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An Alternative Method for Perioperative Estimation of Pulmonary Artery Systolic Pressure by Echocardiography.

Karvandi M*, Piranfar MA*, Ghaffaripour M**, Behnia M*, Gheidari M*, Mohammadi Tofigh AΨ.

* Assistant Professor, Section of Echocardiography, Department of Cardiology, Taleghani Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran, ** Assistant Professor, Section of Cardiac Anesthesia, Department of Anesthesiology and Intensive Care, Lavasani Heart Center, Tehran, Iran, Ψ Assistant Professor, Department of Surgery, Imam Hossein Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Correspondence: Dr. Arash Mohammadi Tofigh, Section of Echocardiograpgy, Taleghani Hospital, Evin, Tehran, Iran. Telephone: +98(21)22432576, fax: +98(21)77557069, E-mail: arash_mtofigh@yahoo.com.

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Abstract:

Backgrounds: In the perioperative setting, pulmonary hypertension is due to ischemia, left-sided valvular regurgitation and stenosis, residual shunt, pulmonary emboli, pericardial effusion etc. The pulmonary artery (PA) pressure can be assessed by different methods, including invasive pulmonary catheters and pulsed Doppler echocardiography. Because of limitations of Doppler echocardiography (conventional method) for evaluation of PA pressure, we purposed this study to determine whether tricuspid annular plane systolic excursion (TAPSE), isovolumic relaxation time (IVRT) and S-wave velocity obtained by tissue Doppler imaging (TDI) can be used as indices of systolic pulmonary artery pressure in perioperative setting.

Materials and Methods*:* Simultaneously, TAPSE by 2-D echocardiography and tissue Doppler velocity (TDV) study by Doppler echocardiography and right heart catheterization by Swan-Ganz catheter were performed in 55 patients (mean age 46 years,30 were male) with left–sided valvular disease (n=25), ischemic heart disease (n=18) and adult-congenital heart disease (n=12).The TAPSE index ,which is expressed as an absolute value (cm or mm), IVRT and S-wave velocity by TDI were measured. We also measured pulmonary artery systolic pressure by right cardiac catheterization.

Results: In patients with moderate and severe pulmonary hypertension (PASP>45mmHg) the TAPSE value was < 17.8 mm with sensivity of 90% and specifity of 80%, the S-wave velocity was <11cm/s with sensivity of 90% and specifity of 86% and the IVRT was >79ms with sensitivity of 93% and specificity of 95% ($p<0.001$). Some factors such as underlying diseases (ischemic heart disease, congenital heart disease) had no effect on this correlation.

Conclusion: We conclude that evaluation of TAPSE index and IVRT and S-wave velocity by echocardiography provides a simple and rapid method for estimating systolic pulmonary artery pressure in perioperative setting.

Key Words: Pulmonary Artery Systolic Pressure, Echocardiography.

Introduction:

Pulmonary artery pressure is an important hemodynamic variable used in the management of patients with cardiovascular and pulmonary disease [1]. Pulmonary artery pressure is estimated invasively by the tricuspid regurgitation jet velocity, pulmonary acceleration time, right ventricular (RV) ejection time, pulmonary regurgitation and isovolumic relaxation time in Doppler echocardiography [2,3]. However, finding a reliable non invasive evaluation of pulmonary artery pressure is still a problem [1]. The aim of the present study is to investigate the relationship between Isovolumic Relaxation Time (IVRT) obtained by Doppler Tissue imaging from tricuspid annulus motion and pulmonary artery pressure in patients with valvular, coronary and congenital heart disease.

Materials and Methods:

Study population: Tricuspid annular plane systolic excursion (TAPSE) by 2-D echocardiography and Tissue Doppler velocity (TDV) study by Doppler echocardiography and right heart catheterization by balloon-tipped flow directed pulmonary artery catheter (Swan-Ganz catheter) were performed in 35 patients in the open heart intensive care unit and 20 patients in open heart operation room which were randomly elected. Our exclusion data were right ventricular myocardial infarctions and previously operated patients. Patient consent was obtained in all cases.

