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Anatomical variation in patients undergoing diagnostic cardiac catheterization for Tetralogy of Fallot.

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All the authors named above take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

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Abstract

Background: Tetralogy of fallot has diverse anatomical variations and associations which has important implications in the surgical management and outcome. This study was done to analyse the various anatomical variations in patients with Tetraloy of fallot seen during diagnostic cardiac catheterization.

Methods: This was a single centre observational study in which 131 consecutive patients with Tetralogy of fallot underwent diagnostic cardiac catheterization before total correction. The z score of pulmonary artery annulus and branch pulmonary arteries, Mc goon ratio and Nakata

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index was calculated. The study group was divided in to 2 groups based on age (group A < 10 years and group B ≥ 10 years) to analyse any difference in anatomy.
Results: The mean age of the study group was 6.3 ± 4.7 years with 69.4% being male. The most common associated anomaly was major aortopulmonary collaterals (MAPCAS) seen in 55 (41.9%) patients with right aortic arch (22.9%) being the next most common associated anomaly. The mean Mc goon ratio and Nakata index were 1.66 ± 0.45 and 263.36 ± 136.10 mm^2 respectively. The incidence of MAPCAS was more in group B (75.7%).
Conclusion: The anatomical variations seen in Tetralogy of fallot patients do not vary with respect to age except for the presence of MAPCAS which was seen more in older children. The most common associated anomaly seen was MAPCAS.
Key words: cyanotic congenital heart disease, tetralogy of fallot, cardiac catheterization, angiography, major aortopulmonary collaterals, Mc goon ratio, Nakata index

1.INTRODUCTION

Tetralogy of fallot (TOF) is the most common form of cyanotic congenital heart disease and of the infants born with congenital heart disease, approximately 1 in 3,600 live births will have this defect (1). Treatment is in the form of surgical intracardiac repair which is usually done between 6 to 12 months of age depending on the institutional policy (2). Without surgical intervention only 66% of babies born with TOF survive to 1 year of age, 49% until 3 years of age, and only 24% live to the age of 10 years (3,4). Thus, early surgery is ideal as shorter duration of exposure to hypoxemia preserves the myocardial and other major organ system. In a developing country like India TOF patients presenting late is not uncommon. In low and middle income countries due to delayed referral, lack of awareness and availability of fewer paediatric cardiac programmes it is not rare to see TOF patients presenting for the first time in the second decade of life (5). This leads to increased incidence of complications like cerebral events, myocardial dysfunction, ventricular arrhythmias, haemoptysis and polycythaemia, all due to exposure to chronic hypoxia. Late presenting patients also have increased association of major aortopulmonary collaterals (MAPCAS). Presurgical assessment needs a detailed evaluation of intra cardiac anatomy and associated other extracardiac anomalies. Transthoracic echocardiography is sufficient for the pre surgical assessment in most of the cases except that MAPCAS can be missed. Cardiac catheterization can delineate individual MAPCAS, which can be coiled preoperatively if found to be significant. Also, cardiac catheterization provides all the anatomical detail needed for surgery (6). Routine cardiac catheterization in all TOF patients who are admitted for elective intra cardiac repair is done especially in those who have borderline anatomy. This study was done to analyse the spectrum of anatomical associations seen on angiography in the TOF patients admitted in our unit for intra cardiac repair.

2. METHOD

This study was a single centre retrospective observational study done in all patients of TOF who were admitted for elective intra cardiac repair form March 2018 to December 2021. Patients who had pulmonary atresia were excluded from the study. The purpose of this study was to analyse the various anatomical associations seen in these patients.

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2.1 Pre procedure assessment:

A detailed 2- dimensional echocardiography was performed before the procedure. Pre procedure investigations (hemoglobin, total counts, platelets and coagulation profile) were done in all patients. Informed consent was taken from the parents after detailed explanation about the procedure.

