

# Comparison of right ventricular outflow tract gradient under anesthesia with post-operative gradient in patients undergoing tetralogy of Fallot repair

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## ABSTRACT

- Background** : Intra-cardiac repair for tetralogy of Fallot has some degree of residual right ventricular outflow tract (RVOT) obstruction. However, the measurement of this gradient intra-operatively might get affected by the depth of anesthesia which is important for the long-term outcome.
- Aims** : The primary aim was to compare intraoperative RVOT gradient post repair under two different anesthetic depths of 1% and 2% end-tidal sevoflurane. The secondary objective was to follow up the changes in RVOT gradient till 1 month postoperatively.
- Design** : Observational study.
- Setting** : Advanced Cardiac Centre of PGIMER, Chandigarh.
- Methods** : Following intracardiac repair, RVOT gradient was measured directly by placing needle into the right ventricle and pulmonary artery at sevoflurane 1%, and subsequently, at 2% end-tidal concentration while maintaining hemodynamic stability. These gradients were also measured using transesophageal echocardiography (TEE) (ClinicalTrials.gov NCT03234582).
- Results** : Twenty-one patients were included in this study that had intra-cardiac repair, of which pulmonary annulus was preserved for 15 cases. Mean RVOT gradients measured invasively and by TEE at end-tidal sevoflurane concentration of 1% and 2% were not significantly different ( $6.67 \pm 4.16$  mmHg vs.  $6.76 \pm 3.82$  mmHg,  $P > 0.05$  invasively and  $13.01 \pm 7.40$  mmHg vs.  $12.53 \pm 7.11$  mmHg,  $P > 0.05$  by TEE, respectively). RVOT gradient measured by trans-thoracic echocardiography (TTE) postoperatively at the time of extubation and during follow-up at 1 month showed significant reduction ( $11.37 \pm 6.00$  mmHg,  $P < 0.05$  and  $9.23 \pm 4.92$  mmHg,  $P < 0.01$  respectively). Six patients who underwent repair with transannular patch had significant pulmonary regurgitation (PR) following surgery, with no significant change in PR severity or RVOT gradient on increasing anesthetic depth.
- Conclusions** : Postoperative RVOT gradient was not altered by changing depth of anesthesia provided systemic blood pressure was maintained. One month postrepair RVOT gradients were significantly reduced as compared to the intraoperative values.
- Keywords** : Anesthetic depth, right ventricular outflow tract gradient, tetralogy of Fallot

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## INTRODUCTION

Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart defect, affecting 3% to 10% of all babies born with congenital heart disease.<sup>[1,2]</sup> Following TOF repair, some degree of residual right ventricular outflow tract (RVOT) obstruction, either fixed or dynamic, is common.<sup>[3]</sup> The obstruction is “fixed” if it does not change in dimensions during the cardiac cycle and tends to worsen over time leading to surgical revision. The “dynamic” obstruction appears diffuse and decreases over time due to RVOT remodelling. Such dynamic obstruction worsens with increased inotropy of the heart, does not need surgical revision, and does not affect early postoperative outcome.<sup>[4]</sup>

There are few studies which attest to the fact that high intraoperative RVOT gradient due to dynamic obstruction decreases significantly in the majority of the TOF patients over time.<sup>[3-5]</sup> However, it does remain high or may become higher after repair in some patients after repair, necessitating reoperation. It is possible that in these cases, the amount of resection for RVOT muscles could have been inadequate, but there was no way to confirm this impression in the past.<sup>[6]</sup>

The question of debate is whether the measurement of RVOT gradient is affected by the depth of anesthesia or not, since the measurement of this gradient under anesthesia may be different from the actual residual gradient because of the effect of the anesthetic drugs. There is a paucity of literature to address this issue, which is important for the long-term outcome of TOF repair. We hypothesized that increasing the depth of anesthesia would be associated with fall in RVOT gradient.

The primary objective of the study was to compare intraoperative post TOF repair RVOT gradient under two different anesthetic depths of 1% end-tidal sevoflurane and 2% end-tidal sevoflurane. The secondary objectives were to follow up the changes in RVOT gradient and right ventricle (RV) functions till 1-month postoperatively, observe the extubation time, assess the inotropes use postoperatively by vasoactive-inotropic score (VIS).<sup>[7]</sup>

## METHODS

After approval from the Institute’s Ethical Committee and written informed consent from the guardians of the children, this prospective open-label observational study was conducted in the Advanced Cardiac Center of Postgraduate Institute of Medical Education and Research, Chandigarh, India, from July 2017 to August 2018. Children between 6 months to 16 years of age undergoing TOF repair were included in the study. TOF patients with pulmonary atresia, atrioventricular canal

defects, and where consent was refused were excluded from the study.

