



# Pattern of Coronary Arteries Anatomy in DTGA and its Impact on Surgical Outcome

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## Abstract

**Background:** D-Transposition of the Great Arteries (DTGA) is a congenital heart defect characterized by a reversal in the origin of the great arteries. The aorta rising from the right ventricle and pulmonary artery from the left ventricle. This anomaly leads to a unique circulatory pattern where oxygen-poor blood is circulated to the body, and oxygen-rich blood is cycled back to the lungs. The coronary anatomy in DTGA patients is quite variable. The aberrant coronary patterns associated with DTGA add a layer of complexity to surgical interventions, during arterial switch operation. of the Great Arteries. **Objectives:** To systematically analyze the pattern of coronary artery anatomy in patients with DTGA and assess their impact on surgical procedure and outcome. **Methods:** This retrospective, single-center study is conducted at Prince Sultan Cardiac Center, Riyadh, Saudi Arabia. Medical records from January 2017 to December 2023 have been reviewed, including patient demographics, coronary arteries anatomy, surgical procedures, and post-operative outcomes. The cohort included all patients diagnosed with DTGA who underwent arterial switch operation (ASO) within the first four months of life. DTGA patients who did not qualify for arterial switch operation were excluded. Descriptive and inferential statistical methods were used to analyze the data. **Results:** A total of 104 patients were included in the study analysis. The mean age of the patients was 23.5 days, and the average weight was 3.21 kg. The gender distribution was 62.5% male and 37.5% female. Majority of patients (64.4%) had DTGA with Intact Ventricular Septum (IVS), while 35.6% had DTGA with Ventricular Septal Defect (VSD). The usual pattern of coronary arteries Left coronary artery (LCA=LAD+LCX) from sinus 1 and RCA from sinus 2, was observed in 65.4% of patients. Other variations in the coronary anatomy were found as follows: a-LAD from sinus 1, and origin of the circumflex artery (LCX) from the right coronary artery from sinus 2 in 22.1% of patients. b-Single left coronary artery in 6, c-single right coronary artery in 8 patients. Intramural LAD is found in 2 patients, one of them was diagnosed preoperatively while, it was discovered intraoperatively in one patient who needed ECMO support and died after 72 hours. The mean cross-clamp time was 124.04 minutes, and the mean post-operative ICU stay was 15.2 days. **Conclusion:** The study highlights the importance of understanding coronary artery patterns in DTGA patients for surgical planning and optimizing post-operative outcomes. Despite limitations due to the retrospective single-center design, the study provides valuable insights into the clinical management of DTGA and emphasizes the need for individualized surgical strategies in patients with unusual coronary anatomy.

**Keywords:** D-Transposition of the Great Arteries; Coronary artery anatomy; Arterial switch operation; Surgical outcomes; congenital heart disease; Echocardiography.

## Introduction

D-Transposition of the Great Arteries (DTGA) is a congenital heart defect characterized by a reversal in the origin of the aorta and the pulmonary artery. The aorta rising from the right ventricle and pulmonary artery from the left ventricle <sup>[1]</sup>. This anomaly leads to a unique circulatory pattern where oxygen-poor blood is circulated to the body, and oxygen-rich blood is cycled back to the lungs <sup>[2]</sup>. As one of the most critical congenital cardiac abnormalities, DTGA poses significant challenges in both diagnosis and treatment <sup>[3]</sup>.

The coronary anatomy in DTGA patients is notably variable and significantly influences surgical outcomes <sup>[4]</sup>. The aberrant coronary patterns associated with DTGA add a layer of complexity to surgical interventions, particularly during arterial switch

operations <sup>[5]</sup>. Given that coronary arteries supply blood to the heart muscle, any variation in their anatomy can have profound implications on the heart's function, especially post-surgery <sup>[6]</sup>.

Surgical correction of DTGA, notably the arterial switch operation, is the primary treatment modality <sup>[1]</sup>. However, the success of these procedures heavily depends on the precise identification and management of the coronary anatomy <sup>[2]</sup>. Surgeons face unique challenges in re-implanting the coronary arteries, a critical step in ensuring adequate myocardial perfusion post-surgery <sup>[3]</sup>.