2.2 Angiography protocol:

Conscious sedation in the form of ketamine and midazolam was used according to the unit protocol. Both femoral vein and femoral artery access was taken. The following angiograms were taken:

- Left Ventricular angiogram was done in Left anterior Oblique (LAO) 60/Cranial 30. This showed the mitral inflow, left ventricular size and function, aortic outflow and presence of additional VSD.
- Aortic root angiogram was done in plain LAO 60/Cranial (20-30). This was done to see the coronary anatomy and any major coronary crossing right ventricular outflow tract (RVOT).
- Aortic arch and Descending aorta angiogram were done in A/P view or LAO 20 view in cases with left aortic arch. Those having right arch RAO (right anterior oblique) 20 view was used. These were done for arch sidedness and to look for MAPCAS or PDA. Also, descending thoracic aorta diameter was calculated at the level of diaphragm.
- Right Ventricular angiogram was done in LAO 30/ Cranial 30 for tricuspid inflow, right ventricular size and function, type of pulmonary stenosis, size of pulmonary artery (PA) annulus, branch PA size at the hilar region, arborization of branch PA's and levophase.
- Innominate vein angiogram was done to look for left superior venacava and its drainage.

MAPCAS which were either more than 2mm size or had significant pulmonary arborization considered significant and were coiled.

2.3 Post procedure analysis:

Adequacy of the size of PA annulus, LPA and RPA was assessed by using the boston z score system (7). They were defined as hypoplastic if the z score was less than -3 (8). Furthermore, Mc goon ratio and Nakata index were calculated for branch PA size assessment. Mc Goon ratio was calculated by dividing the sum of diameter of LPA and RPA (hilar region) with the diameter of descending thoracic aorta at the level of diaphragm. Normal range is 2 to 2.5 (9). The Nakata index was calculated by dividing the sum of the cross-sectional area of LPA and RPA (hilar region) by the body surface area. Normal value was considered as 330 ± 30 mm^2 (10).

Patients were divided into two groups based on age to compare the various anatomical parameters. Group A consisted of patients who were less than 10 years of age and group B had those patients who were 10 years of age or above.

2.4 Statistical analysis:

Descriptive statistics for categorical variables were reported as frequency and percentage, whereas continuous variables were reported as mean and standard deviations. Unpaired t test

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was done to compare the z scores of PA annulus, LPA, RPA, Mc goon ratio and nakata index between group A and B. P value of < 0.05 was taken as statistically significant.

2.5 Ethical standards:

The purpose and design of the study were explained to the patients or the consenting family members. The parents or consenting family members were informed that they can ask to withdraw from the study at any time without having reasons for the same. The confidentiality of information obtained was maintained and revealed only to doctor/auditor involved in study and to regulatory authorities. The study was conducted on ethical guidelines for Biomedical Research on human subjects given by Central Ethical Committee on human research, New Delhi, in addition to principles enunciated in the "Declaration of Helsinki."

3.RESULTS

3.1 Patient characteristics:

A total of 131 patients were enrolled in this study from March 2018 to December 2021. Number of patients in group A were 98 (74.8%) and in group B were 33 (25.2%). The mean age of the study group was 6.3 ± 4.7 years with median of 5 years. Only eight (0.06%) patients were the age of one year or less. A total of 40 patients (30.5%) were female and 91 (69.4%) were male.

Table 1: Demographic of patients

	Number (%)
Total patients	131
Mean age	6.3 ± 4.7 years
Male	91 (69.4)
Female	40 (30.5)
Group A	98 (74.8)
Mean age	4.1 ± 2.3 years
Group B	33 (25.2)
Mean age	13 ± 3.9 years

3.2 Angiographic features:

As shown in table 2 the most common associated anomaly was MAPCAS. A total 55 patients (41.9%) had MAPCAS. Table 3 shows the distribution of MAPCAS group wise. It was seen that out of the 55 patients with MAPCAS 25 (75.7%) patients were of the adolescent age group, i.e., group B with 30 (30.6%) patients belonging to group A. MAPCAS were significant in 20 patients for which coiling was done. Among these 20 patients 14 (42.4%) belonged to group B and 6 (6.1%) patients belonged to group A. Presence of right aortic arch was the next most common association, noted in 30 (22.9%) patients. Coronary artery abnormalities were seen in 18 (0.13%) patients, most common of which was prominent conal branch crossing the right ventricular outflow tract (RVOT) followed by left anterior descending crossing RVOT. Single coronary artery was seen in 2 patients who had right coronary artery from left main coronary artery. Left superior venacava was present in 6 (0.04%) patients, patent ductus arteriosus was present in 4 patients (0.03%) and one patient had additional mid muscular VSD.