### Anesthesia technique

All the patients were evaluated a day before surgery, and their demographic data were recorded. Oral midazolam 0.5 mg/kg with honey was given as premedication under supervision to small children. After shifting the patient to operation theater, standard monitoring with electrocardiogram, pulse oxymetry (Saturation of oxygen in blood [SpO<sub>2</sub>]), and non-invasive blood pressure were done. Induction of anesthesia was done with sevoflurane inhalation in 100% oxygen and post-induction intravenous access was secured. Invasive blood pressure (IBP), central venous pressure, nasopharyngeal temperature, end-tidal carbon dioxide concentration (EtCO<sub>2</sub>), and end-tidal inhalational agent concentration monitoring were instituted after induction. Fentanyl 2 µg/kg was given for analgesia, and intravenous vecuronium 0.1 mg/kg was given for muscle relaxation in all the children. Intubation was done with appropriate size polyvinylchloride endotracheal tube following which pediatric transesophageal echocardiography (TEE) probe was inserted. Standard TEE imaging was acquired as per the American Society of Echocardiography guidelines. Postintubation low flow anesthesia was given with sevoflurane 1.5%–2% end-tidal concentration in 50% oxygen while maintaining normocarbia (PaCO<sub>2</sub> – 35–40 mmHg) till institution of cardiopulmonary bypass (CPB). On bypass, isoflurane 1%–1.5% was used and supplemental analgesia with fentanyl 1 µg/kg was given 2 hourly. Normothermic (temperature >35°C) or mild hypothermic bypass (temperature 32°C–34°C) was used depending on the surgical field requirement. Minimal hemoglobin targets on bypass were 9–10 g/dl and 10–11 g/dl post bypass.

After repair, all the patients were assessed by TEE for adequacy of repair and separated from the CPB using vasopressors and inotropes. Postbypass sevoflurane 1% end-tidal concentration (0.5 minimum alveolar concentration [MAC]) was used in all the patients. RV pressure and gradients across RVOT (mean) were measured directly by placing a 23 gauge needle into the RV and pulmonary artery, and also by TEE using Bernoulli’s equation by placing continuous Doppler across tricuspid regurgitation jet and RVOT along with hemodynamic parameters such as heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure, mean blood pressure (MBP), and SpO<sub>2</sub>. Subsequently, these measurements were repeated on sevoflurane 2% end-tidal concentration (1 MAC) after the patients were stabilized on this new concentration for 5 min while maintaining systemic pressure within a range of 10% of the previous value by the use of titrated small boluses of vasopressor (phenylphrine). Normocarbia was maintained during these measurements.

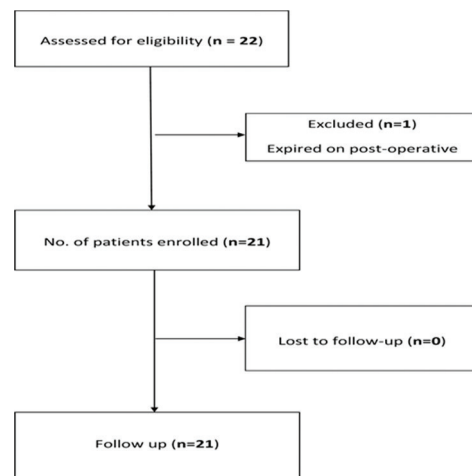
Following the surgery, all the patients were shifted to cardiothoracic intensive care unit (ICU) and extubated once they met the extubation criteria. Postoperative RVOT pressure gradient and RV functions were assessed by TTE at various time intervals: before extubation, 2 h post extubation, at discharge from ICU and after 1 month of surgery on follow-up visit. RV functions on echocardiography were assessed using tricuspid annular plane systolic excursion (TAPSE) and fractional RV area change (RVFAC). The degree of pulmonary regurgitation (PR), cardiac index, and LVEF were also noted. The severity of PR was graded based on the size of the regurgitant jet in relation to the RVOT diameter, with grade 1-no PR (no regurgitant jet); grade 2-mild PR (regurgitant jet  $<1/3^{\text{rd}}$  of RVOT diameter), grade 3-moderate PR (regurgitant jet  $1/3^{\text{rd}}$  to  $2/3^{\text{rd}}$  of RVOT diameter), and grade 4-severe PR (regurgitant jet  $>2/3^{\text{rd}}$  of RVOT diameter). The duration of mechanical ventilation, VIS, and any morbidity or adverse outcome during the hospital stay were also noted.

