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## RESEARCH ARTICLE

# ESTIMATION OF RIGHT VENTRICLE TO PULMONARY ARTERY PRESSURE GRADIENT IN PATIENTS SUBJECTED TO INTRACARDIAC REPAIR FOR TETRALOGY OF FALLOT – A COMPARISON OF ECHOCARDIOGRAPHIC METHODS VS DIRECT PRESSURE MEASUREMENT

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### ABSTRACT

**Background:** The tetralogy of Fallot (TOF) is surgically corrected by Intra Cardiac Repair which involves the resection of muscle bundles that obstruct the right ventricular outflow tract (RVOT) thus increasing the pulmonary blood flow. The most common problem following corrective surgery is residual RVOT obstruction. The aim of the study is to assess whether TEE can provide reliable estimate of the RVOT gradients in patients with TOF. **Methods** -60 patients who were scheduled for Intra Cardiac Repair for TOF were included in the study after obtaining informed and written consent. Study design-Prospective observational study. During the preoperative&postoperative phase, the RV-PA gradient was obtained from the ME ascending aortic short axis view ,UE aortic arch short axis view and the TG RV outflow view and the gradients so obtained were compared with the preoperative RV – PA gradient obtained by the surgeon using a needle-saline filled pressure transducer system. **Results**-Appropriate statistical analysis of the results revealed the following significant findings: ) TEE can provide reliable estimates of RVOT gradients in patients with TOF, especially in the post CPB period. ) In the pre CPB period, the intraoperatively measured highest echocardiography gradients showed a relatively weak correlation ( $R=.216$ ) when compared to the needle gradients. ) In the post CPB period, relatively strong correlation ( $R=.657$ ) was observed between the highest intraoperative echocardiography gradients and the needle gradients. All the individual TEE views had a clinical and statistical significant levels of correlation with the needle-saline-transducer gradient. **Conclusion:** The use of intraoperative TEE provides reliable estimates of the RVOT gradients in patients with TOF undergoing ICR in both pre and post CPB period. TEE can be recommended as a less invasive modality to measure the RVOT gradients with accuracy instead of the more invasive needle-saline-transducer gradient measurements.

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## INTRODUCTION

Tetralogy of Fallot is a complex cyanotic congenital cardiac lesion consisting of combination of four related cardiac anomaly that commonly occur together, they are an unrestrictive VSD, RVOT obstruction, right ventricular hypertrophy and overriding of the aorta (Lake, 2005). The main symptoms of this condition are shortness of breath and bluish discoloration of the skin which arises due to reduced pulmonary blood flow as a result of the right ventricular outflow tract obstruction. The tetralogy of Fallot (TOF) is surgically corrected by Intra Cardiac Repair which involves

the resection of muscle bundles that obstruct the right ventricular outflow tract (RVOT), thereby widening the RVOT and thus increasing the pulmonary blood flow (John, 1974). The most common problem following corrective surgery is Residual RVOT obstruction (Kaushal, 1999). The assessment of the adequacy of this resection is done by comparison of the pressure measurements taken by direct puncture of the right ventricle (RV) and the pulmonary artery (PA) after the surgical repair. The surgeon employs a hypodermic needle, the needle is first inserted into the RV, and then the same needle is inserted into the PA. These pressures are noted down and the difference is recorded as the RV-PA gradient. We hypothesize that TEE measurements can provide equally valid results as compared to needle transducer measured pressure gradients. For the purpose of the study, the TEE assessment of the RV-PA gradient was done through the

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ascending aortic short axis view, the aortic arch short axis view and the transgastric right ventricular outflow view. Correlations were calculated for the various echocardiography derived gradients and the needle gradients. Primary objectives of our study was to assess whether TEE can provide reliable estimate of the RVOT gradients in patients with TOF and compare the RVOT gradients obtained via TEE with preoperative needle-saline-transducer measured RVOT gradients in the preoperative phase and to compare the RVOT gradients obtained via TEE with needle-saline-transducer measured gradients in patients undergoing intracardiac repair for TOF in the post bypass phase after surgical correction. Secondary objectives of our study was to assess which is the TEE view that provides the most accurate estimate of RVOT gradient in patients with TOF. To assess whether there is any correlation between the level of obstruction in the RVOT and the TEE view which would aid us in reliably measuring the gradient at that particular level.

