------------------------------|
| 1 | 11 | 11 |
| 2 | 11 | 11 |
| 3 | 10.5 | 10 |
| 4 | 11 | 11 |
| 5 | 14 | 13 |
| 6 | 11.5 | 12 |
| 7 | 14 | 15 |
| 8 | 11 | 12 |
| 9 | 10.7 | 11 |
| 10 | 14 | 15 |
| 11 | 14 | 15 |
| 12 | 14 | 16 |
| 13 | 10 | 11 |
| 14 | 17 | 18 |
| 15 | 11 | 11 |
| 16 | 13 | 15 |
| 17 | 10 | 12 |
| 18 | 9.6 | 11 |
| 19 | 15 | 19 |
| 20 | 15 | 19 |
| 21 | 11 | 12 |
| 22 | 10 | 12 |
| 23 | 14 | 18 |
| 24 | 15 | 17 |
| 25 | 9 | 10 |
| 26 | 10 | 11 |
| 27 | 15 | 17 |

| | | |
|----|----|----|
| 28 | 11 | 11 |
| 29 | 10 | 11 |
| 30 | 10 | 12 |
| 31 | 11 | 12 |
| 32 | 14 | 18 |
| 33 | 10 | 11 |
| 34 | 13 | 18 |
| 35 | 12 | 12 |

Scatter plot showing correlation between PCWP_{SG} (mm of Hg) measured and estimated by Equation 2 (PCWP_{Vp})



| Correlation | | | |
|------------------------|---------------------|--------------------|--------------------|
| PCW F _{Vp} | Pearson Correlation | PCWP _{Vp} | PCWP _{SG} |
| | Sig. (2-tailed) | 1 | .898 (**) |
| | N | 35 | .001 |
| | | | 35 |

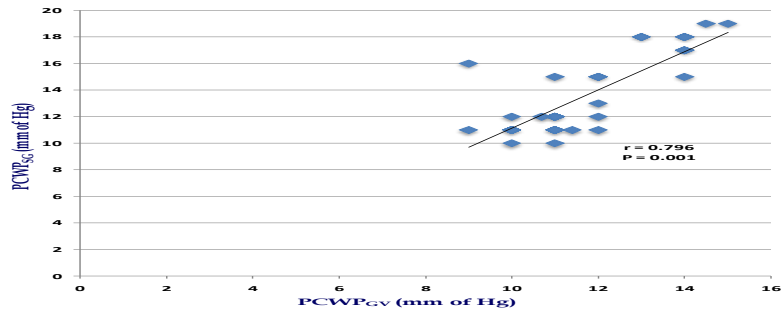
** Correlation is significant at the 0.01 level (2-tailed).

Co-relation of PCWP_{GV} calculated by formula using FPV & IVRT (Gonzalez – Vilchez) with PCWP_{SG} by Swan Ganz Catheter

| No. | Gonzalez – Vilchez formula | PCWP _{SG} (mm of Hg) |
|-----|---|-------------------------------|
| | PCWP _{GV} = 1000/2 IVRT + FPV x 4.5 -9 | |
| 1 | 10 | 11 |
| 2 | 10 | 11 |
| 3 | 11 | 10 |
| 4 | 11 | 11 |
| 5 | 12 | 13 |
| 6 | 11 | 12 |
| 7 | 11 | 15 |
| 8 | 12 | 12 |
| 9 | 10 | 11 |
| 10 | 12 | 15 |
| 11 | 14 | 15 |
| 12 | 9 | 16 |
| 13 | 10 | 11 |
| 14 | 14 | 18 |
| 15 | 11 | 11 |
| 16 | 12 | 15 |
| 17 | 10.7 | 12 |
| 18 | 11.4 | 11 |
| 19 | 14.5 | 19 |
| 20 | 15 | 19 |
| 21 | 11 | 12 |
| 22 | 11 | 12 |
| 23 | 13 | 18 |
| 24 | 14 | 17 |
| 25 | 10 | 10 |

| | | |
|----|----|----|
| 26 | 9 | 11 |
| 27 | 14 | 17 |
| 28 | 11 | 11 |
| 29 | 12 | 11 |
| 30 | 10 | 12 |
| 31 | 11 | 12 |
| 32 | 13 | 18 |
| 33 | 10 | 11 |
| 34 | 14 | 18 |
| 35 | 11 | 12 |