### Statistical analysis

Data analysis was performed using SPSS version 22 (IBM Corp, released 2013, IBM SPSS Statistics for Windows, Version 22.0, Armonk, NY). Continuous variables were expressed as mean  $\pm$  standard deviation or median with inter-quartile range (IQR). Categorical variables were described using the frequency distributions and presented as frequency (%). The same patients were analyzed repeatedly at baseline and post-operatively till 1 month which constitutes the longitudinal measurement of data. Kolmogorov-Smirnov one-sample and Shapiro-Wilk tests were used to assess the normality of distribution of continuous data. Baseline comparison of age, weight, height, Hb involved parametric *t*-test or its non-parametric counterpart "Mann-Whitney U-test. Mann-Kendall's trend test for linear trend was also estimated for serial measured values. Group analysis for hemodynamic parameters at various degree of PR was done using the paired *t*-test. All tests were two tailed with 95% confidence interval, and *P* value was considered statistically significant below 0.05 alpha levels.

## RESULTS

A total of 22 children were enrolled in the study. One of the patients died in the postoperative period, and his data were excluded from the study. Finally, data of 21 patients were analyzed [Figure 1]. All the participants were receiving oral beta-blocker therapy in the preoperative period. None of the patients included in the study had undergone any palliative shunt surgeries before corrective TOF repair. For majority of the patients in our study, the pulmonary annulus was preserved except in 6 patients who underwent intracardiac repair with transannular patch.



**Figure 1: Consort diagram of patients included in the study**

The baseline demographic and hemodynamic and echocardiographic parameters of the study population are presented in Tables 1 and 2, respectively.

### Intra-operative parameters

The mean dose of phenylephrine used was  $22.61 \pm 5.03 \mu\text{g}$  to keep SBP in the comparable range after increasing depth of anesthesia to end-tidal sevoflurane concentration of 2%. Under these conditions, the mean RVOT gradient by direct invasive measurement as well as by TEE at end-tidal sevoflurane 1% and 2% were not statistically significant ( $6.67 \pm 4.16 \text{ mmHg}$  vs.  $6.76 \pm 3.82 \text{ mmHg}$ ,  $P > 0.05$  by invasive measurement, and  $13.01 \pm 7.40 \text{ mmHg}$  vs.  $12.53 \pm 7.11 \text{ mmHg}$ ,  $P > 0.05$  by TEE, respectively) [Table 3].

All six patients who underwent transannular patch repair had moderate to severe degrees of PR in the intraoperative TEE. The severity of PR did not vary with increasing the anesthetic depth.

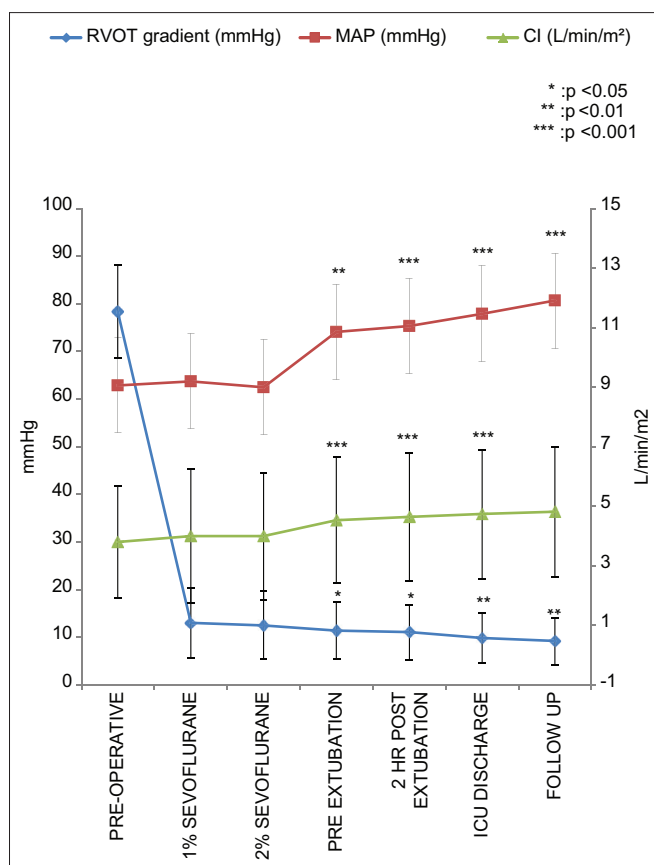
However, LVEF at end-tidal sevoflurane 1% was found significantly higher than at 2% end-tidal sevoflurane ( $53.57 \pm 3.88\%$  vs.  $52.57 \pm 3.88\%$ , respectively, with  $P < 0.05$ ). The distribution of severity of PR at 1% and 2% end-tidal sevoflurane remained same.

