ORIGINAL ARTICLE

CORRELATION BETWEEN INTRAOPERATIVE DIRECT AND TRANSESOPHAGEAL ECHOCARDIOGRAPHIC ASSESSMENT OF RIGHT VENTRICULAR OUTFLOW TRACT PRESSURE GRADIENT IN PATIENTS UNDERGOING TETRALOGY OF FALLOT REPAIR

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Objectives: The objective of this study was to determine the correlation between intraoperative direct (needle) and transesophageal echocardiographic (TEE) assessment of right ventricular outflow tract (RVOT) pressure gradient in patients undergoing Tetralogy of Fallot (TOF) repair.

Methodology: A total of 100 patients underwent for TOF repair were included. After completion of surgery and successful weaning from cardiopulmonary bypass, the TEE derived RVOT gradients were obtained from, the midesophageal ascending aortic short axis (AA Sax) view, upper esophageal aortic arch short axis (Arch Sax) view and trans-gastric RV outflow (TG RV outflow) view. Direct (needle) derived pressures from right ventricular (RV) and pulmonary artery (PA) were obtained by surgeon using a saline filled pressure transducer system. Correlation coefficient was computed between intraoperative direct and TEE assessment of RVOT gradient was evaluated.

Results: In the sample of 100 patients, 41% were females and median age was 8 [5-11] years. The TEE derived RVOT gradients obtained in AA Sax, Arch Sax and TG RV outflow view were 26.46±6.98, 26.60±6.55, and 22.64±6.21 mmHg, respectively. Intraoperative RVOT pressure gradient was 19.05±8.9 mmHg. The correlation between intraoperative direct (needle) and TEE assessment of RVOT pressure gradient obtained in AA Sax, Arch Sax, and TG RV outflow view were 0.588 ($p<0.001$), 0.283 ($p<0.001$), and 0.383 ($p<0.001$), respectively.

Conclusion: Intraoperative TEE assessment of RVOT pressure gradient showed a moderate correlation with the direct (needle) assessment. The ascending aorta short axis view was found to be the superior esophageal view.

Keywords: Tetralogy of Fallot, TOF, transesophageal echocardiography, RVOT gradient

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INTRODUCTION

The Tetralogy of Fallot (TOF) is reported to occur in about 0.23 to 0.63 cases per thousand live births and it has been observed to be one of the commonly found cyanotic congenital heart defect (CHD) accounting for 7 to 10% of the CHD cases and nearly 1/3rd of CHDs cases in patients younger than 15 years of age.[1-4] The TOF has been reported to prevalent in one in 3.5 to 4.3 thousands of adult population.[4] It commonly affects both genders equally at it is found to be nonfamilial and sporadic, however, it has been reported in 1-5% of siblings of the affected parents.

The pathology of TOF is the "malaligned conal septum" which causes obstruction and narrowing of right ventricular outflow tract (RVOT), primarily in the infundibular region. Clinically it can be characterized by the RVOT obstruction, right ventricular hypertrophy, overriding of aorta, and large ventricular septal defect (VSD).[3-5] Conventionally, RV incision was preferred for the repair of TOF, it provide good exposure for relief of RVOT as well as VSD closure.[4,6] Recent advancements operative management, pre- and post-operative care, and anesthetic agents have enabled an early primary repair of TOF.[3] In the early years of 90s decade, the transatrial/transpulmonary approach was preferred for the TOF repair due to its added advantage in

preservation of pulmonic valve and circumventing the right ventricular (RV) functional impairment due to ventriculotomy as well as avoiding the deleterious long-term effects of the transannular patch.[7,8] However, unacceptably high rates of post-operative morbidities due to a residual RVOT obstruction remained the key limitations of these surgical techniques.[9] The optimal TOF repair depends on the adequate relief of RVOT obstruction along with minimum impairment of pulmonic valve.

An incomplete surgical resection can result in either fixed or dynamic RVOT obstruction which are characterized by either "no change in RVOT dimensions during the cardiac cycle" or a significant increase in RVOT dimensions during diastole.[9] The residual RVOT obstruction has significant detrimental effects on diastolic and systolic functions of RV which increases the risk ventricular arrhythmias significantly in these patients.[10] Hence, assessment of intraoperative RVOT gradient can provide important prognostic information. Generally, the assessment of intraoperative RVOT gradient can be done directly by the surgeon (needle) or through transesophageal echocardiography (TEE).[9]

The intraoperative TEE is a useful diagnostic tool as well and monitoring tool during TOF repair in both pediatric and adult patients.[11-13] It can provide useful assessment of anatomical alterations as well as qualitative functionality of RVOT in addition to the assessment of residual RVOT obstruction.[14,15] A strong positive relationship has been reported between the TEE assessment and direct (needle) assessment of RVOT gradient in post-operative patients of TOF.[16] However, data from the developing world on the hemodynamic accuracy of intraoperative TEE to obtain residual RVOT obstruction in patients of TOF repair is scarce.

