Dongola University

FACULTY OF MEDICINE

DEPARTMENT OF COMMUNITY MEDICINE

RESEARCH PROPOSAL

Prevalence and Pattern of Diagnosed Congenital Heart Disease Among Live-Born Newborns at Dongola Specialized Hospital, Sudan 2026

Supervisor:

Dr. Hind Taj Al-Sir

Submitted by:

Siham Diaa Eldin Gamal
Yasmeen Alshiekh Abdallah Alshiekh

Academic year: Sixth Year

1. Introduction

1.1 Background

Congenital heart disease (CHD) refers to structural abnormalities of the heart or great vessels that are present at birth. CHD ranges from relatively mild lesions to critical defects that may require urgent assessment and intervention. Early recognition is important because delayed diagnosis can affect clinical outcomes, while the distribution of diagnosed lesions depends partly on access to examination, echocardiography, referral, and specialist

care (1–3).

Evidence from Sudan remains limited and is largely based on studies conducted in Khartoum or on selected populations. Abdelrahman and Diab reported a hospital-based prevalence of 14.3 per 1,000 pediatric attendees in Khartoum State; this is not directly equivalent to birth prevalence among newborns (4). An earlier study among schoolchildren in Sahafa Town also described CHD in a different age group and setting (5). These studies provide context but do not establish the prevalence of diagnosed CHD among live births in Northern State.

No local estimate has been identified for Dongola Specialized Hospital. Reviewing hospital birth registers alongside newborn, pediatric, cardiology, and echocardiography records may provide a practical estimate of diagnosed CHD among hospital-born live newborns and describe the types of defects documented among eligible cases, including newborns referred from outside the hospital.

1.2 Problem Statement

Global burden. Congenital heart disease (CHD) is one of the most common severe congenital disorders. The World Health Organization (WHO) estimates that congenital disorders cause about 240,000 deaths among newborns within 28 days of birth every year, and a further 170,000 deaths among children aged 1 month to 5 years; nearly nine in ten children born with a serious congenital disorder live in low- and middle-income countries (1). Pooling 114 studies that included 24,091,867 live births and 164,396 cases of CHD, van der Linde et al. found that the reported birth prevalence rose from 0.6 per 1,000 live births in 1930–1934 to 9.1 per 1,000 (95% CI 9.0–9.2) after 1995, equivalent to about 1.35 million newborns with CHD every year, with regional estimates of 9.3 per 1,000 in Asia, 8.2 in Europe and 6.9 in North America (2). The update by Liu et al., covering 260 studies and 130,758,851 live births between 1970 and 2017, reported the highest prevalence so far, 9.41 per 1,000 live births (95% CI 8.60–10.25) in 2010–2017; mild lesions (ventricular septal defect, atrial septal defect and patent ductus arteriosus) accounted for 93.4% of the increase, which the authors linked mainly to better postnatal detection (3). Reported prevalence therefore reflects diagnostic capacity as much as true risk: published incidence ranges from about 4 to 50 per 1,000 live births, depending mainly on how many small ventricular septal defects are detected (6).

Regional burden (Africa). The African picture is incomplete. Liu et al. reported the lowest regional prevalence in the world, 2.3 per 1,000 live births (95% CI 0.43–5.70), compared with 9.3 per 1,000 in Asia, but with a very wide confidence interval (3). This figure probably reflects limited data and case ascertainment rather than a truly lower risk: Zühlke et al. described one of the highest burdens of heart disease among children and young adults in Africa, noted that critical lesions such as left-sided obstructive defects are rarely reported (suggesting early death of affected children and under-estimation of the true prevalence),

and reported that most congenital lesions in Africa are not diagnosed before birth (8). Most African studies describe hospital, referral or school populations rather than birth cohorts; at the national cardiac referral center in Tanzania, for example, CHD was the leading cause of heart disease among 6,058 children, and late referral was common (10), and studies from Nigeria likewise describe referral and school-based populations (9,11).