### Postcardiac repair parameters in the intensive care unit and after 1-month follow-up

After completion of surgery, all patients were initially shifted to ICU for postoperative mechanical ventilation.

The median (IQR) duration of mechanical ventilation was 11 hours (8–17 h), the median (IQR) duration of ICU stay was 4 days (3–5 days), and median (IQR) duration of hospital stay was 11 days (9.5–12.5 days), respectively.

Postcardiac repair significantly higher HR and systemic blood pressure values were recorded before extubation as compared to preoperative baseline and at post repair 1% end tidal sevoflurane ( $P < 0.05$ ) [Table 4 and Figure 2].



**Figure 2: Changes in mean arterial pressure, right ventricular outflow tract gradient (on Trans-esophageal echocardiography) and cardiac index at various time intervals**

The mean RVOT gradient measured postoperatively and during follow-up by transthoracic echocardiography showed significant reduction at the time of extubation from the intraoperative postcorrection values ( $13.01 \pm 7.40$  mmHg vs.  $11.37 \pm 6.00$  mmHg, respectively,  $P < 0.05$ ), and this continued to decrease significantly, reaching to  $9.23 \pm 4.92$  mmHg at 1-month follow-up ( $P < 0.01$ ) [Figure 2]. However, the severity of PR did not change significantly during the postoperative period. The cardiac index showed statistically significant improvement after surgical repair with passage of time up to 1-month follow-up as compared to immediately post repair values measured at end-tidal sevoflurane 1% intraoperatively ( $4.82 \pm 2.18$  L/min/m<sup>2</sup> vs.  $4.00 \pm 2.26$  L/min/m<sup>2</sup> respectively,  $P < 0.001$ ) [Figure 2]. The right ventricular functions (TAPSE and RVFAC) and LVEF did not show any significant change as compared to the intraoperative values during the study period. The inotropic support was significantly reduced by the time patients were extubated as compared to intraoperative value (VIS  $8.24 \pm 2.48$  vs.  $14.67 \pm 4.48$ , respectively,  $P < 0.001$ ), and all the patients were off inotropic support before they were discharged from the ICU.

**Table 1: Demographic and perioperative characteristics**

Variable	Value
Age (years)	7.19±5.00
Sex (%)	
Male	12 (57.2)
Female	9 (42.8)
Weight (kg)	17.75±9.70
Height (cm)	114.00±26.36
BSA (m <sup>2</sup> )	0.754±0.30
BMI (kg/m <sup>2</sup> )	12.80±1.87
Duration of CPB (min)	154.66±43.62
Duration of ACX (min)	115.76±36.81

Continuous variables are expressed as mean±SD and categorical variables as n (%). BSA: Body surface area, BMI: Body mass index, CPB: Cardiopulmonary bypass, ACX: Aortic-cross clamp, SD: Standard deviation

**Table 2: Preoperative hemodynamic and echocardiographic parameters**

Variable	Value
HR (beats/min)	113.52±9.44
SBP (mmHg)	82.33±14.41
DBP (mmHg)	52.4±9.09
MBP (mmHg)	64.80±9.53
Mean RVOT gradient (mmHg)	78.42±9.76
TAPSE (mm)	16.52±2.99
RVFAC (%)	45.87±5.24
LVEF (%)	55.38±2.88
CI (L/min/m <sup>2</sup> )	3.80±1.87
Hb (gm/dl)	17.88±4.22
Room air SpO <sub>2</sub> (%)	80.33±5.20