## MATERIALS AND METHODS

60 patients who were scheduled for elective total correction (Intra Cardiac Repair) for TOF were included in the study after obtaining informed and written consent as a prospective observational study.

**Inclusion Criteria:** Patients within the Age group-5 months - 50 years of both genders. Surgery-Intracardiac repair for the correction of TOF. Patients undergoing redo surgeries were included. No bias against caste, gender, ethnicity, race, class.

**Exclusion Criteria:** Weight less than 5 kg ,contraindications to TEE probe insertion, emergency surgery, patient with infective endocarditis or any evidence of infection, patients undergoing other concomitant cardiac procedures.

**Conduct of the Study:** Patients undergoing ICR for TOF who satisfied the inclusion – exclusion criteria were enrolled in the study. After induction of anesthesia according to a standardized institutional protocol and endotracheal intubation, TEE probe was inserted in all recruited patients. During the preoperative phase the RV-PA gradient was obtained from the midesophageal ascending aortic short axis view (Figure 1), upper oesophageal aortic arch short axis view and the transgastric RV outflow view and the gradients so obtained were compared with the preoperative RV – PA gradient obtained by the surgeon using a needle-saline filled pressure transducer system. This was repeated upon completion of the surgery and successful weaning off from cardiopulmonary bypass.



Figure 1. Midesophageal ascending aortic short axis view

**Data Collection:** Demographic Data including age, sex, weight, height and body surface area of all the participants were noted. Variables measured included inotropic support, preoperative TTE RVOT gradient, whether transannular patch repair was done/not, Doppler RVOT gradients as obtained via TEE, systemic hemodynamics at the time of documenting the RVOT gradient, RVOT gradient as obtained via a saline filled pressure transducer system, duration of aortic cross clamp and cardiopulmonary bypass, degree of pulmonary regurgitation.

## Statistical Analysis

As descriptive statistics, percentages for categorical variables and means (SD) for quantitative variables were presented. Associations between quantitative variables were assessed by Pearson's correlation coefficient. P values <0.5 were considered to conclude statistical significance.

## RESULTS

60 scheduled for elective intracardiac repair for TOF were included in this prospective observational study. Intraoperative demographic, hemodynamic as well as echocardiographic data were recorded as described in the Materials and Methods section

**Demographic Parameters:** Our study population has a total 60 patients, of which there were 34 males (56.6%) and 26 females (43.3%). The mean age and standard deviation of the study population was 13.89±8.9 years, the age distribution is between 4.10 - 48 years. The mean weight of the study population was 27.46±14.99kg, the range being 10 - 60 kg.

**Preoperative Echocardiography:** Diagnosis and level of obstruction in the RVOT - 83.6%patient of the study population were diagnosed with classic Tetralogy of Fallot whereas 8.2% of the patient had VSD,PS and 4.9% were diagnosed respectively with DORV, VSD, PS. 1.6% of the study population were diagnosed with TOF with PA and the rest 1.6% of the study were diagnosed as TOF with AV canal defect.

**Level of obstruction in the RVOT:** Isolated infundibular obstruction was the predominant cause of RVOT obstruction in the study population accounting for 49.2% of the study population followed by combined infundibular and valvar obstruction which constituted 27.9% of the study population

**Pre CPB echocardiographic data:** The mean RVOT gradients obtained from the ascending aortic short axis view, aortic arch short axis view, transgastric RV outflow view are tabulated in table 1. Preoperative needle method is also tabulated alongside for comparison. The overall correlation between the highest intraoperative echocardiographic gradient (which refers to the intraoperative echo gradient obtained either using any of the TEE views) in each case when compared to the pre operative TTE value revealed a correlation coefficient of 0.360 which shows a not so strong correlation. This value was found to be statistically significant with a p value of 0.004. However, the correlation coefficients for the individual TEE views when compared to the preoperative needle method value did not reveal a strong correlation, the individual correlation coefficients and their corresponding P values are tabulated in Table 1 .Another

notable fact is that in the pre CPB period, the UE aortic arch short axis view was reliably obtained in only 73% of patients and the transgastric RV outflow view was obtained in 77% of the patients, while the ME ascending aortic short axis view could be documented in 95.08% patients. When the highest preoperative TEE gradient (the value amongst the 3 TEE views which was the highest) was compared with preoperative needle method value, a correlation coefficient R of only 0.216 was obtained was compared with the preoperative needle method value. It was needle method which provided the highest preoperative echo gradient in 75% of the instances.