The correlation between the patterns of coronary anatomy in DTGA patients and surgical outcomes is a focal area of interest <sup>[6]</sup>. Variations in coronary artery origin, course, and branching patterns can increase the risk of complications such as myocardial ischemia,

arrhythmias, and even sudden cardiac death post-operatively [4]. Analyzing these patterns is crucial for risk stratification. It can guide surgeons in choosing the most appropriate surgical technique, thereby improving the overall success rates and long-term outcomes of DTGA surgeries [5-7].

The present study aims to systematically analyze the patterns of coronary anatomy in patients with DTGA and assess their impact on the surgical procedure and outcomes. This research seeks to provide valuable insights into the anatomical variations and their clinical implications, thereby aiding in developing more effective and individualized surgical strategies [3]. By deepening the understanding of this correlation, the study intends to contribute to the improvement of surgical techniques and post-operative care, ultimately enhancing patient outcomes in DTGA cases [4].

Despite the extensive research and advancements in the management and surgical treatment of d-transposition of the great arteries (D-TGA), there remains a noticeable gap in the literature, particularly in the context of Saudi Arabia and specifically at Prince Sultan Cardiac Center. Most of the existing studies, including those by Cetrano and Carotti, Moll *et al.*, and Villafañe *et al.*, have been conducted in Western or global contexts, which may not fully represent the unique demographic and genetic characteristics found in the Saudi population. Furthermore, regional variations in the prevalence of coronary anomalies, surgical techniques, and post-operative outcomes have not been extensively explored in the Middle Eastern setting. This underscores the need for localized research at Prince Sultan Cardiac Center to provide insights more directly applicable to the Saudi population.

## Methodology

### Research Design

This was a retrospective, single-center study conducted at Prince Sultan Cardiac Center, Riyadh, Saudi Arabia from January 2017 to December 2023.

### Inclusion criteria

The patient cohort includes all patients with a diagnosis of DTGA who underwent arterial switch operation within the first four months of life during the study period (n=104).

DTGA patients who did not qualify for arterial switch operation were excluded

### Data Collection

The study involved a thorough review of medical records from the past five years, providing a contemporary perspective on D-TGA treatment. Key data points included patient demographics, coronary anomaly specifics, surgical procedure details, and post-operative outcomes. This encompassed pre-operative diagnoses, intraoperative findings, post-operative complications, and subsequent interventions or follow-up results.

### Data Analysis

The analysis utilized both descriptive and inferential statistical methods. Descriptive statistics summarized the characteristics of the patient cohort, while inferential statistics explored associations between coronary anatomy variations and surgical outcomes.

## Results

The results in Table (1) summarize the baseline sociodemographic characteristics of the patient cohort. The mean age of the patients is 23.5 days, with a standard deviation of 48.2 days. The average weight is 3.21 kg with a standard deviation of 0.78 kg. The gender distribution shows that 62.5% of the patients are male, and 37.5% are female. Regarding diagnosis, 64.4% of the patients have Transposition of the Great Arteries (TGA) with Intact Ventricular Septum (IVS), and 35.6% have TGA with Ventricular Septal Defect (VSD).

**Table 1: Baseline Sociodemographic and Clinical Characteristics of the Patient Cohort (n=104)**

Variable	M±SD
Age (days)	23.5±48.2
Weight (kg)	3.21±0.78
Gender F(%)	
Male	65 (62.5%)
Female	39 (37.5%)
Diagnosis	
TGA with IVS	67 (64.4%)
TGA with VSD	37 (35.6%)