Pulsed Doppler tissue imaging technique: A commercially reliable ultrasound system (GE VIVID SEVEN) equipped with a multi frequency phased array transducer of M3S, and pulsed Doppler tissue imaging technique was used for transthoracic echocardiography (TTE) in 35 patients and a ACUSON SECUOIA 512 for transesophageal echocardiography (TEE) in the other 20 patients. We used TEE for intraoperative cases and cases with very poor view imaging in TTE ,like patients who were under mechanical ventilation or patients with nonvisible lateral RV wall in TTE [4,5]. All patients were in stable hemodynamic condition and tracing were recorded during end expiration. The tricuspid annular systolic and diastolic velocities and the time intervals were acquired in apical four-chamber views at the junction of the right ventricle free wall and the anterior leaflet of the tricuspid valve by tissue Doppler imaging.6 The acoustic power and filter and gain were adjusted for detecting myocardial velocities [7,8,9].

The peak systolic (Sa), peak early diastolic (Ea), peak late diastolic (Aa) annular velocities and the time between the end of Sa and the beginning of Ea were obtained by placing a sample volume with a fixed length of 0.52 cm at the junction of RV free wall and the anterior leaflet of the tricuspid valve when imaged from the two-dimensional four chamber view by using Doppler tissue imaging [6,10]. All recording were made at a sweep speed of 50 and 100 mm/s. All recording were made with a simultaneous superimposed ECG [11,12]. Values are presented as means of 3 consecutive beats[4]. (fig. 1 and 2)

Left ventricular ejection fraction (LVEF) was not included in this study. The echocardiographic measurements were performed before the Swan-Ganz catheter measurements in all cases so the echocardiographic studies performers were not aware from the systolic pulmonary artery pressures of patients.

TAPSE (Tricuspid annular plane systolic excursion)

During ventricular systole, long axis shortening is created by motion of both atrioventricular valve annulae toward the cardiac apex. Because the septal attachment of the tricuspid annulus is relatively fixed; the majority of tricuspid annular motion occurs in its lateral aspect. This gives the motion of the tricuspid annulus a hinge-like appearance, moving more laterally than medially. This motion contracts with that of the mitral annulus; which has a more symmetrical or piston–like appearance during systole. Tricuspid annular plane systolic excursion (TAPSE) describes this long axis systolic excursion of the lateral aspect of the tricuspid annulus; and it has validated as a useful additional measure of global RV systolic function (fig. 3).Measurement of TAPSE can be expressed as an absolute value(cm or mm) or as a maximal major-axis shortening fraction [13].

Cardiac catheterization: A balloon-tipped flow directed pulmonary artery catheter (Swan – Ganz catheter) was used for hemodynamic measurements. The catheter was inserted in the internal jugular vein in all cases. Systolic pulmonary artery pressure (SPAP) and wedge pressure were measured.

Statistical analysis: A commercially available statistical program (SPSS 10.1 and 11.1) was used. Clinical, echocardiographic, and right heart catheterization data expressed as mean ± standard deviation. Pearson's correlation and linear regression analysis were plotted to show certain relationship. A p-value less than 0.05 was considered significant. The study protocol was approved by the Institutional Review Board of Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Results:

General characteristics of the study population: The study population comprised 25 female and 30 male subjects, ranging in age from 18 to 73 years (mean 46±3.3 years). 25 patients had aortic and mitral valve disease. 12 patients had congenital heart disease and 18 patients had coronary artery disease. The referral diagnoses are presented in table 1. The patients were divided into two groups by the values obtained from Swan-Ganz catheter; group I: pulmonary artery systolic pressure in 25-45mmHg range (n=31), group II: in 46-80 mmHg range (n=24) (table 2).

Relationship between Right ventricular isovolumic relaxation time, S-wave velocity, TAPSE and pulmonary artery pressure: A significant relationship was found between the IVRT, S-wave velocity, TAPSE and pulmonary artery systolic pressure ($r= 0.99$, $P<0.0001$). (Fig 4, 5, 6)

