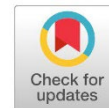


Research Article

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Vascular Complications of Trans catheter Interventions in Congenital Heart Disease: A Single-Center Experience in Benghazi

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Abstract

Vascular complications remain a major concern during transcatheter interventions in congenital heart disease (CHD). This study aimed to evaluate vascular complications of transcatheter cardiac procedures in CHD patients. A retrospective descriptive study was conducted at the National Heart Center from 2020 to 2025. The study included 256 patients who underwent diagnostic or interventional cardiac catheterization. The analysis examined the correlation between patient characteristics, procedural factors, and vascular complications. The study population comprised 256 patients, of whom 57.8% were female and 42.2% were male. 31.1% of patients were under the age of 3 years. 84% of the procedures were interventional, and 16% were diagnostic. Transcatheter ASD closure was the most frequent procedure, accounting for 34% of cases. Vascular complications, including vascular injury and device mobilization, were observed in 3.2% of the patients, while 96% of patients experienced no complications. Bivariate analysis revealed significant associations between the occurrence of vascular injury and younger age, lower body weight, and the use of arterial access. Additionally, a higher delivery sheath-to-weight ratio was significantly associated with an increased incidence of vascular complications ($p < 0.05$). Transcatheter interventions for CHD remain safe, while vascular challenges are influenced by patient age, weight, and procedural factors, highlighting the need for cautious patient selection and appropriate sheath sizing to optimize procedural safety.

Keywords: Congenital Heart Disease (CHD), Cardiac Catheterization Complications, Benghazi, Libya

INTRODUCTION

Congenital heart disease (CHD) remains one of the most prevalent birth defects, affecting 1.8 in every 100 live births (Ganea et al., 2023). Percutaneous cardiac catheterization was initially utilized in 1962 for managing patients with CHD (Ali et al., 2023; Alsherif et al., 2024). Over the past two decades, this field has included major developments with rapid advancements in technology and expanded access to resources, with particular emphasis on quality improvement (QI) in CHD catheterization, resulting in a reduction in overall annual mortality rates (Tokel et al., 2018). Cardiac catheterization is still crucial in CHD despite advancements in non-invasive diagnostic modalities, including cardiovascular computed tomography (CT) and cardiac magnetic resonance imaging (MRI). With fewer complications and a shorter hospital stay than open heart surgery, its role has



expanded from diagnostics to encompass various interventions to substitute open heart surgery for certain types of congenital heart disease (Quinn et al., 2024). Diagnostic catheterization allows for comprehensive hemodynamic evaluation during the preoperative assessment of patients with CHD and guides appropriate surgical strategies and optimizes outcomes. Transcatheter techniques have advanced since 1970, with advancements in interventional catheterization that have revolutionized strategies for the treatment of CHD, which include transcatheter device closure of atrial septal defects (ASD) and ventricular septal defects (VSD), patent ductus arteriosus (PDA), stent coarctation of the aorta (CoA) angioplasty, balloon valvuloplasty for pulmonary and aortic valve stenosis, stent placement for vessel narrowing, and embolization of collateral vessels (Gamboa et al., 2022). With expanded options and improved outcomes, cardiac catheterization remains an invasive procedure with associated risks (Fattouh et al., 2017; Mbabazi et al., 2024). While the overall incidence of complications is minimal, vascular complications remain the most frequent, including vascular injury, heart or vascular perforation, thrombosis, hematoma, and device mobilization (Gerçeker et al., 2022). Kou et al. (2020) revealed that femoral artery thrombosis is the most prevalent complication, occurring in 11% of patients undergoing transcatheter intervention. Recognizing the clinical relevance of these issues, recent research has evaluated risk variables, such as age and procedure type, to predict potential complications and inform preventive strategies. Post-procedural complications remain a clinical concern, highlighting the importance of careful monitoring and preventive strategies following cardiac catheterization in children (Afkar et al., 2018).

This study aims to analyze the frequency and variety of vascular complications arising from transcatheter cardiac procedures in CHD, and to identify risk factors for vascular injury during these procedures in patients with CHD in Benghazi, Libya.

MATERIALS AND METHODS

This was a retrospective observational study that involved the review and analysis of the medical records of 256 patients with congenital heart disease (CHD). The patients, who ranged in age from neonates to adults, underwent diagnostic and interventional catheterizations at the National Heart Center in Benghazi between 2020 and 2025.

Exclusion Criteria: All procedures performed outside the center and patients who underwent open-heart surgery were excluded from this study.