As shown in Table 2, the mean cross-clamp time was 124.04 minutes (SD = 30.5), and the mean post-operative ICU stay was 15.2 days (SD = 23.04). Regarding the pattern of coronary arteries, 65.4% (n = 68) had the usual pattern with the LCA from the left facing sinus and the RCA from the posterior and rightward facing sinus, 22.1% (n = 23) had the origin of the circumflex artery (LCx) from the RCA, 2.9% (n = 3) had a single RCA from the posterior facing sinus, 2.9% (n = 3) had a single LCA from the left facing sinus, 3.8% (n = 4) had inverted arteries, 1.0% (n = 1) had inverted RCA and LCx, and 1.9% (n = 2) had an intramural LCA. For the procedures, 98.1% (n = 102) underwent ASO, and 1.9% (n = 2) underwent a two-stage switch operation. Regarding operative outcomes, 78.8% (n = 82) did not have a closed chest, while 21.2% (n = 22) did. Conversely, 21.2% (n = 22) had no open chest, while 78.8% (n = 82) did. Conventional MV was not used in 8.7% (n = 9) of cases but was used in 91.3% (n = 95). ECMO was not used in 92.3% (n = 96) of cases but was used in 7.7% (n = 8). All patients (100.0%, n = 104) had a pre-operative diagnosis of coronary issues by transthoracic echocardiography. Post-operatively, 97.1% (n = 101) had the same diagnosis, while 2.9% (n = 3) had a different diagnosis.

**Table 2: Clinical Outcomes and Procedural Details of the Patient Cohort**

Characteristic	Frequency	Percent
Cross Clamp (M±SD)	124.04±30.5	
Post-operative ICU stay (M±SD)	15.2±23.04	
Pattern of Coronary Arteries		
Usual pattern with the LCA from the left facing sinus and the RCA from the posterior and rightward facing sinus	68	65.4
Origin of the circumflex artery (LCx) from the RCA	23	22.1
Single RCA from the posterior facing sinus	3	2.9
Single LCA from the left facing sinus	3	2.9
Inverted arteries (note that this pattern is similar to the normal heart)	4	3.8
Inverted RCA and LCx	1	1.0
Intramural LCA	2	1.9

Procedure		
ASO	102	98.1
Two stage switch operation	2	1.9
Operative Outcome: Close Chest		
No	82	78.8
Yes	22	21.2
Operative Outcome: Open Chest		
No	22	21.2
Yes	82	78.8
Operative Outcome: Conventional MV		
No	9	8.7
Yes	95	91.3
Operative Outcome: ECMO		
No	96	92.3
Yes	8	7.7
Pre OP Diagnosis of Coronary		
ECHO	104	100.0
Post OP Diagnosis of Coronary		
Same	101	97.1
Different	3	2.9

**Pattern of Coronary Anatomy in DTGA Based on Cohort’s Characteristics**

The usual pattern of coronary arteries by gender was observed in 46 males (70.8%) and 22 females (56.4%). The origin of the circumflex artery (LCx) from the RCA was found in 13 males (20.0%) and ten females (25.6%). The chi-square test indicated no significant difference ( $\chi^2=4.297, p=0.637$ ).

Regarding the pattern of coronary arteries by diagnosis, the usual pattern was found in 41 patients with TGA with IVS (61.2%) and 27 with TGA with VSD (73.0%). The origin of the circumflex artery (LCx) from the RCA was observed in 17 patients with TGA with IVS (25.4%) and six patients with TGA with VSD (16.2%). The chi-square test revealed no significant difference ( $\chi^2=7.442, p=0.282$ ).

The usual pattern of coronary arteries by commissure alignment was found in 59 patients with aligned commissure (69.4%) and nine with misaligned commissure (47.4%). The origin of the circumflex artery (LCx) from the RCA was seen in 18 patients with aligned commissures (21.2%) and five patients with misaligned commissures (26.3%). The chi-square test indicated no significant difference ( $\chi^2=8.195, p=0.224$ ).

Finally, for the pattern of coronary arteries by procedure, the usual pattern was observed in 67 patients who underwent ASO (65.7%) and one patient who underwent a two-stage switch operation (50.0%). The origin of the circumflex artery (LCx) from the RCA was seen in 22 patients who underwent ASO (21.6%) and one patient who underwent a two-stage switch operation (50.0%). The chi-square test revealed no significant difference ( $\chi^2=1.046, p=0.984$ ).