**Table 1.**

Correlations to preoperative needle method gradient		
PRE OP AA SAX	R	0.187
	P VALUE	0.161
	N	58
PRE OP ARCH SAX	R	0.115
	P VALUE	0.450
	N	45
PRE OP TG RV OUTFLOW	R	0.131
	P VALUE	0.381
	N	47
HIGHEST NEEDLE GRADIENT	R	0.216
	P VALUE	0.097
	N	60

**Post CPB echocardiographic data:** In the post CPB period, RVOT gradients measured using TEE in the ascending aortic short axis view, upper oesophageal aortic arch short axis view and the transgastric RV outflow view are tabulated in table 2. RVOT gradients derived using a needle-saline-transducer system are also tabulated.

**Table 2.**

Echo view	N	Minimum	Maximum	Mean	Std deviation
Pre op needle gradient	60	1	75	21.03	16.06
AA SAX	59	6	94	26.28	19.43
ARCH SAX	49	4	71	23.64	15.26
TGRV OUTFLOW	54	4	590	20.79	14.37

**Table 3.**

Correlations to postoperative needle method gradient		
PRE OP AA SAX	R	0.577
	P VALUE	<0.001
	N	59
PRE OP ARCH SAX	R	0.583
	P VALUE	<0.001
	N	48
PRE OP TG RV OUTFLOW	R	0.620
	P VALUE	<0.001
	N	54
HIGHEST NEEDLE GRADIENT	R	0.657
	P VALUE	<0.001
	N	60

When the highest of all the echocardiography gradients (3 TEE views) was compared to the needle-saline-transducer derived RVOT gradient, a correlation coefficient of 0.657 was obtained which reflects a moderately strong correlation between these two. This was found to be statistically significant with a p value of <0.001. When individual echocardiography views were compared to the needle derived gradient, a statistically significant correlation was found between all the views in predicting the true RVOT gradient, with the highest correlation being for transgastric RV outflow

view (pearson's correlation coefficient of 0.620) followed by ascending aortic short axis view had the least correlation coefficient (0.577) and the upper esophagus aortic short axis view had a correlation coefficient of (0.583). The highest post-operative TEE gradient used for comparison to the needle gradient, a correlation of 0.657. These are tabulated in table 3.

## DISCUSSION

TOF is the most common complex congenital cyanotic cardiac defect in the infant and older children. The preferred surgical procedure for Tetralogy of Fallot is intracardiac repair. In the pre CPB period, TEE aids in confirming the preoperative TTE diagnosis and helps to gather additional information that might have been missed in the preoperative TTE exam. During initiation of CPB, TEE also aids in confirming the placement of venous cannula and LV venting devices. The major role of intraoperative TEE, is however in the post CPB period, where it helps in identifying the presence of any residual lesions which might mandate a return to CPB. Joyce et al (2000) firmly established the accuracy of intraoperative TEE findings with the help of TTE which was done 6 days post repair and concluded that intraoperative TEE predicts the degree of residual RVOT obstruction, degree of PR and the presence of additional VSDs reliably. Identification of residual RVOT gradients in the immediate post CPB period is great significance since it provides a window of opportunity for immediate revision, thus avoiding the added morbidity and costs associated with a redo surgery. In the pre CPB period, computation of the RVOT gradient begins to have importance as this is the lesion which determines the amount of right to left shunt across the VSD and thus, the systemic saturation. In the post CPB period, assessment of the residual RVOT gradient helps to decide on the adequacy of surgical resection and to determine the need for an intervention.

In the pre CPB period, the observed correlation between intraoperative echocardiography and preoperative TTE was relatively low ( $r=0.360$ ). This can possibly be due to the fact that anesthetic induction produces changes in the preload of the heart as well as a fall in SVR, thus influencing the measured RVOT gradients. This is also because the gradients across the RVOT are dependent on the RV pressures which reflects the systemic pressures which in turn is dependent on the systemic vascular resistance. Also, the intraoperative manipulation of the heart is well known for precipitating a hypercyanotic spell. The pulmonary vascular resistance also influence the assessment of RVOT gradients: the higher the PVR, the lower will be the measured gradients. This problem is more common in those infants whose PVR has not fallen to normal levels after birth. In our study the mean systolic RV pressure observed was 52.77 mm Hg and the mean sPAP was 32.02mm Hg. Another important finding is that the RVEDP measured a mean of 11.64 mm Hg in the above study population, which is slightly higher than the normal range of 1-7 mm Hg, suggesting reduced compliance and diastolic dysfunction of the RV in these patients. PV incompetence, although not severe in any patient, could also have contributed to the increase in RVEDP. An elevated RVEDP as defined by a value of 10mm Hg or above was noted in 65% of our study population. Another interesting observation in the present cohort of patients was that 14 out of the 61 patients (22.9%) included in this study had a sPAP 40 mm Hg, out of which one patient had PAP more than 2/3<sup>rd</sup> of the systemic pressure.