Therefore, we planned this study to determine the precision of intraoperative TEE as a noninvasive modality to measure RVOT gradient in comparison to the more invasive direct (needle) RVOT gradient measurement in patients of TOF repair. This study will not only aid in the limited pool of information, regarding the accuracy of intraoperative TEE in immediate identification of residual RVOT obstruction in patients of TOF repair. This will also help in precise measurement of residual RVOT pressure gradient to support the post bypass decision making of surgeons for the need of an instant revision, thus to avoid high post-operative mortality and rate of reoperations.

METHODOLOGY

This cross-sectional study was conducted at the department of paediatric cardiology, National Institute of Cardiovascular Diseases (NICVD), Karachi, Pakistan between the study duration of six months from September 17, 2020 to March 16, 2021. Study was approved by the institutional ethical review committee and written consent was obtained either from patient or parents/legal caretaker of the patients for under aged (< 18 years) patients.

For this study a sample of consecutive patients undergoing TOF repair were included who have full filled the inclusion criteria; either gender, age between 5 months to 30 years, and undergoing TOF repair. Specific exclusion criteria included; non-consenting patients, patients with weight <5 kg, patients with contraindications to the use of TEE probe, patients with esophageal stricture, esophageal spasm, esophageal laceration, esophageal diverticula, and/or esophageal perforation, patients with significant dysphagia, upper gastrointestinal bleeding, and/or odynophagia, patient who received extensive radiation to the mediastinum, patients with large diaphragmatic hernia, atlantoaxial disease, patients with infective endocarditis or any evidence of infection, and cases undergoing other concomitant cardiac procedures were also excluded.

Data for this study were collected on a pre-defined structured proforma. Demographic characteristics was recorded such as age (years), gender, weight (kg), height (cm), and body surface area (BSA).

Pre-operative transthoracic echocardiographic (TTE) was performed in all patients and primary diagnosis, preoperative RVOT gradient and level of obstruction was recorded in the proforma. A TEE probe was inserted after induction of anesthesia and endotracheal intubation and keep in position during the surgery, for intra operative study. All the TOF repair surgeries were performed by consultant as per the routine clinical practice and hospital policies. The intraoperative direct (needle) derived pressures from right ventricular (RV) and pulmonary artery (PA) were obtained by surgeon using a saline filled pressure transducer system.[16] The direct (needle) derived RVOT pressure gradients was calculated as; direct RVOT gradient = [right ventricular systolic blood pressure (RVSBP) – systolic pulmonary artery pressure (sPAP)].

At the end of surgery and after the successful weaning from cardiopulmonary bypass, the TEE derived RVOT gradients obtained on multiple views, which

included the midesophageal ascending aortic short axis (AA Sax) view, upper esophageal aortic arch short axis (Arch Sax) view and trans-gastric RV outflow (TG RV outflow) view using the ultrasound system IE 33 (Philips medical systems) with TEE probes according to the age group of all patients and RVOT gradients were obtained by standard views according to American Society of Echocardiography Guidelines.[17]

A sample size of 27 patients was calculated considering the correlation value between needle and the intra operative AA sax echocardiographic RVOT gradients measurement as 0.584, power of test =90% and confidence level 95%. However, he researcher decided to include 100 patients in this study to achieve more statistical power in the estimation. Patients' data were compiled and analyzed with the help of IBM SPSS version 21.

Mean ± standard deviation (SD) or median [interquartile range (IQR)] were calculated for quantitative variables e.g. age, height, weight, BSA, pre-operative transthoracic echocardiographic RVOT gradient, intraoperative TEE derived AA sax, Arch sax, and TG RVOT gradients), Direct (needle) derived RV and PA pressure and post bypass parameters (include hemodynamic variables, cardiopulmonary bypass, and aorta cross clamp duration). Frequency and percentage was computed for qualitative variables. Pearson correlation coefficient (r) was computed between the intraoperative direct (needle) and TEE assessment of RVOT pressure gradient and for the assessment of agreement between the two measurements, the Bland-Altman plot was obtained along with the estimated limits of agreement.