The Statistical Package for the Social Sciences (SPSS), version 27, was used to analyze the data. Descriptive statistics for categorical variables were presented as frequencies and percentages. Comparisons between two groups (those with vascular injury and those without vascular injury) were performed using Fisher's exact test for categorical variables and the Mann-Whitney U test for continuous variables. Given the low incidence of vascular complications ($n = 10$), we focused on bivariate analysis to identify associations between risk factors and vascular injury. A p -value of less than 0.05 was considered statistically significant.

RESULTS

Table (1) illustrates transcatheter procedures conducted on 256 patients. At 31.3% ($n = 80$) of the entire sample, the largest number of patients were in the age group below three years. Children aged 4–10 made up 25.3% of the total ($n = 65$). 18% ($n = 46$) were older children and adolescents (10–18 years old). Adults 18 years and older constituted the remainder of the age group, representing 25.3% ($n = 65$). Males represented 42.2% ($n = 108$) of patients, while females accounted for 57.8% ($n = 148$). The patients' geographical distribution revealed that Benghazi accounted for over 50 percent of the patients (53.5%), while patients from other regions accounted for 46.5%.

Table (1). Demographics of patients

Patients (N: 256)	Frequency (n)	Percentage (%)
Male	108	42.2
Female	148	57.8
Less than 3 years	80	31.3
4 – 10 years	65	25.3
10 – 18 years	46	18
More than 18 years	65	25.3
< 10 kg	30	11.8
10 – 20 kg	71	27.7
20 – 50 kg	80	31.2
> 50 kg	75	29.3
Benghazi	137	53.5
Other Regions	119	46.5

The annual frequency of cardiac catheterization procedures varied within the study period, as described in Table 2. The highest rate was recorded in the years 2022–2023 (37.5%), followed by 2020–2021 (36.7%). Based on medical data, the most common indication for cardiac catheterization was ASD (34%, n = 87), followed by PDA (23.8%, n = 61) and pulmonary stenosis (18.7%, n = 48). PFO accounted for 10.1% (n = 26) of the cases, in addition to other congenital heart defects representing 7.4% (n = 19). AS 2.3% (n = 6), COA 2.7% (n = 7), and the least frequent procedure, right heart pressure measurement (PHT), 0.8% (n = 2).

Table (2). catheterization characteristics

Patients (N: 256)	Frequency (n)	Percentage (%)
Year of Catheterization		
2020 – 2021	94	36.7
2022 – 2023	96	37.5
2024 – 2025	66	25.8
Type of Catheterization		
Diagnostic	41	16
Interventional	215	84
Vascular Access type		
Venous	157	61.3
Arterial	99	38.7
Diagnosis		
ASD	87	34
PDA	61	23.8
PS	48	18.7
PFO	26	10.1
COA	7	2.7
AS	6	2.3
PHT	2	0.8
Other CHD	19	7.4

ASD (Atrial Septal Defect), PDA (Patent Ductus Arteriosus), PS (Pulmonary Stenosis), PFO (Patent Foramen Ovale), AS (Aortic Stenosis), PHT (Pulmonary Hypertension), COA (Stent or Balloon)

In Table 3, analysis of procedure-related issues revealed that in 96% (n = 246) of cases, no complications occurred. Among the recorded complications (4%, n = 10), femoral artery injury and device mobilization were the most common major issues (3.2%). Hematomas were categorized as minor complications (0.8%) requiring just follow-up and medical treatment.

Table (3). Frequency of complications according to catheterization procedure type:

Complication Type	Diagnostic (n=41)	Interventional (n=215)	Total (N=256)
No Complication	39 (95.1%)	207 (96.3%)	246 (96%)
Vascular Injury	1 (2.4%)	2 (0.9%)	3 (1.2%)
Thrombosis	0 (0%)	2 (0.9%)	2 (0.8%)
Hematoma	1 (2.4%)	1 (0.5%)	2 (0.8%)
Device Mobilization	0 (0%)	3 (1.4%)	3 (1.2%)
Total	41 (100%)	215 (100%)	256 (100%)

Table 4 presents the risk factors for vascular injury. The analysis demonstrated that younger age, lower weight, arterial/artery-vein access, and a high DS/WT ratio were significantly associated with an increased risk of vascular injury.