National burden (Sudan). In Sudan, the available data are few, dated and geographically narrow. Suliman, reviewing the state of heart disease in a country of more than 39 million people, reported CHD in about 0.2% of children (14). The earliest Sudanese reports date from 1994 (13) and 1997 (5). The most recent, by Abdelrahman and Diab, reviewed records of four pediatric hospitals in Khartoum State between January 2018 and December 2019 and identified 596 children with CHD among 41,437 pediatric patients, a hospital-based prevalence of 14.3 per 1,000 (13.9 in 2018 and 14.8 in 2019). The commonest lesions were ventricular septal defect (26.6%), tetralogy of Fallot (14.1%), patent ductus arteriosus (10.6%), atrial septal defect (6.2%) and transposition of the great arteries (5.9%); 67.1% of children were diagnosed before the age of 2 years, and about 20% were diagnosed after the age of 5 years, suggesting delayed detection. The authors also stated that no local database existed before their study and that poor quality of medical records limited the analysis of risk factors (4). In El-Obeid, Kordofan, CHD accounted for 70% of structural heart disease among 80 children, with ventricular septal defect (22.5%) and tetralogy of Fallot (11%) the most frequent lesions (12). None of these figures is a birth-based estimate, because their denominators are hospital attendees or schoolchildren rather than live births.

Local gap. No local estimate has been identified for Northern State, and the prevalence and pattern of diagnosed congenital heart disease among live-born newborns at Dongola Specialized Hospital have not been systematically described. Without local data, the hospital and researchers have limited evidence on the number of hospital-born newborns with documented CHD, the distribution of lesion types, and the clinical and perinatal characteristics recorded for affected newborns. Records also include referred newborns born elsewhere, but these cases cannot be combined with hospital-born cases when calculating prevalence using the hospital's live-birth total.

1.3 Justification

No birth-based estimate exists in Sudan. All Sudanese estimates identified use hospital attendees or schoolchildren as denominators (4,5,12), so they cannot be compared with the global figures of 9.1–9.4 per 1,000 live births (2,3). A live-birth denominator, as used in registry-based studies such as EUROCAT (live-birth prevalence 7.2 per 1,000) (7), is needed to place Sudan on the same scale as other populations. The hospital birth register at Dongola Specialized Hospital makes this possible.

Why Northern State and Dongola Specialized Hospital. The Sudanese evidence comes from Khartoum State, Kordofan and Sahafa Town (4,5,12), and no data have been identified from Northern State. The Khartoum data come from large pediatric and cardiac referral centers, including the Sudan Heart Center (4); lesion patterns in such centers reflect referral pathways and access to echocardiography as well as the underlying burden (8,10), so they cannot be assumed to apply to newborns delivered at a state hospital. The very low and

imprecise African estimate (3) further shows that local data from settings with limited diagnostic access are needed before the burden can be judged.

Why newborns. Congenital disorders cause about 240,000 newborn deaths each year (1), critical lesions are rarely reported in Africa (8), and late referral and late diagnosis have been documented in Tanzania (10) and in Khartoum, where about 20% of children were diagnosed after the age of 5 years (4). The newborn period is the earliest point at which CHD can be documented, and describing what is diagnosed, how, and when among newborns at Dongola will show where diagnosis is being missed or delayed.

Feasibility and expected benefit. This retrospective record review uses existing hospital records, without additional clinical procedures, and adapts the WHO birth-defects surveillance approach (15). It will produce local baseline information on the prevalence and pattern of diagnosed CHD, will separate hospital-born from referred newborns so that the estimate remains valid, and will document gaps in diagnosis and record keeping of the kind reported in Khartoum (4). The results can inform service planning (echocardiography access and referral pathways) and future prospective studies in Northern State, and add a Sudanese data point for comparison with the Khartoum and Kordofan studies (4,12).

1.4 General Objective

To assess the prevalence and describe the pattern of diagnosed congenital heart disease among live-born newborns at Dongola Specialized Hospital during January–August 2026, using a retrospective review of hospital records.

1.5 Specific Objectives

1.To estimate the prevalence of documented CHD among live-born newborns delivered at Dongola Specialized Hospital from 1 January to 31 August 2026.

2.To describe the types and distribution of CHD lesions documented among eligible diagnosed newborns, including hospital-born and referred newborns, reported separately where relevant.

3.To describe selected demographic, maternal, perinatal, and clinical characteristics recorded for eligible newborns with diagnosed CHD.

4.To describe diagnostic documentation, including the use and recorded findings of echocardiography, and referral status/source where available.

Research Questions

What is the prevalence and pattern of diagnosed congenital heart disease among live-born newborns at Dongola Specialized Hospital during January–August 2026, and what clinical and epidemiological characteristics are

documented among eligible diagnosed cases?