RESULTS

In the sample of 100 patients, 41% were females and median age was 8 [5-11] years. Preoperatively, all the patients were diagnosed with classic TOF characterized by large ventricular septal defect (VSD), right ventricular hypertrophy, RVOT obstruction, and overriding of aorta. Mean preoperative TTE derived RVOT gradient was 73.3 ± 26.20 mmHg. The most common level of RVOTO was valvular + infundibular shown in graph below. Half (50) of the study population required transannular patch (TAP) technique for the relief of right ventricular outflow tract obstruction (RVOTO) whereas 50 patients were repaired with pulmonic valve sparing technique. The intraoperative TEE derived RVOT gradients obtained in AA Sax, Arch Sax, and TG RV outflow view were 26.46 ± 6.98, 26.60 ± 6.55, and 22.64 ± 6.21 mmHg, respectively. Intraoperative direct RVOT gradient was 19.05 ± 8.9 mmHg (Table 1).

Table 1: Pre-operative and intraoperative parameters of the patients undergoing TOF repair

	Total
Total (N)	**100**
Gender	
Male	59 (59%)
Female	41 (41%)
Age (years)	8 [5-11]
≤ 5 years	26 (26%)
6-17 years	67 (67%)
≥ 18 years	7 (7%)
Body mass index (kg/m^2)	14.3 ± 6.6
Body surface area (m^2)	0.8 ± 0.2
Level of RVOT obstruction	
Valvar + Infundibular	92 (92%)
Valvar + Infundibular + supravalvular	8 (8%)
Intraoperative TEE driven RVOT gradient (mmHg)	
AA Sax RVOT gradient	26.46 ± 6.98
Aortic arch sax RVOT gradient	26.60 ± 6.55
TG RV outflow gradient	22.64 ± 6.21
Intraoperative direct (needle) driven parameters	
Right ventricular systolic blood pressure (mmHg)	47.6 ± 11
Right ventricular end-diastolic pressure (mmHg)	9 ± 4.6
Systolic PAP (mmHg)	28.5 ± 11.4
Diastolic PAP (mmHg)	9.5 ± 4
Mean PAP (mmHg)	14.9 ± 8.1
RVOT gradient (mmHg)	19.1 ± 8.9
Intraoperative off bypass hemodynamic parameters	
Heart rate (bpm)	118.5 ± 14.4
Systolic blood pressure (mmHg)	81.8 ± 13.8
Diastolic blood pressure (mmHg)	46.7 ± 9.4
Mean arterial pressure (mmHg)	58.7 ± 6.6
Central venous pressure (mmHg)	5.7 ± 3.3
Arterial SaO2 (mmHg)	98 ± 6.7
FiO2 (%)	100.3 ± 1.7
End tidal CO2 (mmHg)	30 ± 6.7
Cardiopulmonary bypass duration (min)	74.1 ± 34.1
Aorta cross clamp duration (min)	45.5 ± 18.6
Right ventricular pressure to systemic pressure ratio (%)	59.9 ± 18.6%

RVOT: right ventricular outflow tract, AA Sax: midesophageal ascending aortic short axis view, Arch Sax: upper esophageal aortic arch short axis view, TG RV: trans-gastric RV, TEE: transesophageal echocardiographic, PAP: pulmonary artery pressure

TEE derived RVOT gradients on AA Sax view were 27.6±7.2 vs. 25.2±6.6 mmHg; p=0.088, on Arch Sax view were 26.8±6.6 vs. 26.4±6.5 mmHg; p=0.753, and TG RV outflow view were 22.7±6.7 vs. 22.6±5.7 mmHg; p=0.94 for the patients who required TAP technique versus patients who were repaired with pulmonic valve sparing technique, respectively. Similarly, the intraoperative RVOT gradients were 21.5±8.4 vs. 16.5±8.7 mmHg; p=0.005 for the patients

who required TAP technique versus who patients were repaired with pulmonic valve sparing technique, respectively.

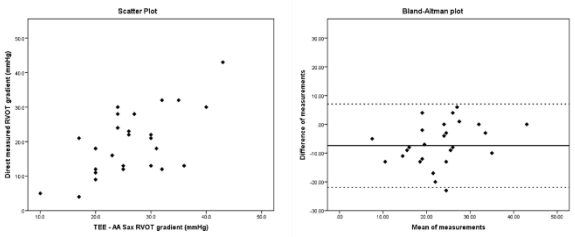

Figure 1: Scatter plot and Bland-Altman plots between the intraoperative RVOT pressure gradient measured directly (needle) and through TEE in AA Sax view

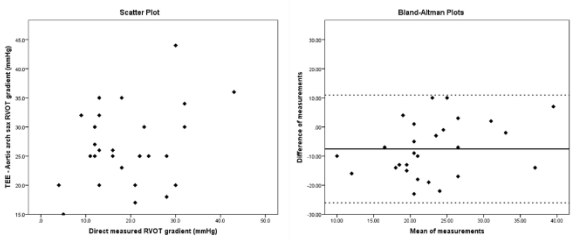

Figure 2: Scatter plot and Bland-Altman plots between the intraoperative RVOT pressure gradient measured directly (needle) and through TEE in Aortic arch sax view