Table (4). Risk Factors Associated with Vascular Injury in CHD Catheterization:

Variable	Vascular Injury: Yes (n=10)	Vascular Injury: No (n=246)	P-value
Age (years) (Mean $\pm$ SD)	4.00 $\pm$ 2.16	9.85 $\pm$ 6.42	
Age < 3 Years (n, %)	7 (70%)	73 (29.6%)	0.029*
Body Weight (kg) (Mean $\pm$ SD)	21.25 $\pm$ 14.8	35.60 $\pm$ 22.4	0.050
Procedural Factors			
Type: Diagnostic	1 (10%)	40 (16.3%)	1.000
Type: Intervention	9 (90%)	206 (83.7%)	
Vascular Access: Artery/Artery Vein	7 (70%)	89 (36.2%)	0.044*
Vascular Access: Vein	3 (30%)	157 (63.8%)	
Catheter Ratios			
DS/WT Ratio (Mean $\pm$ SD)	0.028 $\pm$ 0.04	0.011 $\pm$ 0.02	0.029*

* Statistically significant (P < 0.05). Delivery sheath-to-weight ratio (DS/WT). Vascular injury (VI)

DISCUSSION

Transcatheter procedures for congenital heart disease (CHD) have been studied in Libya, whereas attention has mainly focused on the procedural success rate and short-term outcomes. Notably, previous Libyan studies on transcatheter intervention in CHD have not comprehensively covered a variety of complications, particularly the prevalence and risk factors associated with vascular complications and device-related issues (Madany et al., 2022). This study attempts to bridge this gap by assessing risk factors contributing to these complications.

The proportion of female patients in our study was 57.8%, which is consistent with the findings of Ibrahim et al. (2020), who also reported a relatively high percentage of female patients undergoing cardiac catheterization. This gender distribution may be attributed to the higher prevalence of spe-

cific types of CHD, such as atrial septal defects (ASD), in females compared to males. Regarding procedural distribution, transcatheter ASD closure was the most frequent intervention, followed by pulmonary balloon valvuloplasty and patent ductus arteriosus (PDA) closure. While this contrasts with Habeeb et al. (2021) and Qawasmeh et al. (2018), who identified PDA closure as the most prevalent procedure, these discrepancies likely reflect institutional variations in patient referral and clinical focus. Furthermore, our study highlights the predominance of therapeutic interventions over diagnostic procedures, aligning with Habeeb et al. (2021), whereas Tokel et al. (2018) found diagnostic catheterization to be more prevalent in their cohort. In this study, there were associations between age, introducer sheath size, and vascular complications; this finding reinforces the evidence that younger patients are particularly vulnerable to vascular injury because of the small vessel caliber relative to sheath size. The present findings correspond with previous reports by Praditukrit et al. (2025) and Abalı et al. (2022), which identified patient age, body weight, and sheath size as independent predictors of vascular complications in patients undergoing cardiac catheterization. Also, our results support the evidence provided by Kou et al. (2020), who highlighted that a higher sheath-to-vessel diameter ratio increased the risk of vascular access-related injury, thus emphasizing the clinical necessity of careful sheath selection in this population.

Our results are consistent with the findings of Amoozgar et al. (2019), who emphasized that younger children are particularly susceptible to vascular complications because smaller vessel diameters increase the likelihood of arterial obstruction when larger introducer sheaths are used. Furthermore, the sheath-to-vessel ratio becomes proportionally larger in infants and younger children, increasing the risk of vascular injury and impaired distal perfusion. The rate of device mobilization observed in the present study was 1.4%, which appears lower than that reported by Ibrahim and Khorsheed (2020). Nevertheless, device embolization remains an important procedural complication of transcatheter interventions in children with congenital heart disease and warrants careful attention during device deployment and follow-up.

Consistent with our findings, a variety of studies have shown that interventional catheterization has a higher incidence of vascular complications than diagnostic catheterization. As an illustration, Moustafa et al. (2016) concluded that patients who underwent interventional catheterization experienced a higher complication rate (8.2%) than those who had diagnostic procedures (1.5%). The researchers revealed that younger age and a higher ratio of sheath size to weight were significant predictors of vascular complications during catheterization. The incidence of vascular injury and thrombosis in our study was 2%, compared with the higher rates reported by Amoozgar et al., who documented arterial and venous complications in 5% and 4% of patients, respectively. This discrepancy may be attributable to differences in patient characteristics, procedural complexity, operator experience, and vascular access strategies between the two studies.