Hypothesis

This is a descriptive study, and no formal hypothesis testing is planned. The working hypothesis is that the prevalence of diagnosed and documented CHD among live-born newborns at Dongola Specialized Hospital will be at or below the global estimate of about 9 per 1,000 live births (2,3), because of limited access to diagnostic services, and that septal defects and patent ductus arteriosus will be the most frequent lesions, as reported in Sudanese studies 4,12,13)).

2. Literature Review

2.1 Global

Global studies demonstrate that reported CHD birth prevalence varies by study period, population, diagnostic approach, and completeness of case ascertainment. The systematic review by van der Linde et al. pooled 114 studies and reported that birth prevalence rose from 0.6 per 1,000 live births in 1930–1934 to 9.1 per 1,000 after 1995, with the highest regional estimate in Asia (9.3 per 1,000), followed by Europe (8.2 per 1,000) and North America (6.9 per 1,000). The authors suggested that limited access to health care and diagnostic facilities probably explains differences between high- and low-income countries (2). Liu et al. subsequently updated the evidence base and estimated a prevalence of about 9.4 per 1,000 for the 2010–2017 period (3).

Much of this variation is methodological. Hoffman and Kaplan found that reported incidence ranged from about 4 to 50 per 1,000 live births, depending mainly on how many small ventricular septal defects were included, which in turn depends on how early and how intensively the diagnosis is sought (6). Population-based registries show a similar picture: across 29 EUROCAT registries covering 3.3 million births in Europe, the total prevalence of CHD was 8.0 per 1,000 births, the live-birth prevalence was 7.2 per 1,000, and severe non-chromosomal CHD occurred in 2.0 per 1,000 births (7). For this reason the present study defines its case definition and exclusions explicitly and reports the prevalence of diagnosed and documented CHD.

Detection in newborns also depends on screening practice; where pulse oximetry screening is not routine, some newborns with CHD may be recognized only later, which is relevant to a record-based study.

2.2 African Evidence

African studies frequently describe children evaluated in hospitals or specialist referral services rather than complete birth cohorts. Their denominators therefore differ from the total number of live births, and their case mix may reflect referral pathways and availability of echocardiography as well as the underlying population burden. In a review of African data since 2005, Zühlke et al. described one of the highest burdens of heart disease among children and young adults, noted that critical lesions such as left-sided obstructive defects were rarely reported, which suggests poor survival of affected children and under-estimation

of the true prevalence, and reported that most congenital lesions in Africa are not diagnosed before birth (8).

Studies from Nigeria and Tanzania, for example, describe the clinical spectrum of pediatric cardiac disease in referral settings (9,10). At the national cardiac referral center in Tanzania, CHD was the leading cause of heart disease among 6,058 children with complete first-echocardiography reports, acyanotic lesions were more frequent than cyanotic lesions, and the authors noted a tendency toward late referral (10). A school-based study in the Niger Delta region of Nigeria likewise reported a predominance of acyanotic lesions among children with CHD (11).

2.3 Sudanese Evidence

In Sudan, Abdelrahman and Diab described CHD among pediatric attendees in Khartoum State between 2018 and 2019, reporting a hospital-based prevalence of 14.3 per 1,000 attendees and common lesions including ventricular septal defect, tetralogy of Fallot, and patent ductus arteriosus (4). Khalil et al. studied schoolchildren in Sahafa Town, which represents a different age group and sampling frame (5).

Hospital-based studies from other parts of Sudan describe a similar spectrum. In a study of 80 children aged up to 18 years attending pediatric services in El-Obeid, Kordofan, CHD accounted for 70% of structural cardiac disease; the most frequent lesion was ventricular septal defect (22.5% of all children), followed by tetralogy of Fallot (11%), and Down syndrome was documented in 6% (12). Earlier Sudanese reports cited in that study, including those of El Hag and Suliman, also identified ventricular septal defect, atrial septal defect, tetralogy of Fallot, patent ductus arteriosus, and pulmonary stenosis as the commonest lesions (13,14). Because rheumatic heart disease remains an important acquired condition in Sudan, studies from mixed pediatric cardiac clinics combine congenital and acquired disease and are not directly comparable with a birth-based estimate (12). The available evidence does not provide a directly comparable estimate for live births at Dongola Specialized Hospital.