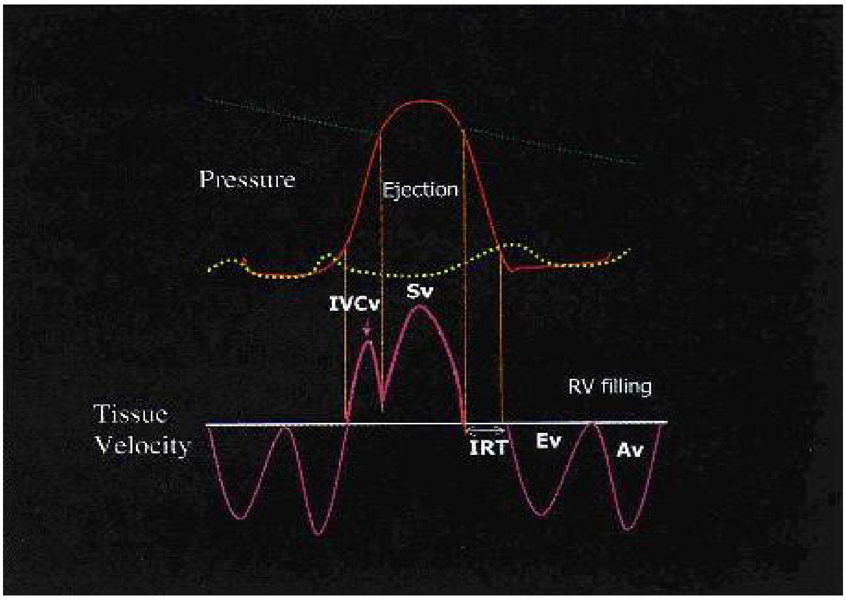

Fig. 1, Schematic traces from Doppler tissue imaging with superimposed ventricular and atrial pressures. IVC: Isovolumic contraction velocity, Sv: Systolic velocity during ejection period, Ev: Early diastolic velocity, Av: Atrial velocity, IRT: Isovolumic relaxation time.

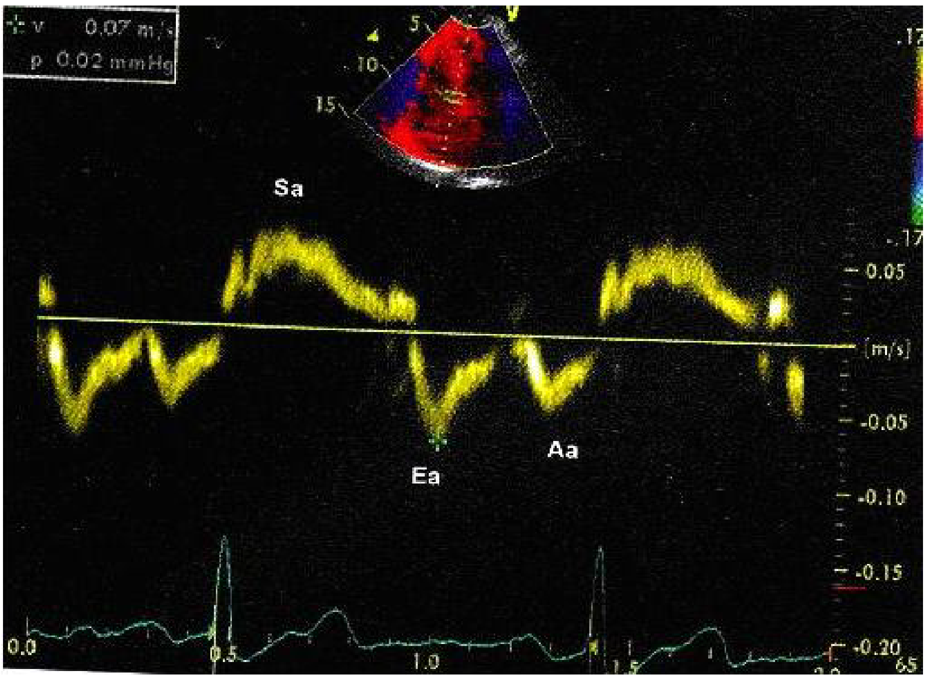

Fig. 2, Illustration of pulsed TDI of TV in a patient with MR. Sa: Peak systolic velocity at the anterior leaflet of TV, Ea: Peak early diastolic velocity at the anterior leaflet of TV, IVRT: The time between the end of Sa and the beginning of Ea.