This study has several limitations; the first is the relatively small number of cases, which depended on the annual workshop program. The number of procedures performed was determined according to the availability of cardiac catheterization materials during these workshops. This is similar to what was previously reported by Mbabazi et al. (2024) and Gelaw et al. (2025). Their work also depended on the availability of equipment, resulting in delayed management of patients with CHD. However, to improve procedural safety in future practice, the focus should be on reducing access-related risks. The routine use of ultrasound-guided vascular access is strongly recommended, as it significantly lowers the incidence of arterial puncture and hematoma formation. In addition, selective use of clip-based vascular closure devices, particularly for large-bore access, may enhance hemostasis and reduce late vascular complications.

CONCLUSION

Vascular complications after transcatheter procedures in CHD were significantly associated with procedural factors (vascular access and delivery sheath-weight ratio) and younger age predicted complications. Vascular injury and device embolization represent the most frequent procedural complications. While limited by the small number of patients included in this study compared with large international centers, these findings require careful patient selection, appropriate device and sheath sizes, and continuous improvement of procedures and techniques to ensure safety and favorable results. Subsequent procedures should focus on reducing procedure-related complications by utilizing clip-based vascular closure devices when large-bore access is performed, to achieve secure hemostasis and ensure patient safety. Larger sample sizes and multicenter studies are also needed to confirm these findings and further improve risk stratification and outcomes.

ETHICS

This retrospective observational, non-interventional study was undertaken utilizing anonymized medical data, with formal consent acquired from the heads of the departments at Benghazi National Heart Center.

FINANCIAL SUPPORT AND SPONSORSHIP:

Nil.

CONFLICTS OF INTEREST:

There are no conflicts of interest.

Author contributions: Mariam Madany created and designed the study, collected and analyzed the data, and created the manuscript. Murshed Haidar, Abdeljawad Algasi, Amal Khazmi, Rasmia Feituri, and Hajir Alkeelani contributed to data collection and manuscript preparation.

REFERENCES

- Ali, F., Yeh, M. J., Bergersen, L., Gauvreau, K., Polivenok, I., Ronderos, M., ... & Hasan, B. S. (2023). Congenital cardiac catheterization in low- and middle-income countries: the international quality improvement collaborative catheterization registry. *JACC: Advances*, 2(4), 100344. <https://doi.org/10.1016/j.jacadv.2023.100344>
- Fattouh, A. M., Sobhy, R., Abo-Seif, M., & Abd-El Aziz, F. M. (2017). Retrospective analysis of cardiac catheterization procedures in a tertiary care pediatric cardiac center. *Egyptian Pediatric Association Gazette*, 65(1), 15-20. <https://doi.org/10.1016/j.epag.2017.01.002>.
- Alsherif, H. F., Bahgat, R. S., Elshiegh, R. G., & Dawood, B. M. (2024). Effect of Implementing Educational Strategies on Nurses' Performance Regarding Cardiac Catheterization for Children with Congenital Heart Disease. *Tanta Scientific Nursing Journal*, 33(2).
- AFKAR, R. M., SALMA, G. M., ELSISI, A. M., & MARWA, A. I. (2018). Effect of Nursing Guidelines for Nurses on Occurrence of Selected Post-Therapeutic Cardiac Catheterization Complications Among Children. *The Medical Journal of Cairo University*, 86(June), 2127-2139.
- Kou, L., Wang, Q., Long, W. A., Tang, F., & Li, L. (2020). Emerging predictors of femoral artery occlusion after pediatric cardiac catheterization. *Scientific Reports*, 10(1), 14001. <https://doi.org/10.1038/s41598-020-70891-5>