Continuous variables are expressed as mean±SD. HR: Heart rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MBP: Mean blood pressure, RVOT: Right ventricular outflow tract, TAPSE: Tricuspid annular plane systolic excursion, RVFAC: Right ventricular fractional area change, LVEF: Left ventricular ejection fraction, CI: Cardiac index, Hb: Hemoglobin, SpO<sub>2</sub>: Saturation of oxygen in blood, SD: Standard deviation

None of the patients had intraoperative RVOT gradient that exceeded 40 mmHg in the post-operative period, and none required reintervention in the follow-up period. Furthermore, the postoperative course in our patient was generally well tolerated with few complications (1 patient had junctional ectopic tachycardia and another one had pulmonary edema), and there was no mortality till 1-month post-operatively.

#### Data analysis based on post repair pulmonary regurgitation severity

On the basis of post repair PR severity, patients were divided into two groups for further analysis: group 1 with no to mild PR included 15 patients, and Group 2 with moderate-to-severe PR included 6 patients intra-operatively as well as till 2 h post-extubation.

At the time of discharge from ICU, one patient with no PR developed mild PR and another one with mild PR previously worsened to moderate PR (GROUP 1:  $n = 14$ , Group 2:  $n = 7$ ). Further during the follow-up visit after 1 month, one patient with no PR at time of ICU discharge



**Table 3: Comparison of hemodynamic and echocardiographic parameters at 1% sevoflurane with 2% sevoflurane**

Parameters	1% sevoflurane	2% sevoflurane	P
HR (beats/min)	114.81±14.74	114.71±13.87	0.765
SBP (mmHg)	82.95±15.32	82.62±14.54	0.808
DBP (mmHg)	50.57±12.43	49.90±10.87	0.213
MBP (mmHg)	63.76±12.55	62.52±11.53	0.135
SPAP (mmHg)	31.48±10.61	31.67±8.99	0.894
DPAP (mmHg)	11.86±5.50	11.67±5.01	0.710
MPAP (mmHg)	20.19±5.55	19.67±5.62	0.440
Invasive peak RVOT gradient (mmHg)	13.33±8.29	13.67±9.01	0.755
Invasive mean RVOT gradient (mmHg)	6.67±4.16	6.76±3.82	0.823
RVOT gradient on TEE (mmHg)	13.01±7.40	12.53±7.11	0.205
TAPSE (mm)	10.19±3.31	10.29±2.50	0.765
RVFAC (%)	47.88±6.24	47.16±4.79	0.462
LVEF (%)	53.57±3.92	52.57±3.84	0.019*
CI (L/min/m <sup>2</sup> )	4.00±2.26	4.00±2.13	0.967
PR grade (%)			
1	5 (23.8)	5 (23.8)	
2	10 (47.6)	10 (47.6)	
3	5 (23.8)	5 (23.8)	
4	1 (4.8)	1 (4.8)	
VIS	14.67±4.48	13.91±5.07	0.164

Continuous variables are expressed as mean±SD and categorical variables as n (%). HR: Heart rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MBP: Mean blood pressure, SPAP: Systolic pulmonary artery pressure, DPAP: Diastolic pulmonary artery pressure, MPAP: Mean pulmonary artery pressure, RVOT: Right ventricular outflow tract, TAPSE: Tricuspid annular plane systolic excursion, RVFAC: Right ventricular fractional area change, LVEF: Left ventricular ejection fraction, CI: Cardiac index, PR: Pulmonary regurgitation, VIS: Vasoactive inotropic score, SD: Standard deviation, TEE: Trans-esophageal echocardiography