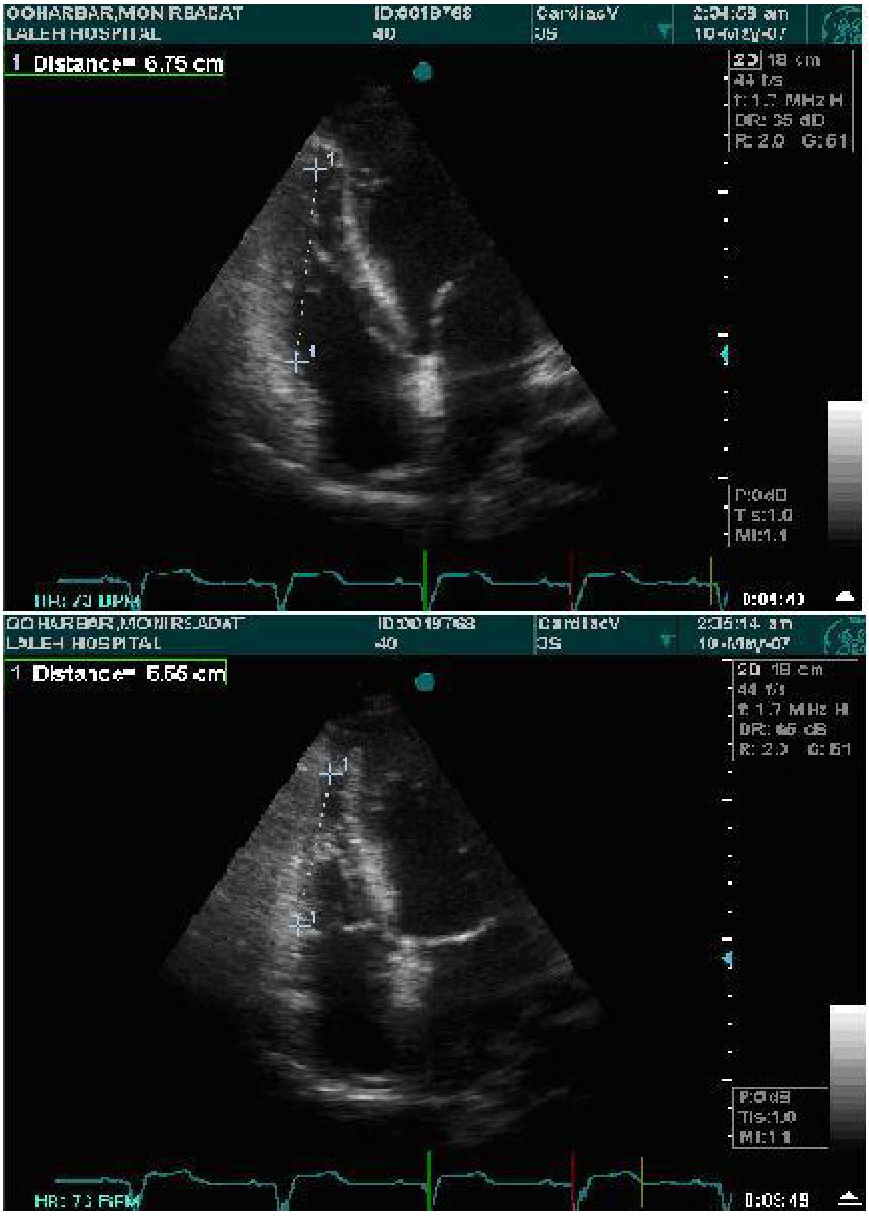

Fig. 3, Measurement of tricuspid plane sytolic excursion (TAPSE) measured during diastole (Top) and systole (Bottom)

The IVRT value has been compared in the two groups; group I: 51.79 ms ±13.35 STD, group II: 91msec ± 11.7 STD (table 3).The S-wave value has been compared in the two groups; group I: 13±2cm/s STD, group II: 10± 2 STD (table 3).

The TAPSE value has been compared in the two groups; group I: 23±3mmSTD, group II: 18±1 STD (table 3).

The IVRT, S-wave, TAPSE values showed significant differences between the two groups ($P<0.0001$). In patients with significant pulmonary hypertension (PASP>45mmHg) the TAPSE value was <17,8mm with sensivity of 90% and a specifity of 80%, S-wave velocity <11cm/s with sensivity of 90% and a specifity of 86% and IVRT>79msec with sensivity of 93% and a specifity of 95 % ($p<0.0001$).