2.4 Research Gap

This study will address the local evidence gap through a retrospective review of birth registers and relevant clinical records. Because record-based diagnosis may miss defects that were not recognized or documented during the review period, the study will estimate the prevalence of diagnosed and documented CHD rather than claim to measure all congenital defects present at birth.

3.1 Study Design

A hospital-based retrospective record review with a descriptive component will be

conducted. The study will use existing birth registers and clinical records to identify eligible hospital-born live newborns and documented CHD diagnoses during the defined period.

3.2 Study Area

The study will be conducted at Dongola Specialized Hospital, Dongola, Northern State, Sudan.

3.3 Study Setting

The setting is the hospital's delivery, neonatal, and pediatric services, together with any cardiology and echocardiography services available. Relevant sources may include the maternity/delivery register, neonatal unit records, newborn and pediatric files, cardiology records, echocardiography reports, and referral documentation, subject to administrative approval and availability. The availability of pediatric cardiology and echocardiography services at the hospital, and whether echocardiography is routinely performed for newborns with suspected CHD, will be confirmed with hospital administration at the start of the study and described in the report.

3.4 Study Period

The birth cohort will include live births delivered at Dongola Specialized Hospital from 1 January to 31 August 2026. Records will be reviewed for CHD diagnoses documented up to a review cut-off date of 15 November 2026, so that every newborn in the birth cohort has at least 10 weeks of potential follow-up for diagnosis. Data abstraction will be undertaken after the required ethical and administrative approvals. Diagnoses documented after the cut-off date will not be actively followed up for this study.

3.5 Study Population

Two related groups will be described separately:

Prevalence cohort: all live-born newborns delivered at Dongola Specialized Hospital and recorded in the birth/delivery register between 1 January and 31 August 2026. The denominator will be the total number of eligible live births in this cohort, and only CHD cases born within this cohort and diagnosed by the review cut-off date will contribute to the numerator.

Diagnosed-case cohort: eligible newborns with documented CHD identified in the hospital records during the review period, including newborns born at Dongola and newborns born elsewhere who were referred to or assessed at Dongola. Referred cases born elsewhere will be included in the descriptive analysis of lesion patterns and available characteristics, but excluded from the hospital-born prevalence numerator.

Newborn eligibility: for the prevalence cohort, all live births recorded in the birth register are included, and any CHD diagnosis documented up to the review cut-off date is counted. For referred cases born elsewhere, a newborn is defined as an infant aged 28 days or less at the date of first assessment or documented diagnosis at Dongola Specialized Hospital. The data form will capture date of birth, date of diagnosis/assessment, and place of birth so eligibility can be checked transparently. Referred infants older than 28 days at first

assessment will not be treated as newborn cases.

3.6 Sampling and Sample Size

A census approach will be used: all eligible records available within the defined period will be reviewed. No sample-size calculation is required for the planned total-coverage record review. The final numbers included will depend on the completeness and accessibility of the hospital registers and clinical records.

3.7 Inclusion Criteria

Live-born newborns delivered at Dongola Specialized Hospital from 1 January to 31 August 2026 and recorded in the birth register, for inclusion in the prevalence denominator.

Newborns with a documented CHD diagnosis in eligible hospital records available during the review period.

- Newborns born outside the hospital and referred to or assessed at Dongola during the review period, for descriptive case analysis only, when they meet the newborn eligibility criteria and have a documented CHD diagnosis.

3.8 Exclusion Criteria

Records with no reliable evidence of congenital heart disease or where the diagnosis cannot be verified from available documentation.

Acquired cardiac conditions without a documented congenital structural defect.

Duplicate records for the same newborn; repeat visits will be linked to one unique study record.

Records outside the newborn eligibility criteria.

- Isolated patent foramen ovale, and isolated patent ductus arteriosus in preterm infants (less than 37 weeks); these will be recorded separately and not counted as CHD.

3.9 Methods of Data Collection

Data will be extracted using a structured data-abstraction form adapted from relevant World Health Organization birth-defects surveillance guidance (15). The team will review birth registers to establish the total number of eligible live births and identify hospital-born diagnosed cases. Eligible clinical records, neonatal records, pediatric/cardiology notes, echocardiography reports, and referral notes will then be reviewed using a study code. The form will record place of birth and diagnostic timing to distinguish the prevalence cohort from referred cases.