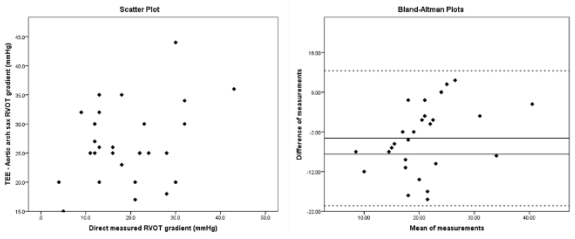

Figure 3: Scatter plot and Bland-Altman plots between the intraoperative RVOT pressure gradient measured directly (needle) and through TEE in TG RV outflow view

The correlation between intraoperative direct (needle) and TEE assessment of RVOT pressure gradient obtained in AA Sax, Arch Sax, and TG RV outflow view were 0.588 (p<0.001), 0.283 (p<0.001), and 0.383 (p<0.001), respectively. The Bland-Altman plot for the assessment of agreement between the measurement of intraoperative RVOT pressure gradient through direct and different views of TEE are presented in Figure 1 through Figure 3. The mean differences and 95% agreement limits (AL) between the direct and TEE measurement were found to be -7.41 [95% AL:-21.9 to 7.08], -7.55 [95% AL:-26.03 to 10.93], and -3.59 [95% AL:-20.59 to 13.41] through in AA Sax, Arch Sax, and TG RV outflow view, respectively.

DISCUSSION

The Intra Cardiac Repair (ICR) is the preferred surgical procedure for the TOF repair in the early years of the patient with primary aim to improve pulmonary blood flow by resection of muscle bundles obstructing the RVOT.[17,18] The residual RVOT obstruction remained one of the main limitation of surgical repair of TOF. Hence in this series of 100 patients of TOF repair our aim was to evaluate the correlation between intraoperative direct (needle) and TEE assessment of RVOT pressure gradient. We have observed moderate correlation between the two assessments with the best figures achieved from the ascending aorta short axis view correlation coefficient of 0.588 (p<0.001) and mean differences and 95% AL of -7.41 [95% AL:-21.9 to 7.08]. It is apparently clear that regardless of the view, TEE tends to overestimate the RVOT pressure gradients.

A similar observation was made by the Silvilairat et al.[19] and the possible mechanism for the overestimation was explained as; in the direct (invasive) assessment the pulmonary artery systolic pressure do not strike at the same point as RV systolic pressure, while, TEE measures maximum instantaneous pressure gradient across RVOT simultaneously. A study conducted by Ronakh R et al.[20] had a similar observations as ours that there was a weak correlation (r=0.216) between needle gradients and TEE gradient. However, moderate (r=0.657) correlation was observed between needle gradients and TEE gradient pot cardiopulmonary bypass time. In a study conducted by Borodinova O et al.[21], it has been observed that the RVOT gradient reduced significantly over a one month period after TOF repair. Another study by Toshkhani D et al.[18] also reported a significant reduction in postoperative RVOT gradient in comparison to the intraoperative RVOT gradient. Additionally, the death of anesthesia was not found to be associated with the alternations in the postoperative RVOT gradient. In the pediatric patients, the RV restrictive physiology after repair of TOF were reported to be associated with longer aortic cross clamping time, longer cardiopulmonary bypass time, lower systolic pulmonary artery pressure (PASP), lower TAPSE, hypertrophy, lower SP02, transannular patch repair, and lower TAPSE/PASP ratio.[22] Tan C et al.[23] conducted a study 342 patients undergoing TOF repair, post repair gradient was found to be >36 mmHg in a 37% of the patients with about moderate

obstruction in 22% and at a median follow-up of 2 years, 14% were found to have recurrent obstruction.

Even though, we have very limited data available regarding the correlation between direct and TEE assessment of intraoperative RVOT gradient. The singe center coverage and limited sample size remains the mail limitation in the generalization study findings.

CONCLUSION

Intraoperative TEE assessment of RVOT pressure gradient showed a moderate correlation with the direct (needle) assessment. The ascending aorta short axis view was found to be the superior esophageal view. This finding underlines the importance of performing a comprehensive off bypass intraoperative TEE study to assess the multiple levels of RVOT obstruction, in all cases of TOF repair.

AUTHORS' CONTRIBUTION

FA and ASS: Concept and design, data acquisition, interpretation, drafting, final approval, and agree to be accountable for all aspects of the work. SKB, AK, NR, MUR, and NP: Data acquisition, interpretation, drafting, final approval and agree to be accountable for all aspects of the work.

Conflict of interest: Authors declared no conflict of interest.

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