Table 1- Referral diagnosis of patients

<table>
<tr><th>Diagnosis</th><th colspan="7"></th><th>N</th></tr>
<tr><td rowspan="2">VHD
(n)</td><td>MS</td><td>MS+MR</td><td>AS+AI</td><td>AS</td><td>AI</td><td>AI+MS</td><td>MR+AI</td><td rowspan="2">25</td></tr>
<tr><td>7</td><td>4</td><td>4</td><td>2</td><td>2</td><td>3</td><td>3</td></tr>
<tr><td rowspan="2">CAD
(n)</td><td colspan="4">CAD+ISCHEMIC MR</td><td colspan="3">PURE CAD</td><td rowspan="2">18</td></tr>
<tr><td colspan="4">8</td><td colspan="3">10</td></tr>
<tr><td rowspan="2">CHD
(n)</td><td colspan="2">ASD</td><td colspan="3">VSD</td><td colspan="2">SMALL PDA</td><td rowspan="2">12</td></tr>
<tr><td colspan="2">7</td><td colspan="3">4</td><td colspan="2">1</td></tr>
</table>

VHD: valvular heart disease, MS: mitral stenosis, MR: mitral regurgitation, AS: aortic stenosis, AI: aortic insufficiency, CAD: coronary artery disease, CHD: congenital heart disease, ASD: atrial septal defect, VSD: ventricular septal defect.

Table 2- Systolic pulmonary artery pressure in two groups of patients based on Swan-Ganz catheter measurement.

Group	I	II
SPAP (mm hg)	25-45	46-68
N	31	24

SPAP: systolic pulmonary artery pressure

Table 3- Echocardiographic measurements in two groups

index	Group I	Group II
S-wave Velocity (cm/s)	13±2	10±2
IVRT (msec)	51.79±13.35	91±11.7
TAPSE (mm)	23±3	17±1

TAPSE = TV annular plane systolic excursion; S-wave = systolic wave in TDI; IVRT= Isovolumic relaxation time.

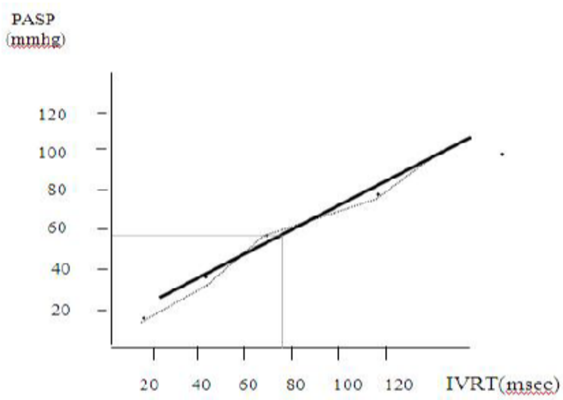

Fig. 4, Correlation between IVRT (Isovolumic Relaxation Time) and PASP (pulmonary systolic artery pressure)

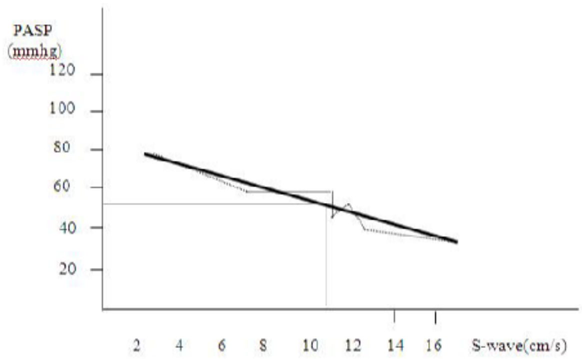

Fig. 5, Correlation between S-wave velocity and PASP (pulmonary systolic artery pressure)

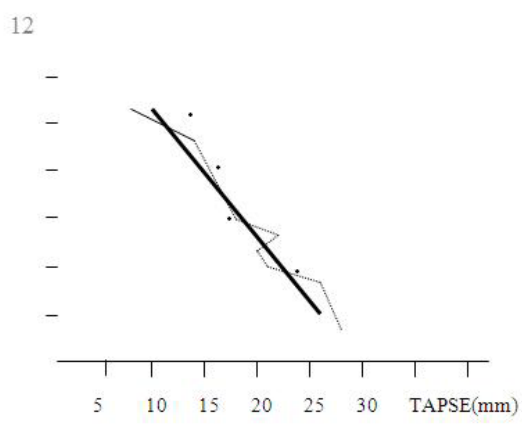

Fig. 6, Correlation between TAPSE (tricuspid annular plane systolic excursion) and PASP (pulmonary systolic artery pressure)