The form will be pretested on a small number of records that will not be included in the final dataset where feasible. The investigators will agree on variable definitions and coding before full abstraction. Duplicate entries will be checked using available non-identifying linkage information, and uncertain data will be rechecked against the source record.

3.10 Study Variables

Variables will include study code; date of birth; sex; place of birth; residence if recorded; date and age at diagnosis; referral status and referral source; diagnostic basis (echocardiography and/or clinician documentation); CHD lesion/type; cyanotic or acyanotic classification if supported by the record; single or multiple lesions; selected maternal and perinatal characteristics available in the file (gestational age, birth weight, maternal age, parity, consanguinity, maternal diabetes or other chronic illness, and family history of CHD); associated congenital anomalies or syndromes (for example Down syndrome); relevant clinical presentation; and documented referral or initial management. Missing or undocumented information will be coded as missing/unknown and will not be inferred.

3.11 Operational Definitions

Live-born newborn: A baby showing signs of life after birth, delivered at Dongola Specialized Hospital during 1 January–31 August 2026 and recorded in the hospital birth/delivery register.

Diagnosed CHD: A structural congenital cardiac defect documented in the clinical record by a qualified clinician and/or confirmed by echocardiography. The basis of diagnosis will be recorded; suspected cases without a documented diagnosis will not be counted as confirmed cases.

Hospital-born prevalence cohort: All eligible live-born newborns delivered at Dongola Specialized Hospital during the study birth period. Only diagnosed CHD cases from this cohort will contribute to the prevalence numerator.

Referred case cohort: A newborn aged 28 days or less at first assessment, born outside Dongola Specialized Hospital and referred to or assessed at the hospital during the defined record-review period. These cases may contribute to lesion-pattern and characteristics descriptions but will not be added to the prevalence numerator when the denominator is hospital live births.

CHD classification: Lesions will be coded using ICD-10 Chapter Q20–Q26 and grouped into main categories (for example septal defects, valvular and outflow tract lesions, and complex cyanotic lesions).

3.12 Data Management and Analysis

Data will be coded and entered into a password-protected spreadsheet or statistical package. Records will be checked for missing values, duplicate entries, impossible dates, and internal inconsistencies. A record with missing data for one variable may still contribute to analyses for other variables when appropriate.

The prevalence of diagnosed CHD will be calculated as:

Prevalence (%) = (eligible hospital-born live newborns with documented CHD ÷ total eligible live births at Dongola Specialized Hospital during 1 January–31 August 2026) × 100.

- The estimate will also be expressed per 1,000 live births. A 95% confidence interval will be calculated using the Wilson score method. Referred newborns born elsewhere will not be added to the numerator for this estimate. Lesion types and clinical/epidemiological characteristics will be summarized as frequencies and

percentages among eligible diagnosed cases; hospital-born and referred cases will be identified and reported separately where needed. For newborns with more than one lesion, patient counts and lesion counts will be distinguished. Continuous variables will be summarized using mean and standard deviation or median and interquartile range, depending on their distribution and data completeness. The study is primarily descriptive; any comparisons will be limited to variables with adequate and reliable data.

3.13 Quality Assurance, Bias, and Limitations

A standardized abstraction form and written variable definitions will be used. The investigators will review a subset of extracted records for consistency, reconcile discrepancies with source records, and check for duplicate patients. Diagnosis will be classified according to documented clinical and/or echocardiographic evidence; suspected cases without a documented diagnosis will not be counted as confirmed CHD.

Selection and information bias may arise because the study depends on hospital attendance, referral patterns, diagnostic access, and completeness of records. Some defects may not be recognized or documented by the review cut-off date of 15 November 2026, especially among newborns born near the end of August 2026, although every newborn in the birth cohort has at least 10 weeks of potential follow-up. Limited availability of echocardiography may also lead to under-diagnosis and therefore under-estimation. Therefore, the estimate represents the prevalence of diagnosed and documented CHD identified in the available records during the specified review window and may underestimate the true prevalence of CHD present at birth. Referred cases born elsewhere do not have a matching denominator in this study and will be used only for descriptive analyses. Findings will not be generalized to all newborns in Northern State or Sudan.

3.14 Ethical Considerations

Ethical approval will be obtained from the Ministry of Health (MOH), and official permission will be secured from the administration of Dongola Specialized Hospital. Because this is a retrospective review of existing records with no contact with newborns or their families, a waiver of individual informed consent will be requested. Data will be abstracted using study codes without names or other direct identifiers, stored in a password-protected file accessible only to the research team, and reported in aggregate form only.