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Table 2: Anatomic features on angiography

Anatomic feature	**Number (%)**
Aortopulmonary collaterals	55 (41.9)
Coiling (pre operative)	20 (15.2)
Type of arch	
Left arch	111 (84.7)
Right arch	30 (22.9)
Coronary artery abnormality	18 (0.13)
Prominent conal branch crossing RVOT	12 (0.09)
LAD crossing RVOT	5 (0.038)
Single coronary artery	2 (0.01)
LSVC	6 (0.04)
Patent ductus arteriosus	4 (0.03)
Additional VSD	1 (0.007)

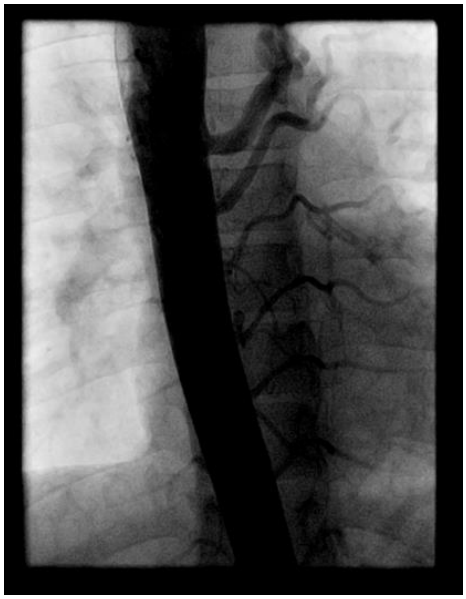
RVOT = right ventricular outflow tract, LSVC = left superior venacava, LAD = left anterior descending, VSD – ventricular septal defect

Table 3: Table showing group wise incidence of MAPCAS:

	MAPCAS	
	Total number	Significant/Coiled
Group A (n = 98)	30 (30.6%)	6 (6.1%)
Group B (n = 33)	25 (75.7%)	14 (42.4%)
Total (n = 131)	55 (41.9%)	20 (15.2%)

MAPCAS = major aortopulmonary collaterals

Figure 1: Descending aortogram (A/P view) showing MAPCAS



Legend: Descending aortogram showing Significant MAPCAS originating from the D5 level. (MAPCAS = Major aortopulmonary collaterals).

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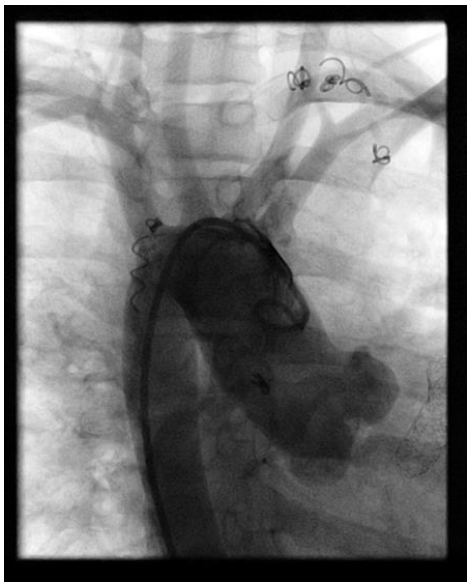
Figure 2: Figure showing MAPCAS coiling



Legend: Aortic arch angiogram done in RAO 30 view which shows presence of right arch. Also, the patients had undergone MAPCAS coiling. (MAPCAS = Major aortopulmonary collaterals, RAO = right anterior oblique).