Discussion:

We have demonstrated that isovolumic relaxation time of the right ventricular free wall measured by pulsed Doppler tissue imaging, systolic velocity of tricuspid valve (TV) annulus obtained by pulsed Doppler tissue imaging and tricuspid annular plane systolic excursion by 2D echocardiography can be used to estimate pulmonary artery pressure in the perioperative setting. Previous investigators have described the use of various Doppler parameters to evaluate pulmonary pressure. These efforts have focused on timing of events such as right ventricular pre-ejection time, ejection time, tricuspid regurgitation (TR) jet and IVRT (by conventional Doppler echocardiography). The right ventricular isovolumic relaxation time is the interval between pulmonic valve closure and tricuspid valve opening. Based on previous studies, this time increases with pulmonary hypertension [3, 14-17]. In adults, pulmonic valve closure is difficult to ascertain, and the short time interval tends itself to measurement variability and error [3]. Determination of TR-jet and Timing need good views and resolution in 2D and conventional Doppler echocardiography. Thus, in patients with poor view imaging or patients without TR-jet, pulmonary pressure measurement is not possible by TR peak velocity and gradient measurement. But, for evaluation of tricuspid annular motion (TAPSE) by 2-D echocardiography or Tissue-Doppler velocity study, a visible lateral (free) wall of right ventricle is adequate which is independent of the quality and resolution of images in 2D-echocardiography.

Diastolic RV dysfunction (lower tricuspid valve peak E velocity in TV inflow, lower E/A velocity and prolonged RV IVRT) and Systolic RV dysfunction (lower tricuspid valve peak S-wave and lower TAPSE) has been demonstrated in patients with pulmonary hypertension and in those with symptomatic congestive heart failure, even in the absence of pulmonary hypertension, suggesting a potential role for ventricular interdependence in impaired RV filling [18]. It must be mentioned that prolonged significant pulmonary hypertension resulting RV remodeling (dilatation and dysfunction), lead to increased IVRT and decreased S-wave velocity and TAPSE [3].

Thus we used TDI for precise determining of peak systolic velocity, the time interval between the end of peak systolic velocity (Sa) and the beginning of early diastolic (Ea) in tricuspid annular velocities and 2-D echocardiography for absolute value of TV annular excursion (TAPSE), along with simultaneous electrocardiography.

In a recent study, Per Lindquist et al. showed that isovolumic contraction velocity can be useful in detection of patients with elevated right ventricular filling pressure such as patients with pulmonary hypertension [4]. Bolca et al. showed that IVRT is a reliable measurement of pulmonary artery pressure and vascular resistance with valvular and congenital heart disease by using Doppler tissue imaging [19].

Kaul S et al. showed that compared with radionuclide RV ejection fraction as the reference method for assessing global RV function, TAPSE has been found to correlate more closely percent change in RV area during systole [20] and Meluzin J et al conclude that systolic velocity of tricuspid annular systolic motion could estimate RV function, in the other hand, S-wave >11.5cm/s is predictive of normal RV ejection fraction [24].

In present study, we found that IVRT, TAPSE, S-wave velocity were influenced by pulmonary pressure. Moderate to severe pulmonary artery hypertension causes reduced RV systolic and diastolic function that is correlated with an increase in IVRT and a decrease in S-wave velocity and TAPSE. Some factors such as underlying disease (valvular heart disease, coronary artery disease, and congenital heart disease), age and sex had no effect on it.

Conclusion:

Noninvasive determination of pulmonary pressure is possible using variables that are routinely obtained by Doppler tissue imaging.

We conclude that the evaluation of isovolumic relaxation time and S-wave velocity from tricuspid annulus by Pulsed Doppler tissue imaging and TAPSE by 2D echocardiography provides a simple, rapid and non invasive tool for estimating of pulmonary hypertension in patients with Valvular, Coronary and Congenital heart disease in perioperative setting.

References:

1. Amr E. Abbas, David Fortuin , Nelson B. Schiller MD, Christopher P. Appleton, Carlos A. Moreno, Steven J. Lester. A simple method for noninvasive estimation of pulmonary vascular resistance, Journal of the American College of Cardiology 2003; 41: 1021-7.