4. Time-line

Phase	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11
Proposal finalization and ethical/administrative approval											
Pilot testing of data-collection sheet											
Data collection from medical records											

Phase	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11
Data entry and cleaning											
Statistical analysis											
Report writing, review, and final submission											

5. Budget Breakdown

Item	Estimated Cost
Print out	150,000 SDG
Transport	100,000 SDG
Internet	100,000 SDG
Analysis	100,000 SDG
Total	450,000 SDG

7. References

1. World Health Organization. Congenital disorders [Internet]. Geneva: World Health Organization; 2023 Feb 27 [cited 2026 Sep 29]. Available from: https://www.who.int/news-room/fact-sheets/detail/birth-defects.

2. van der Linde D, Konings EEM, Slager MA, Witsenburg M, Helbing WA, Takkenberg JJM, et al. Birth prevalence of congenital heart disease worldwide: a systematic review and meta-analysis. J Am Coll Cardiol. 2011;58(21):2241-7. doi:10.1016/j.jacc.2011.08.025.

3. Liu Y, Chen S, Zühlke L, Black GC, Choy MK, Li N, et al. Global birth prevalence of congenital heart defects 1970-2017: updated systematic review and meta-analysis of 260 studies. Int J Epidemiol. 2019;48(2):455-63. doi:10.1093/ije/dyz009.

4. Abdelrahman O, Diab R. Prevalence and pattern of congenital heart disease among children in Khartoum State, Sudan: a reflection of the current cardiac profile. Cureus. 2022;14(1):e21196. doi:10.7759/cureus.21196.

5. Khalil SI, Gharieb K, El Haj M, Khalil M, Hakiem S. Prevalence of congenital heart disease among schoolchildren of Sahafa Town, Sudan. East Mediterr Health J. 1997;3(1):24-8. doi:10.26719/1997.3.1.24.

6. Hoffman JI, Kaplan S. The incidence of congenital heart disease. J Am Coll Cardiol. 2002;39(12):1890-900. doi:10.1016/s0735-1097(02)01886-7.

7. Dolk H, Loane M, Garne E; European Surveillance of Congenital Anomalies (EUROCAT) Working Group. Congenital heart defects in Europe: prevalence and perinatal mortality, 2000 to 2005. Circulation. 2011;123(8):841-9. doi:10.1161/CIRCULATIONAHA.110.958405.

8. Zühlke L, Mirabel M, Marijon E. Congenital heart disease and rheumatic heart disease in

Africa: recent advances and current priorities. Heart. 2013;99(21):1554-61. doi:10.1136/heartjnl-2013-303896.

9. Ekure EN, Kalu N, Sokunbi OJ, Kruszka P, Olusegun-Joseph AD, Ikebudu D, et al. Clinical epidemiology of congenital heart disease in Nigerian children, 2012-2017. Birth Defects Res. 2018;110(16):1233-40.

10. Majani NG, Koster JR, Kalezi ZE, Letara N, Nkya D, Mongela S, et al. Spectrum of heart diseases in children in a national cardiac referral center, Tanzania, Eastern Africa: a six-year overview. Glob Heart. 2024 Jul 1. doi:10.5334/gh.1342.

11. Ujuanbi AS, Tabansi PN, Otaigbe BE. Prevalence of congenital heart diseases among primary school children in the Niger Delta region of Nigeria, West Africa. Ann Pediatr Child Health. 2016;4(5):1116.

12. Mustafa AEM, Ali NMT, Abd Elrahim SY, Bharti RK, Chaudhary S. The major clinical presentations and echocardiographic features of structural cardiac disease among children in Kordofan, Sudan. Pak J Med Health Sci. 2018;12(4):1760.

13. el Hag AI. Pattern of congenital heart disease in Sudanese children. East Afr Med J. 1994;71(9):580-6.

14. Suliman A. The state of heart disease in Sudan. Cardiovasc J Afr. 2011;22(4):191-6. doi:10.5830/CVJA-2010-054.

15. World Health Organization. Birth defects surveillance: a manual for programme managers [Internet]. 2nd ed. Geneva: World Health Organization; 2020 [cited 2026 Oct 12]. Available from: https://www.who.int/publications/i/item/9789240015395.