**Table 4: Comparison of hemodynamic and echocardiographic parameters in intensive care unit and after 1 month**

Parameters	1% sevoflurane	2% sevoflurane	Preextubation	2 h postextubation	ICU discharge	Follow up 1 month
HR (beats/min)	114.81±14.74	114.71±13.87	122.76±16.95*	123.57±14.84*	111.95±14.84	109.38±14.80
SBP (mmHg)	82.95±15.32	82.62±14.54	96.86±12.01‡	96.38±11.02‡	101.24±10.56‡	104.29±8.99‡
DBP (mmHg)	50.57±12.43	49.90±10.87	62.62±8.02‡	62.48±6.85‡	63.76±6.30‡	66.38±5.76‡
MBP (mmHg)	63.76±12.55	62.52±11.53	74.14±8.54‡	75.38±8.20‡	77.95±7.21‡	80.67±6.57‡
RVOT gradient on TTE (mmHg)	13.01±7.40	12.53±7.11	11.37±6.00*	11.07±5.81*	9.82±5.34‡	9.23±4.92‡
TAPSE (mm)	10.19±3.31	10.30±2.50	10.31±2.20	10.43±2.17	9.77±3.49	11.06±2.38
RVFAC (%)	47.88±6.24	47.16±4.79	48.59±6.39	50.20±5.10	49.43±4.58	50.43±3.82
LVEF (%)	53.57±3.92	52.57±3.84*	53.83±3.31	53.90±3.83	54.21±2.81	54.75±2.96
CI (L/min/m <sup>2</sup> )	4.00±2.26	4.00±2.13	4.53±2.12‡	4.64±2.15‡	4.74±2.16‡	4.82±2.18‡
PR grade (%)						
1	5 (23.8)	5 (23.8)	5 (23.8)	5 (23.8)	4 (19.0)	3 (14.2)
2	10 (47.6)	10 (47.6)	10 (47.6)	10 (47.6)	10 (47.6)	10 (47.6)
3	5 (23.8)	5 (23.8)	5 (23.8)	5 (23.8)	6 (28.6)	7 (33.4)
4	1 (4.8)	1 (4.8)	1 (4.8)	1 (4.8)	1 (4.8)	1 (4.8)
VIS	14.64±4.48	13.91±5.07	9.51±2.94‡	8.24±2.48‡	0	0

Continuous variables are expressed as mean±SD and categorical variables as n (%). \*P<0.05, †P<0.01, ‡P<0.001 as compared to 1% sevoflurane. HR: Heart rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MBP: Mean blood pressure, RVOT: Right ventricular outflow tract, TAPSE: Tricuspid annular plane systolic excursion, RVFAC: Right ventricular fractional area change, LVEF: Left ventricular ejection fraction, CI: Cardiac index, PR: Pulmonary regurgitation, VIS: Vasoactive inotropic score, ICU: Intensive care unit, SD: Standard deviation, TEE: Trans-esophageal echocardiography

had mild PR and one patient with mild PR was diagnosed to have moderate PR (Group 1: n = 13, Group 2: n = 8).

Most of the echocardiographic and hemodynamic parameters remained comparable between these two groups at various time intervals during the study period except for TAPSE [Table 5]. RV functions, as assessed by TAPSE remained comparative in both the groups at all measurement time points except at the time of discharge from ICU when it was significantly lower in Group 2 as compared to Group 1 (7.42 ± 4.44 mm

vs. 10.94 ± 2.28 mm respectively, P < 0.05). At 1-month follow-up, TAPSE was less in Group 2 as compared to Group 1 but did not reach statistical significance.

The LVEF, CI, and RVOT gradient values were lower in Group 2 as compared to Group 1 at all-time intervals during the study period, but did not reach statistical significance.

The duration of mechanical ventilation was more in Group 2 as compared to Group 1 (24.17 ± 24.47 h vs.