2. Akira Kitabake, Michitochi Inoue, Masato Asao, Tohru Masuyama, Joutanouchi M. Non-invasive evaluation of pulmonary hypertension by a Pulsed Doppler technique, Circulation 1983; 68: 302-309.

3. Otto C, editor, Echocardiographic findings in Acute and chronic pulmonary disease. Text book of clinical Echocardiography, Philadelphia, PA: W.B.Saunders. 2002; 739-757

4. Per Lindquist, Anders Waldenstrom, Gerhard Wikstrom, Elsading Kazaam. The use of isovolumic contraction velocity to determine right ventricular state of contractility and filling pressures a pulsed Doppler tissue imaging study. Eur J Echocardiography 2005; 6: 264-270.

5. Schiller NB, Shah PM, Crawford M, De Maria A, Devercux R, Feigenbaum H, et al. Recommendations for quantitation of the left ventricle by two- dimensional echocardiography. American society of Echocardiography committee on standards, subcommittee on quantitation of Two- dimensional echocardiograms. J Am soc Echocardiogr 1989; 2: 358-67.

6. J. Meluzin, L. Spinarova, J. Bakala, J. Toman, J. Krejci, P. Hude, et al, Pulsed Doppler tissue imaging of the velocity of tricuspid annular systolic motion. European Heart Journal 2001; 22: 340-348.

7. J. De Baker, D. Matthys, T. C Cille bert, A. De Paepe, J. De sutter. The use of tissue Doppler imaging for the assessment of changes in myocardial structure and function in inherited cardiomyopathies. Eur J Echocardiography 2005; 6: 243-250.

8. Waggoner AD, Bierig SM. Tissue Doppler imaging: a useful echocardiographic method

for the cardiac sonographer to assess systolic and diastolic ventricular function. J Am Soc Echocardiogr 2001; 14 (12): 1143-52.

9. Isaaz K. What are we actually measuring by Doppler tissue imaging? J Am Coll Cardiol 2000; 36 (3): 897-9.

10. Alam M, Wardell J, Andersson E, samad B, Nordlander R. Characteristics of mitral and tricuspid annular velocities determined by Pulsed wave Doppler tissue imaging in healthy subjects. J Am soc Echocardiogr 1999; 12: 618-28.

11. Sutherland GR, Hatle L. Pulsed Doppler myocardial imaging. A new approach to regional longitudinal function? Eur J Echocardiogr 2000; 1: 81-3.

12. Garcia- Fernandez MA, Azevedo J, Moreno M, Bermejo J, perez- Castellano N, Puerta P, et al. Regional diastolic function in ischemic heart disease using Pulsed wave Doppler tissue imaging. Eur Heart J 1999; 20: 496-505.

13. Hammerstron E, Wranne B, Pinto FJ. Tricuspid annular motion. J Am Soc Echocardiography 1991;14:31-9.

14. Yock PG, Popp RL: Non invasive estimation of right ventricular systolic pressure by Doppler ultrasound in patients with tricuspid regurgitation. Circulation 1984; 70: 657- 662.

15. Berger M, Haimowitz A, Van Tosh A, et al: Quantitative assessment of pulmonary hypertension in patients with tricuspid regurgitation using continuous wave Doppler ultrasound. J AM Coll Cardiol 1985; 6: 359-365.

16. Currie PJ, Seward JB, Chan KL, et al: Continuous wave Doppler determination of right ventricular pressure: A simultaneous Doppler-catheterization study in 127 patients. J Am coll Cardiol 1985; 6: 750-756.

17. Stevenson JG: Comparison of several non invasive methods for estimation of pulmonary artery pressure. J Am soc Echocardiography 1989; 2: 157-171.

18. Yuc C, Sanderson J, Chan S, Right Ventricular diastolic dysfunction in heart failure. Circulation 1996; 93: 1509- 1514.

19. Bolca O, Hobikoglue G, Norgaz T, Asilturk R, Unal S, Gurkan U, et al. The prediction of pulmonary artery systolic pressure and vascular resistance by using tricuspid annular tissue Doppler imaging. Anadolu kardiyol Derg. 2002; 2 (4): 302-6.

20. Kaul S, Tei C, Hopkins JM, Shah PM . Assessment of right ventricular function using two-dimensional echocardiography. Am Heart J 1984;107:526-31.