**Table 3: Cross tabulation of Pattern of Coronary Arteries by Gender and Diagnosis**

Pattern of Coronary Arteries	Gender		Diagnosis		Commissure Alignment		Procedure	
	Male	Female	TGA with IVS	TGA with VSD	Aligned	Mis-aligned	ASO	Two stage switch operation
Usual pattern	46(70.8%)	22(56.4%)	41(61.2%)	27 (73.0%)	59(69.4%)	9(47.4%)	67(65.7%)	1 (50.0%)
Origin of the circumflex artery (LCx) from the RCA	13(20.0%)	10(25.6%)	17(25.4%)	6 (16.2%)	18(21.2%)	5 (26.3%)	22(21.6%)	1 (50.0%)
Single RCA from the posterior facing sinus	2 (3.1%)	1(2.6%)	3 (4.5%)	0 (0.0%)	1 (1.2%)	2 (10.5%)	3 (2.9%)	0 (0.0%)
Single LCA from the left facing sinus	1 (1.5%)	2 (5.1%)	2 (3.0%)	1 (2.7%)	2 (2.4%)	1 (5.3%)	3 (2.9%)	0 (0.0%)
Inverted arteries	2 (3.1%)	2 (5.1%)	1 (1.5%)	3 (8.1%)	3 (3.5%)	1 (5.3%)	4 (3.9%)	0 (0.0%)
Inverted RCA and LCx	0 (0.0%)	1 (2.6%)	1 (1.5%)	0 (0.0%)	1 (1.2%)	0 (0.0%)	1 (1.0%)	0 (0.0%)
Intramural LCA	1 (1.5%)	1 (2.6%)	2 (3.0%)	0 (0.0%)	1 (1.2%)	1 (5.3%)	2 (2.0%)	0 (0.0%)
Total	65	39	67	37	85	19	102	2
X2	4.297		7.442		8.195		1.046	
P-value	0.637		0.282		0.224		0.984	

A one-way analysis of variance (ANOVA) was conducted to examine the differences in intensive care unit (ICU) stay duration based on the pattern of coronary arteries. The results indicated that the mean ICU stay varied across different coronary artery patterns, with the highest mean ICU stay observed in patients with inverted arteries (M = 22.75, SD = 29.11) and the lowest in those with an

inverted RCA and LCx (M = 8.00, SD not available). Patients with the usual coronary pattern had a mean ICU stay of 15.91 days (SD = 26.94), while those with the origin of the circumflex artery (LCx) from the right coronary artery (RCA) had a mean ICU stay of 12.65 days (SD = 10.38). Other coronary variations showed mean ICU stays ranging from 11.00 days (SD = 12.12) in patients with a single

RCA from the posterior facing sinus to 15.33 days (SD = 11.37) in those with a single left coronary artery (LCA) from the left facing sinus. However, the ANOVA results demonstrated no statistically

significant differences in ICU stay duration among the different coronary artery patterns,  $F = 0.1549$ ,  $p = .987$ .

**Table 5: One-Way Analysis of Variance for the differences in ICU stay based on the Pattern of Coronary Arteries**

Pattern of Coronary Arteries	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		F	Sig.
				Lower Bound	Upper Bound		
Usual pattern	15.91	26.94	3.26	9.38	22.43		
Origin of the circumflex artery (LCx) from the RCA	12.65	10.38	2.16	8.16	17.14	0.1549	0.987
Single RCA from the posterior facing sinus	11.00	12.12	7.00	-19.11	41.11		
Single LCA from the left facing sinus	15.33	11.37	6.56	-12.91	43.58		
Inverted arteries	22.75	29.11	14.55	-23.57	69.07		
Inverted RCA and LCx	8.00	.	.	.	.		
Intramural LCA	14.00	8.48	6.00	-62.23	90.23		
Total	15.18	23.04	2.26	10.70	19.66		

## Discussion

This study aimed to investigate the baseline demographic characteristics, clinical outcomes, and procedural details of patients with Transposition of the Great Arteries (TGA) and to analyze the patterns of coronary arteries based on gender, diagnosis, commissure alignment, and surgical procedure. This comprehensive analysis provides valuable insights into TGA patients' clinical management and outcomes.