Scatter plot showing correlation between PCWP_{SG} (mm of Hg) measured and estimated by Equation 3 (PCWP_{GV})



| Correlation | | | |
|--------------------|---------------------|--------------------|--------------------|
| PCWP _{GV} | | PCWP _{GV} | PCWP _{SG} |
| | Pearson Correlation | 1 | .796(**) |
| | Sig. (2-tailed) | .35 | .001 |

** Correlation is significant at the 0.01 level (2-tailed).

E/Ea Ratio Vs PCWP_{SG} Crosstabulation

| | | | PCWP _{SG} (mm of Hg) | |
|------|-------|--------------------------------|-------------------------------|--------|
| | | | <=12 | >=12.1 |
| E/Ea | <=8 | Count | 10 | 1 |
| | | % within E/Ea8 | 90.9% | 9.0% |
| | | % within PCWP _{SG} 12 | 52.4% | 27.0% |
| | >=8.1 | Count | 10 | 14 |
| | | % within E/Ea8 | 41.7% | 58.3% |
| | | % within PCWP _{SG} 12 | 47.6% | 100.0% |

| | | | PCWP _{SG} (mm of Hg) | |
|------|-----------------|-------|-------------------------------|--------|
| | | | <=15 | >=15.1 |
| <=15 | Count | 26 | 4 | |
| | % within E/Ea15 | 86.7% | 13.3% | |

| | | | | |
|------|-------|--------------------------------|--------|--------|
| E/Ea | | % within PCWP _{SG} 15 | 100.0% | 44.4% |
| | | Count | 0 | 5 |
| | ≥15.1 | % within E/Ea15 | .0% | 100.0% |
| | | % within PCWP _{SG} 15 | .0% | 55.6% |

E/FPV Ratio Vs PCWP_{SG} Crosstabulation

| | | PCWP _{SG} (mm of Hg) | | |
|-------|----|--------------------------------|-------|-------|
| | | ≤15 | ≥15.1 | |
| E/FPV | ≤2 | Count | 22 | 1 |
| | | % within E/FPV2 | 95.7% | 4.3% |
| | | % within PCWP _{SG} 15 | 84.6% | 11.1% |
| | ≥2 | Count | 4 | 8 |
| | | % within E/FPV2 | 33.3% | 66.7% |
| | | % within PCWP _{SG} 15 | 15.4% | 88.9% |

Discussion:-

Insertion of pulmonary artery catheter (Swan-Ganz) is invasive procedure and has multiple known complications. Thus if Echocardiographic estimation of PCWP is accurate and comparable, it would be very useful in managing post CABG patients in ICU. In the present study, the relationship between E/Ea ratio and PCWP was the strongest of all Doppler variables measured. A statistically significant positive correlation of E/Ea ratio ($r = 0.954$) was observed with catheter derived PCWP ($P < 0.001$). Also, the pulmonary capillary wedge pressure calculated from equation 1 by using E/Ea ratio ($PCWP_{Ea}$) had significant positive correlation with measured PCWP ($r = 0.918$, $P < 0.001$). But the relationship between peak early diastolic wave velocities (E) and measured PCWP by Swan-Ganz was not statistically significant ($r = 0.311$, $p = 0.069$) in our study.

Firstenbers M.S. et. al. (2000) found in their study that in healthy volunteers, the peak velocity of early mitral flow (E) is the best predictor of an elevated PCWP. But the peak E velocity increases with preload and decreases with impaired relaxation and tachycardia.

In spontaneously breathing cardiac patients, tachycardia and impaired left ventricular relaxation are frequently observed acting as confounding factors on E, which is no longer an accurate predictor of elevated left ventricular filling pressure. These were the findings of the study conducted by Ommen S.R. et. al. (2000) and similar findings were observed in the present study.

Several investigators have shown that the E/Ea (E/E') relationship is valid for determining filling pressures in various patients population with underlying cardiac disease similar to the present study group. Nagueh (1997) and colleagues have validated the relationship between E/E' and measured PCWP in patients with either impaired or pseudonormal relaxation or with sinus tachycardia.

Sundereswaran et. al. (1998) studied the post heart transplant patients for estimation of left and right ventricular filling pressures by echocardiography and correlated with measured PCWP. He concluded that E/E' ratio was best correlated with invasive measurement for PCWP.

The E/Ea ratio correlation with PCWP was also validated in coronary artery disease with normal LV systolic function and valvular heart disease. Diwan A et. al. (2005) studied the patients with mitral valve disease and found the positive correlation between TE –Ea (interval between onset of mitral E and annular early diastolic velocity (Ea) by Tissue Doppler) and E/E' ratio for calculation of PCWP.