3.3 Anatomy of pulmonary arteries:

The mean z score for PA annulus was -3.27 ± 1.4 for the whole group and a total of 66 (50.3%) patients had a hypoplastic PA annulus. There was no statistically significant difference in PA annulus size between group A and B with p value of 0.15 (table 3). Confluent branch PA were present in all patients except one who had LPA from descending aorta. The mean Z score of LPA and RPA was 0.60 ± 2.0 and 0.56 ± 1.8 for the whole study group. A total of 14 (10.6%) patients had both LPA and RPA hypoplasia. The number of patients with isolated hypoplastic LPA was 19 (14.5%) and isolated hypoplastic RPA was 4 (0.03%). The mean Z scores of the branch PAs were comparable between the two groups with p value of 0.33 (LPA) and 0.44 (RPA). The mean Mc goon ratio was 1.66 ± 0.45 and the mean Nakata index was 263.36 ± 136.10 mm2 for the whole group. Group wise analysis showed no statistically significant difference in the Mc goon ratio and Nakata index as shown in table 4. There were 19 patients who had Nakata index less than 150 mm2 and 30 patients who had mc goon ration less than 1.5. There was one patient of TOF with absent pulmonary valve whose mc goon ratio was 4.2 and Nakata index 1138 mm2.

Table 4: Pulmonary artery and branch PA anatomy

	Whole group Mean ± SD	Group A Mean ± SD	Group B Mean ± SD	P value
PA annulus (z score)	-3.27 ± 1.4	-3.2 ± 1.5	-3.5 ± 1.2	0.15
LPA (z score)	0.60 ± 2.0	0.55 ± 2.1	0.73 ± 1.7	0.33
RPA (z score)	0.56 ± 1.8	0.55 ± 1.44	0.60 ± 1.3	0.44
Mc Goon ratio	1.66 ± 0.45	1.64 ± 0.48	1.74 ± 0.32	0.13
Nakata Index (mm2)	263.36 ± 136.10	260.72 ± 145.41	271.34 ± 102.5	0.35

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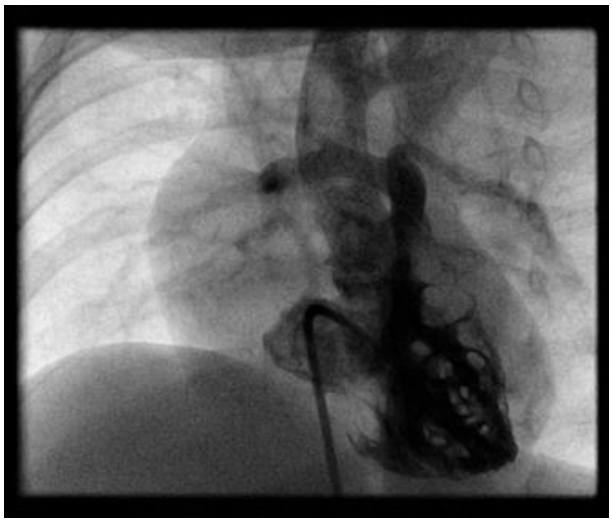
PA = pulmonary artery, LPA = left pulmonary artery, RPA = right pulmonary artery

Figure 3: Figure showing RV angiogram



Legend: RV angiogram done in LAO 30/ cranial 20 view which shows severe infundibular and valvular pulmonary stenosis along with diffusely hypoplastic left pulmonary artery. (LAO = left anterior oblique).

4.DISCUSSION

Cine angiography is the gold standard for the preoperative evaluation in TOF patients especially for the evaluation of pulmonary vasculature and MAPCAS (11). Magnetic resonance angiography and CT pulmonary angiography have been used but they frequently require anaesthesia in small children and do not allow intervention to be done if needed (12). In this study most of the patients were more than one year of age with mean age of 6.3 ± 4.7 years. This shows that unlike the developed world were TOF patients are diagnosed prenatally, in a developing country like India we are still encountering children at a later age.