Our findings indicate that most of the patients were male, which is consistent with existing literature suggesting a higher incidence of congenital heart defects in males. This gender disparity might be due to genetic and hormonal differences that influence the development of the cardiovascular system. Pugnali *et al.*<sup>[11]</sup> reported that congenital heart defects are more prevalent in males, potentially due to sex-linked genetic factors or differences in prenatal exposure to environmental factors. Understanding gender distribution helps tailor clinical interventions and follow-up strategies to address specific needs, as gender-specific differences in cardiac function and structure may influence surgical outcomes and long-term management.

The diagnosis distribution in our cohort revealed that most patients had TGA with Intact Ventricular Septum (IVS), while a significant portion had TGA with Ventricular Septal Defect (VSD). This distribution is aligned with previous studies that highlight TGA with IVS as the more common form. For instance, van der Palen *et al.*<sup>[12]</sup> found that TGA with IVS is more prevalent and generally associated with better surgical outcomes compared to TGA with VSD, which can complicate surgical procedures due to increased hemodynamic burden. The presence of VSD in some patients necessitates different surgical approaches. It has implications for post-operative management and outcomes, as it can influence the complexity and risk profile of the surgical intervention.

In terms of coronary artery patterns, the usual pattern was the most common, followed by the origin of the circumflex artery from the right coronary artery (RCA). The pattern of coronary arteries plays a crucial role in the surgical planning and outcomes of arterial switch operations. Variations in coronary anatomy can pose significant challenges during surgery and influence the risk of post-operative complications. Ahlström *et al.*<sup>[13]</sup> emphasized that understanding coronary anatomy is vital for successful surgical outcomes in TGA patients, as specific patterns may increase the difficulty of re-implanting the coronary arteries, potentially leading to complications such as myocardial ischemia or arrhythmias.

When examining the relationship between coronary artery patterns and gender, our study found no significant differences. This

suggests that the distribution of coronary artery patterns is relatively uniform across genders. This supports findings from other studies that have observed no gender-based discrepancies in coronary anatomy among TGA patients. Sayed *et al.*<sup>[14]</sup> noted that while gender differences exist in the prevalence of congenital heart defects, the anatomical variations in coronary arteries do not differ significantly between males and females. This uniformity implies that surgical strategies and considerations for coronary artery re-implantation can be applied consistently across genders.

The alignment of commissures was another variable of interest. Our results showed no significant difference in the pattern of coronary arteries between patients with aligned and misaligned commissures. Commissure alignment is critical in determining the success of the arterial switch operation, but our findings suggest that it does not significantly affect the coronary artery pattern. Konstantinov *et al.*<sup>[15]</sup> discussed that while commissure alignment can impact the ease of the arterial switch operation, the intrinsic coronary artery pattern is a more critical determinant of surgical complexity and success, highlighting the multifaceted nature of surgical planning in TGA.

Surgical procedure types, precisely the arterial switch operation (ASO) and the two-stage switch operation did not show significant differences in coronary artery patterns. The ASO is the preferred surgical technique for TGA and has a high success rate. The two-stage switch operation is less common and is usually reserved for specific clinical scenarios. Engele *et al.*<sup>[16]</sup> found that while both procedures are effective, the choice between them is primarily influenced by the patient's overall clinical condition and specific anatomical considerations rather than coronary artery patterns alone. Our findings support this, suggesting that coronary artery patterns do not dictate the choice of surgical procedure but rather the overall clinical context.

The post-operative outcomes revealed a high success rate for the arterial switch operation, with most patients being discharged successfully. This aligns with existing literature that reports excellent outcomes and survival rates for TGA patients undergoing ASO. Stoica *et al.*<sup>[17]</sup> highlighted that the ASO is associated with low mortality and morbidity rates, provided that experienced surgical teams in well-equipped centers perform the surgery. Our study's low incidence of post-operative complications underscores the effectiveness of this surgical approach and the importance of specialized care.

The use of Extracorporeal Membrane Oxygenation (ECMO) was relatively rare in our cohort, indicating that most patients did not require this level of intensive post-operative support. ECMO is typically reserved for severe cases with significant complications,

and its limited use in our study (for patients with intramural coronary artery not diagnosed pre-operatively) suggests favorable surgical and immediate post-operative outcomes. Wu *et al.*<sup>[18]</sup> discussed that ECMO is a valuable tool for managing severe post-operative complications in congenital heart surgery but should be used judiciously due to its associated risks and complexities.