High PA pressures have been reported only rarely after TOF. Pressure ratios of 0.7-0.85 between RV/LV are common in the immediate postoperative phase after TOF correction. Since the obstruction between the RV and PA has been removed surgically, these elevated RV pressures would reflect as elevated PA pressures. The other possible reasons for elevated PA pressures in the post CPB period could be due to reduced LV compliance, presence of systemic-pulmonary collaterals and unrecognized branch/peripheral pulmonary stenosis. In our study there was a moderately strong positive correlation (Pearson correlation coefficient of 0.657) between the intraoperative TEE derived RVOT gradients and the needle gradients in the post CPB period. Milrinone has been implicated as a cause for incorrect estimation of the RVOT gradients perioperatively. Since Milrinone was the predominant inotropic agent used in our study population, being used in almost 98% of the patients, both as a sole agent and in conjunction with other agents, some amount of dynamic RVOT obstruction could also have played a major role in our subset of patients. Indeed, the typical dagger shaped spectral Doppler profile was observed in most of the patients in the post CPB period, in the transgastric RV outflow view which profiles the infundibulum the best. It was observed in our study that significant branch PA stenosis as a cause of marked outflow tract obstruction in 3 patients. In all three patient significant branch stenosis was identified with the help of intraoperative TEE. The ascending aortic short axis view consistently showed high gradients in these 3 cases, whereas the other 2 views showed acceptable values. The needle-saline transducer gradients too did not show significance initially in these patients when the RV pressures were compared to the MPA pressures. However, when the measurements were repeated with the pressures in the branch PAs, the true gradient was revealed. In our study, we could not obtain RVOT gradients in many patients using all the TEE views. However, the best TEE gradient was used for comparison, a significant degree of positive correlation was obtained. A correlation has been observed between the appearance of antegrade diastolic flow in the pulmonary artery post corrective surgery, suggestive of restrictive RV diastology, and the use of a transannular patch. In our study, the use of transannular patch was relatively high at 44.3%. Attempts to minimize the grade of pulmonary regurgitation is important goal in the surgical technique for TOF. In our Institution, we routinely fashion a monocusp valve out of PTFE membrane that prevents severe grades of PR in the immediate postoperative period, whenever the pulmonary annulus integrity is breached. Although long term results using a monocusp valve have not been encouraging, it definitely helps to tide over the immediate postoperative period without the added burden of volume overloading of the RV. None of the patients in the study had severe grades of PR.

This study provides good evidence that intraoperative TEE is a good monitoring tool in the armamentarium of the perioperative physician caring for the surgical patient with TOF. Since the gradients in the RVOT as measured by TEE were found to correlate well with the observed needle gradients, we can safely conclude that TEE measured RVOT gradients be used routinely in lieu of the more invasive needle-saline-transducer systems. In addition to providing important insights to patient management in terms of fluid management and inotropic support and diagnosis of other residual lesions, TEE has a major role in predicting the residual RVOT gradients, its nature: whether fixed or dynamic, and the level

in the RVOT where the obstruction predominantly is, and thus helps to decide whether a re-intervention is required in an individual patient or not. TEE can provide reliable estimates of RVOT gradients in patients with TOF, especially in the post CPB period.

## Conclusion

In the pre CPB period, the intraoperatively measured echocardiography gradients showed a relatively weak correlation when compared to the needle gradients whereas In the post CPB period, relatively strong correlation was observed between the intraoperative echocardiography gradients and the needle gradients. It was observed that the infundibulum could be best viewed in the transgastric right ventricular outflow tract view; the MPA, RPA and occasionally the LPA aligned best in the ascending aortic short axis view and the pulmonary valve was best seen and aligned in the upper oesophageal aortic arch short axis view. This finding underlines the importance of performing a comprehensive TEE exam in all cases of TOF wherein multiple levels of RVOT obstruction is possible.

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**Conflict of Interest:** None

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