- Tokel, K., Gümüş, A., Ayabakan, C., Varan, B., & Erdoğan, İ. (2018). Complications of cardiac catheterization in children with congenital heart disease. *The Turkish Journal of Pediatrics*, 60(6), 675–683. <https://doi.org/10.24953/turkjpeds.2018.06.008>
- Mbabazi, N., Aliku, T., Namuyonga, J., Tumwebaze, H., Ndagire, E., Obongonyinge, B., ... & Lubega, S. (2024). Congenital heart disease cardiac catheterization at Uganda Heart Institute, a 12-year retrospective study of immediate outcomes. *BMC Cardiovascular Disorders*, 24(1), 463. <https://doi.org/10.1186/s12872-024-04085-6>
- Gerçeker, E., Yılmaz, M. M., Meşe, T., Vuran, G., & Zihni, C. (2022). Validation of the Turkish Version of the Catheterization Risk Score for Pediatrics. *Anatolian journal of cardiology*, 26(12), 864–871. <https://doi.org/10.5152/AnatolJCardiol.2022.2008>
- Madany, M. M., Yousif, A. B., Rahouma, S., Khazmi, A., & Feituri, R. (2022). Libyan Experience in Congenital Heart Disease Interventions in the Eastern region of Libya at the National Heart Center, Benghazi, 2022.
- Habeeb, N. M. M., Nasef, M. W. A. E., & Elsharnouby, D. O. Y. (2021). Registry of Cardiac Patients who Underwent Cardiac Catheterization or Invasive Imaging Procedures at New Children's Hospital Ain Shams University. *Ain Shams Medical Journal*, 72(2), 341–349.
- Qawasmeh, Y., Hijazi, I., Altarawneh, H., Almomani, A., & Abu Haweleh, A. (2018). Interventional cardiac catheterization in congenital heart disease: Experience at Queen Alia Heart Institute. *JRMS*, 25(2), 64–67. DOI: 10.12816/0049835
- Ibrahim, S. A., & Khorsheed, N. T. (2020). Complications of Cardiac Catheterization of Congenital Heart Diseases in Pediatrics. *Indian Journal of Public Health Research & Development*, 11(4).
- Amoozgar, Hamid, Naghshzan, Amir, Edraki, Mohammad Reza, Jafari, Hamed, Ajami, Gholam Hossein, Mohammadi, Hamid, Mehdizadegan, Nima, Borzouee, Mohammad, & Keshavarz, Kambiz. (2019). Arterial and Venous Complications Early After Cardiac Catheterization in Children and Adolescents: A Prospective Study. *Iranian Journal of Pediatrics*, 29(5), 0-0. SID. <https://sid.ir/paper/755175/en>
- Praditukrit, A., Wongwaitawee Wong, K., Sangsupawanich, P., Roymanee, S., Jarutach, J., Buntharikpornpun, R., & Puttharak, S. (2025). Development of a Pediatric Vascular Catheterization Complication Score (Ped-VCCScore) for predicting post-cardiac catheterization complications. *PloS one*, 20(6), e0325044. <https://doi.org/10.1371/journal.pone.0325044>
- Quinn, B. P., Gunnelson, L. C., Kotin, S. G., Gauvreau, K., Yeh, M. J., Hasan, B., ... & Bergersen, L. (2024). Catheterization for congenital heart disease adjustment for risk method II. *Circulation: Cardiovascular Interventions*, 17(3), e012834. <https://doi.org/10.1161/CIRCINTERVENTIONS.123.01283>
- Gamboa, R., Bravo, A., Damsky-Barbosa, J., Benítez, E., Pedroni, P., Roth, M., Mollón, F. P., & Solari, E. (2023). Complicaciones del cateterismo cardiaco en cardiopatías congénitas. 30 años de experiencia. Un nuevo score ajustado al riesgo [Complications of cardiac catheterization in congenital heart disease. 30 years of experience. A new risk-adjusted

score]. *Archivos de cardiologia de Mexico*, 93(2), 189–196.
<https://doi.org/10.24875/ACM.21000319>

- A Moustafa, G., Kolokythas, A., Charitakis, K., & V Avgerinos, D. (2016). Diagnostic cardiac catheterization in the pediatric population. *Current Cardiology Reviews*, 12(2), 155-162. DOI: <https://doi.org/10.2174/1573403X12666160301120955>
- Gelaw, T. T., & Alebachew, B. Z. (2025). Consequences and complications of un-intervened congenital heart defects in children: A retrospective cross-sectional study. *Progress in Pediatric Cardiology*, 76, 101776. <https://doi.org/10.1016/j.ppedcard.2024.101776>.
- Yavaş Abalı, Z., Nişli, K., Dindar, A., Eker, R., & Aydoğan, Ü. (2022). Evaluation of Complications Associated with Cardiac Catheterization: A Single-center Experience. *Trends in Pediatrics*, 3(4), 156-162. <https://doi.org/10.4274/TP.2022.46330>
- Ganea, G., Cintează, E. E., Filip, C., Iancu, M. A., Balta, M. D., Vătăşescu, R., Vasile, C. M., Cîrstoveanu, C., & Bălgrădean, M. (2023). Postoperative Cardiac Arrhythmias in Pediatric and Neonatal Patients with Congenital Heart Disease—A Narrative Review. *Life*, 13(12), 2278. <https://doi.org/10.3390/life13122278>