Finally, the consistency between pre-operative and post-operative coronary anatomy diagnoses highlights pre-operative imaging techniques' accuracy. Accurate pre-operative diagnosis is crucial for surgical planning and optimizing outcomes, as it allows surgeons to anticipate and manage anatomical variations effectively. Pushparajah *et al.*<sup>[19]</sup> emphasized the importance of high-quality imaging, such as echocardiography and cardiac MRI, in diagnosing congenital heart defects, ensuring that surgical teams have precise information to guide their interventions.

In addition, the one-way ANOVA assessing the impact of coronary artery patterns on ICU stay duration demonstrated no significant differences among the groups ( $F = 0.1549$ ,  $p = .987$ ). While patients with inverted arteries had the longest mean ICU stay (22.75 days), and those with an inverted RCA and LCx had the shortest (8.00 days), these variations were not statistically meaningful. These results align with existing literature suggest that coronary anomalies may not independently dictate post-operative outcomes but could interact with other clinical and surgical factors. The lack of significant findings may be attributed to sample size limitations or the inherent adaptability of surgical techniques to accommodate coronary variations. Future research should explore these relationships in larger, multicenter cohorts to determine whether subtle anatomical differences contribute to long-term post-operative morbidity and recovery.

A notable limitation of this study is its retrospective design and reliance on data from a single center, Prince Sultan Cardiac Center in Saudi Arabia. This limits the generalizability of the findings to broader populations and different healthcare settings. Retrospective studies are inherently limited by the accuracy and completeness of existing medical records, which can introduce biases and affect the reliability of the data. The study's focus on a specific population may not capture the full spectrum of coronary anatomy variations and their impact on surgical outcomes in diverse demographic groups. The absence of a control group and the inability to account for all potential confounding factors, such as genetic background and environmental influences, further limit the robustness of the conclusions. Future studies should include multiple centers and a prospective design to enhance the validity and applicability of the findings. Moreover, incorporating advanced imaging and diagnostic techniques could provide a more comprehensive understanding of coronary anatomy variations in DTGA patients and their clinical implications.

## Conclusion

In conclusion, this study provides a detailed analysis of the baseline demographic characteristics, clinical outcomes, and coronary artery patterns in patients with Transposition of the Great Arteries (TGA). The findings highlight the predominance of male patients, the common occurrence of TGA with Intact Ventricular Septum (IVS), and the frequent use of the arterial switch operation (ASO) as a successful surgical intervention. The study underscores the importance of understanding coronary artery patterns for surgical planning and optimizing post-operative outcomes.

## List of Abbreviations

DTGA: D-Transposition of the Great Arteries

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TGA: Transposition of the Great Arteries  
IVS: Intact Ventricular Septum  
VSD: Ventricular Septal Defect  
LCA: Left Coronary Artery  
RCA: Right Coronary Artery  
LAD: Left Anterior Descending artery  
LCx: Left Circumflex artery  
ASO: Arterial Switch Operation  
ECMO: Extracorporeal Membrane Oxygenation  
ICU: Intensive Care Unit  
MV: Mechanical Ventilation  
ECHO: Echocardiography  
ANOVA: Analysis of Variance  
MRI: Magnetic Resonance Imaging  
CT: Computed Tomography

## Declarations

### Authorship contribution

SA: perceived the research idea and acted as mentor for the study and senior author for the manuscript writing and editing

AAA: is the primary investigator and first author, took the lead role in data collection and manuscript writing.

All coauthors played an active part in compilation of the study, manuscript writing and editing.

### Conflict of interest

All authors have declared No conflict of interest.

### Financial disclosure

The study did not receive any financial support.

### Ethical approval

The study has been performed in accordance with ethical standards of the institutional research committee and with the 2013 Helsinki declaration of comparable ethical standards,

The study has been approved by the institutional review board of Prince Sultan Cardiac Center, Riyadh, Saudi Arabia under IRB approval no: IR 1689. The need for written informed consent was waived by the IRB.

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