**Table 5: Comparison of hemodynamic and echocardiographic parameters between the groups at various time intervals**

Parameter	Group	1% sevoflurane	2% sevoflurane	Preextubation	2 h postextubation	ICU discharge	Follow up
HR (beats/min)	1	112.40±14.93 (n=15)	112.93±14.53 (n=15)	121.80±19.76 (n=15)	122.80±14.97* (n=15)	108.86±15.08 (n=14)	106.92±17.20 (n=13)
	2	120.83±13.57 (n=6)	119.17±12.07 (n=6)	125.17±6.79 (n=6)	125.50±15.71 (n=6)	118.14±13.20 (n=7)	113.38±9.44* (n=8)
SBP (mmHg)	1	85.60±15.93 (n=15)	84.53±15.19 (n=15)	98.33±11.77 <sup>‡</sup> (n=15)	98.27±11.55 <sup>‡</sup> (n=15)	102.57±10.56 <sup>‡</sup> (n=14)	105.77±9.45 <sup>‡</sup> (n=13)
	2	76.33±12.42 (n=6)	77.83±12.67 (n=6)	93.17±12.89* (n=6)	91.67±8.66 (n=6)	98.57±10.84* (n=7)	101.88±8.18 <sup>‡</sup> (n=8)
DBP (mmHg)	1	52.13±13.03 (n=15)	51.53±11.23 (n=15)	63.73±6.89 <sup>‡</sup> (n=15)	63.73±6.91 <sup>‡</sup> (n=15)	65.00±5.15 <sup>‡</sup> (n=14)	66.69±5.58 <sup>‡</sup> (n=13)
	2	46.67±10.80 (n=6)	45.83±9.60 (n=6)	59.83±10.57 (n=6)	59.33±6.12* (n=6)	61.29±8.01* (n=7)	65.88±6.40 <sup>‡</sup> (n=8)
MBP (mmHg)	1	66.00±12.76 (n=15)	64.67±11.45 (n=15)	75.33±7.09 <sup>‡</sup> (n=15)	76.53±7.85 <sup>‡</sup> (n=15)	78.36±5.93 <sup>‡</sup> (n=14)	80.31±5.49 <sup>‡</sup> (n=13)
	2	58.17±11.01 (n=6)	57.17±10.79 (n=6)	71.17±11.62 (n=6)	72.50±9.09 (n=6)	77.14±9.80 <sup>‡</sup> (n=7)	81.25±8.43 <sup>‡</sup> (n=8)
Mean RVOT gradient (mmHg)	1	13.56±8.40 (n=15)	13.22±8.14 (n=15)	11.46±6.76* (n=15)	11.29±6.45* (n=15)	11.05±5.88* (n=14)	10.24±5.59* (n=13)
	2	11.63±4.28 (n=6)	10.81±3.38 (n=6)	11.15±4.02 (n=6)	10.51±4.26 (n=6)	7.37±3.09 (n=7)	7.58±3.27 (n=8)
TAPSE (mm)	1	10.04±3.55 (n=15)	10.47±2.80 (n=15)	10.33±2.37 (n=15)	10.49±2.42 (n=15)	10.94±2.28 (n=14)	11.71±2.15 (n=13)
	2	10.55±2.89 (n=6)	9.87±1.69 (n=6)	10.27±1.91 (n=6)	10.27±1.55 (n=6)	7.42±4.44§ (n=7)	10.00±2.53 (n=8)
RVFAC (%)	1	48.09±4.56 (n=15)	46.84±4.67 (n=15)	48.08±6.57 (n=15)	48.94±5.04 (n=15)	48.57±4.43 (n=14)	49.43±4.16 (n=13)
	2	47.34±9.86 (n=6)	47.96±5.45 (n=6)	49.86±6.30 (n=6)	53.35±4.04 (n=6)	51.15±4.70 (n=7)	52.06±2.67 (n=8)
LVEF (%)	1	53.65±4.23 (n=15)	52.65±4.15 (n=15)	53.83±3.63 (n=15)	54.62±4.24 (n=15)	54.86±3.18 (n=14)	55.42±3.18 (n=13)
	2	53.19±3.37 (n=6)	52.35±3.27 (n=6)	53.83±5.63 (n=6)	52.10±1.65 (n=6)	52.91±1.17 (n=7)	53.68±2.36 (n=8)
CI (L/min/m <sup>2</sup> )	1	4.14±2.53 (n=15)	4.16±2.38 (n=15)	4.77±2.33 <sup>‡</sup> (n=15)	4.86±2.37 <sup>‡</sup> (n=15)	5.13±2.39 <sup>‡</sup> (n=14)	4.79±1.84 <sup>‡</sup> (n=13)
	2	3.65±1.54 (n=6)	3.60±1.33 (n=6)	3.93±1.48 (n=6)	4.09±1.52* (n=6)	3.95±1.43* (n=7)	4.87±2.79 <sup>‡</sup> (n=8)

Continuous variables are expressed as mean±SD. \*P<0.05, <sup>‡</sup>P<0.01, <sup>‡‡</sup>P<0.001 within the group, §P<0.05 between the groups. HR: Heart rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MBP: Mean blood pressure, RVOT: Right ventricular outflow tract, TAPSE: Tricuspid annular plane systolic excursion, RVFAC: Right ventricular fractional area change, LVEF: Left ventricular ejection fraction, CI: Cardiac index, SD: Standard deviation

11 ± 4.89 h, respectively,  $P > 0.05$ ); however, this was not statistically significant. Similarly, the duration of ICU stay and hospital stay was not found to be significantly different between the groups.