Thus the present study findings of strongest correlation of measured PCWP with E/Ea ratio are consistent with various previous studies.

In the present study, an attempt was also made to determine the sensitivity and specificity of E/Ea ratio below 8 and above 15 for predicting the pulmonary capillary wedge pressure. The cross tabulation is done between E/Ea 8 versus PCWP_{SG} 12 (measured) and E/Ea 15 versus PCWP_{SG} 15 (measured). We found that if E/Ea ratio is < 8, it indicates normal pulmonary capillary wedge pressure (< 12 mm Hg) with 90.9% sensitivity and 58.3% specificity and if E/Ea ratio > 15, it indicates raised pulmonary capillary wedge pressure (> 15 mm of Hg) with 86.7% sensitivity and 100% specificity. Thus, the present study showed that E/Ea ratio < 8 is suggestive of normal PCWP and E/Ea ratio > 15 was closely associated with elevated pulmonary capillary wedge pressure.

The study findings are consistent with previous study done by Frank Lloyd Dini et al (2010) and with previous literature from various textbooks. Frank Lloyd Dini et al tested a decision model for non invasive estimation of left ventricular filling pressure in patients with left ventricular dysfunction. He concluded that E/E' ratio > 13, E wave deceleration time < 150 ms and E/FPV ratio > 2 was closely associated with elevated left ventricular filling pressure (> 15 mm of Hg).

Furthermore, in this study the author also correlated the E/FPV ratio with measured PCWP by Swan Ganz catheter. A statistically significant positive correlation of E/FPV ratio ($r = 0.858$) was observed with catheter derived PCWP ($P < 0.001$). Also, the pulmonary capillary wedge pressure calculated from equation 2 using E/FPV ratio (PCWP_{vp}) had significant positive correlation with measured PCWP ($r = 0.898$, $P < .001$).

Paulo Marcelino et. al. (2006) compared the haemodynamic measurements obtained by Swan – Ganz catheter and transthoracic echocardiography in post liver transplant patients. He concluded that Echocardiography was not appropriate for calculation of filling pressures of left ventricle. He used formula by Gonzallez – Vilchez (PCWP = {1000/2 IVRT + FPV} x 4.5 – 9) for calculation of pulmonary capillary wedge pressure noninvasively.

In present study, we used the above formula in Equation 3 to estimate PCWP_{GV} noninvasively. We found statistically significant positive correlation ($r = 0.796$, $P < 0.001$) between estimated PCWP_{GV} by Echocardiography with measured PCWP_{SG} by Swan – Ganz catheter.

In our present study we have included all patients who underwent CABG surgery electively on pump. So we could not study the effect of cardiopulmonary bypass with cardioplegic arrest on left ventricular relaxation and compliance postoperatively. It requires more comprehensive comparative studies between on pump and off pump CABG patients. Eric E.C. de Waal et al included 20 on pump and 12 off pump CABG patients in his study. Comprehensive transthoracic echocardiography was done, a day before and a day after elective CABG in both groups. A similar improvement in relaxation and compliance were observed in both groups. He concluded that myocardial relaxation improved the day after CABG irrespective of the use of cardiopulmonary bypass with cardioplegic arrest. Thus it may be feasible to use our findings in all CABG patients either on pump or off pump.

Conclusion:-

The present study provides evidence that in patients with coronary artery disease who underwent elective CABG surgery, Pulmonary Capillary Wedge pressure can be reliably and accurately estimated by combining Doppler Echocardiographic variables of mitral flow and Tissue Doppler imaging. In the present study, the relationship between E/Ea ratio and measured PCWP by Swan Ganz catheter was the strongest of all Doppler variables determined. E/Ea ratio < 8 indicates normal PCWP and E/Ea ratio > 15 indicates elevated PCWP. There was no statistically significant correlation between peak E wave velocities and measured PCWP by Swan-Ganz catheter ($r =$

0.311, $p = 0.069$). The E/FPV ratio > 2 for predicting an elevated PCWP ($> 15\text{mmHg}$) in post CABG patients had good sensitivity (96%) and specificity (89%). It should be determined in conjunction with E/Ea ratio for the assessment of both diastolic function and filling pressure. It was found that PCWP determined by different Echocardiographic equations had significant positive correlation with PCWP measured by Swan-Ganz Catheter, but additional studies are required to identify the accuracy and physibility of Echocardiographic technique in other category of patients. This simple, repeatable, readily available noninvasive tool may reduce the need for right heart catheterization in acutely ill patients and may provide us with easy bedside method of estimating and monitoring PCWP.

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