The most common associated abnormality found in this study was MAPCAS. Significant MAPCAS have clinical implications preoperatively, during the surgery and in the post operative period thus coiling them is necessary (13). A total of 55 (41.9%) patients had MAPCAS of which 20 (15.2%) were significant and had to be coiled. In previous studies it was seen that the incidence of MPACAS is very low in the absence of pulmonary atresia with one study showing only 2 % patients having MAPCAS (14). But in a recent study by Afshan et al where the median age of the study group was 6 years the incidence of MAPCAS was 53 % (13). It was seen that out of the 33 patients in group B in our study 14 patients underwent coiling amounting to 42.4%. This showed that the incidence of MAPCAS is more in children presenting at a later age, most probable due to chronic long-standing hypoxia.

Half (50.3%) of the patients in our study had hypoplastic pulmonary valve annulus. In previous studies abnormality in PA annulus was similarly seen in up to 40 % of patients with a patent RVOT (14 and 15). In this study bilateral branch PA hypoplasia was seen in 14 (10.6%) patients. Isolated LPA origin stenosis was more common than isolated RPA stenosis in this study (14.5% vs 0.03%). Similar findings were seen in a study by Afshan et al where number of patients with isolated LPA stenosis were more than isolated RPA stenosis (9% vs

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3.5%) (13). The high incidence of isolated LPA stenosis can be explained by the fact that PDA insertion is more common at LPA origin causing it to become narrow with closure of PDA. In a study done by Sharma et al the right pulmonary artery and the left pulmonary artery were stenosed in 25 (41%) and 26 (42.6%) patients, respectively (16). The higher incidence of up to 40 % in the study by Sharma et al can be explained by the fact that they included TOF with pulmonary atresia also in their study group. The mean Mc goon ratio was 1.66 ± 0.45 and the mean Nakata index was 263.36 ± 136.10 mm2 for the whole group. The cut off for single stage intracardiac repair in TOF patients is a Mc goon ratio of 1.5 and Nakata index of 150 mm/m2 (17 and 10). There were 19 patients who had Nakata index less than 150 mm2 and 30 patients who had mc goon ration less than 1.5. Group wise analysis did not reveal any significant difference in the PA annulus and branch PA anatomy either by z score analysis or by using Mc goon ratio and Nakata index as shown in table 3.

The incidence of right aortic arch was 22.9% in this study. In various studies the incidence of right aortic in TOF patients is between 20 to 25 % which is concordant to our study (18). Coronary artery abnormalities have a significant baring on the surgical outcome of TOF patients especially if a major coronary crosses the RVOT in patients who need a transannular patch. The incidence of coronary artery abnormality varies from 5 to 7 % (19). In this study 18 (0.13%) patients had coronary artery anomalies, most common of which was prominent conal branch crossing the right ventricular outflow tract (RVOT) followed by left anterior descending crossing RVOT. Single coronary artery was seen in 2 patients who had right coronary artery originating from left main coronary artery. PDA was seen in only 0.03% of patients as opposed to 6 % seen in a study by Harikrishnan et al (15). The lower incidence of PDA in our study can be explained by the late presentation of TOF patients seen in our study causing the PDA to close spontaneously. Presence of LSVC is important for cannulation before cardiopulmonary bypass. Left superior venacava was present in only 0.04% of patients in our study as compared to the reported incidence of 4 to 10 % in various studies (20). The relatively lower incidence of LSCV can be due to the smaller sample size of our study. Lastly only one patient (0.07%) had additional muscular VSD which is similar to other studies (21).

Limitations:

The post operative outcomes of the patients were not analysed in this study. Also, the number of patients in group B were lesser as compared to group A.

Conclusion:

The anatomical variations seen in TOF patients do not vary with respect to age except for the presence of MAPCAS which was seen more in older children in this study. Thus, a lower threshold for cardiac catheterization must be kept especially for children who present beyond the first decade of life. The most common associated anomaly was MAPCAS followed by the presence of right aortic arch. Fifty percent of patients had hypoplastic pulmonary artery annulus. Isolated LPA stenosis was more common than isolated RPA stenosis.

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