## DISCUSSION

Following TOF repair, some degree of residual RVOT obstruction is common. The acceptable level of RVOT gradient, however, remains controversial. A postoperative RV/LV pressure >0.85 is not acceptable and requires surgical revision.<sup>[8-10]</sup> Since these hemodynamic pressures are estimated soon after separation from bypass under anesthesia, one of the important aspects is to define the effect of anesthetic depth on RV pressure and residual RVOT gradient. In our specified literature search, we failed to discover a comparable clinical study to demonstrate that altering intraoperative depth of anesthesia does not affect the measurement of RVOT gradient as long as the systemic pressures are maintained. In our study, RVOT

gradient at 1% and 2% end tidal sevoflurane was similar. Therefore, increasing the depth of anesthesia should not affect gradients across RVOT. We measured this pressure gradient invasively as well as by TEE technique and found that the measured value of RVOT pressure gradient by TEE was higher than the invasive pressure gradient, though not statistically significant.

Silvilairat *et al.* explained the possible mechanism of this higher gradient on TEE in comparison to invasive pressure gradient. Right ventricular systolic pressure and pulmonary artery systolic pressure do not peak at same point of time when measured invasively. In contrast, Doppler measures the maximum instantaneous pressure gradient between RV and PA at the same time; hence, measuring higher values.<sup>[11]</sup>

Our study also demonstrated a significant decrease in the RVOT gradient over the period of time till 1 month after repair. Similar decline in the RVOT gradient was also seen by Kaushal *et al.*<sup>[6]</sup> Immediately postbypass,

there is a hypercontractile state as a result of inotropes and hypovolemia, and this leads to systolic clamping of the RVOT. With passage of time, the hypercontractility decreases along with remodeling of RVOT; thereby, decreasing the RVOT gradient.

In this study, the MBP and the cardiac index significantly improved with the passage of time following surgery. This was possibly due to decreased RVOT gradient following repair which led to improvement in flow across the RVOT. This improves stroke volume of RV as well as left ventricle (LV); thereby, subsequently increasing the systemic blood pressure.

In our study, the echocardiographic parameters of RV and LV functions did not change after surgery except for TAPSE which showed a significant decline at the time of ICU discharge in patients with moderate-to-severe PR. This could be because the RV longitudinal contraction postoperatively is impaired by the pericardectomy and adhesions between the heart and surrounding tissues. This was also confirmed in previous studies where this decrease in longitudinal movement was attributed to a long-term tethering of the right heart wall.<sup>[12,13]</sup>

In this study, the patients had varying degree of PR after TOF repair. PR following surgical repair of TOF is common in all the patients and is a result of the aggressive infundibulectomy involving the pulmonary valve annulus and the use of transannular patch during RVOT reconstruction. We divided our study population into two groups of no or mild PR and moderate to severe PR, to analyse the effect of severity of PR on hemodynamic parameters in the post TOF repair period. Moderate-to-severe PR after transannular patch repair of RVOT was seen in 28.5% of the patients in the immediate post-bypass period. This analysis between these groups demonstrated the comparative hemodynamic parameters, RVOT gradient, and LV functions during the observation period except for RV functions as assessed by TAPSE which showed a significant decrease in patients with moderate-to-severe PR at the time of discharge from the ICU.

In our study, the duration of mechanical ventilation, ICU, and hospital stay were not significantly longer in patients with moderate-to-severe PR as compared to mild PR. This is in contrast to the study by Sasson *et al.* who observed a significantly longer duration of mechanical ventilation and ICU stay in patients who underwent pulmonary valve preservation surgery for TOF correction.<sup>[14]</sup> This could be due to the less number of patients enrolled in our study as compared to their study (21 vs. 163, respectively).

The study has some limitations. Only 21 patients were enrolled due to the limitation of study duration out of which

15 patients had no or mild PR and 6 had moderate-to-severe PR postoperatively. The number of patients was too small for drawing a valid conclusion for group analysis. The gradients were measured using TEE intra-operatively, whereas TTE was used in the postoperative period, which may lead to the difference in the values measured by these modalities. The follow-up period in the study was only 1 month; hence, long-term changes following corrective surgery could not be evaluated.

## CONCLUSION

This study shows that the post-operative RVOT gradient was not altered with changing the depth of anesthesia provided the systemic blood pressure was maintained close to the baseline pressures. Also, the RVOT gradient decreased over a period of time after repair of TOF whereas the systemic blood pressure and cardiac index significantly increased during this period.

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## Conflicts of interest

There are no conflicts of interest.

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