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Risk Assessment in Pregnant Women with Congenital Heart Disease: A Meta-Analysis Study

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Abstract

Pregnant women with congenital heart disease (CHD) have a significantly increased risk of cardiovascular complications. Prediction of patients at the highest risk of life-threatening complications remains a major challenge (Chu et al., 2020). A meta-analysis has been conducted to examine the risk assessment of pregnant women with CHD to provide useful information and treatment guidelines concerning the associated risk.The search protocol involved literature published on established databases before September 2023. The combined risk and 95% confidence intervals (CIs) of pregnant women with CHD suffering from cardiovascular complications were analysed; the risk of preterm labor and small for gestational age (SGA) in women with CHD was also assessed. The analysis included 29 studies of 19,647 pregnant women with CHD. The risk of pregnant women with CHD suffering from cardiovascular complications was 3.90 (95% CI, 2.90–5.24). The risk of preterm labour in pregnant women with CHD was 1.82 (95% CI, 1.39–2.38), and the risk of SGA was 1.50 (95% CI, 1.13–1.99) (Dhiman et al., 2024). Owing to the high incidence of adverse events, pregnant women with CHD require more frequent prenatal examinations, and healthcare professionals should provide timely interventions to effectively ensure maternal and fetal safety (Regitz-Zagrosek et al., 2018; Siu & Colman, 2019).

Keywords: *Congenital Heart Disease, Pregnancy; Women's Health, Risk; Meta-Analysis, Cardiovascular Disease, Infant Complications, Postoperative Complications.*

Introduction

Heart disease complicates up to 4% of pregnancies worldwide and remains an important cause of maternal mortality, particularly in low- and middle-income countries (Dhiman et al., 2024; Regitz-Zagrosek et al., 2018). Advances in healthcare and increased longevity have led to a rising number of women with heart disease reaching childbearing age (Siu & Colman, 2019). Congenital heart disease (CHD) constitutes over 75% of adult cardiac disease in this population, as many affected mothers opt to conceive despite the potential risks (Gerber & Pignatelli, 2017). Pregnancy poses significant challenges for women with heart disease, with increased risks of complications such as heart failure, stroke, arrhythmia, and myocardial infarction (Silversides et al., 2018). Pregnancies complicated by CHD are also associated with a heightened incidence of premature labor, operative interventions, and maternal mortality (van Hagen et al., 2015; ROPAC, 2017).

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Background on Congenital Heart Disease

The improved prognosis of patients with congenital heart disease (CHD) has resulted in a steady increase in the number of women with CHD who are planning pregnancy. A substantial proportion of women with CHD remain at risk for the development or progression of heart failure, stroke, arrhythmia and myocardial infarction during pregnancy. Up to 4% of all pregnancies are complicated by maternal heart disease and this still remains one of the commonest causes of maternal mortality especially in low- and middle-income countries (Dhiman et al., 2024). Pregnancies with maternal CHD are associated with complications such as preterm labour, increased operative procedures like instrumental and caesarean delivery as well as maternal mortality. Neonates born to women with heart disease carry an increased risk of adverse outcomes like small for gestational age, preterm birth and recurrence of CHD or other congenital anomalies. Although many studies have reported adverse pregnancy outcomes like prematurity, small for gestational age and stillbirth in women with heart disease, data on pregnancy outcomes in women with CHD are limited. Additionally, very few studies have compared fetal outcome in women with CHD and those without heart disease and addressed the effect of surgery and cyanosis on fetal outcome.

Features of pregnancy with CHD include altered haemodynamics, hypercoagulability, neurohormonal activation and inability to exercise. These allow the impact of known risk factors to be determined and the findings to be validated in a separate cohort. Such studies take advantage of the availability of prospectively collected data, which were later aggregated in a meta-analysis to determine the most significant predictors.

Definition and Classification

Maternal heart disease complicates up to 4% of pregnancies worldwide and is a significant cause of maternal mortality and adverse pregnancy outcomes, especially in low- and middle-income countries (Dhiman et al., 2024). Owing to improved diagnosis and timely intervention, a growing number of women with congenital heart disease (CHD) are surviving to childbearing age and presenting for pregnancy. Nonetheless, pregnancy poses additional risks for women with CHD—including heart failure, stroke, arrhythmia, and myocardial infarction. Pregnancies in women with CHD are associated with higher rates of preterm labor, operative deliveries, and maternal death. Neonates born to mothers with CHD face increased risks of being small for gestational age, preterm birth, and recurrence of CHD or other congenital anomalies.

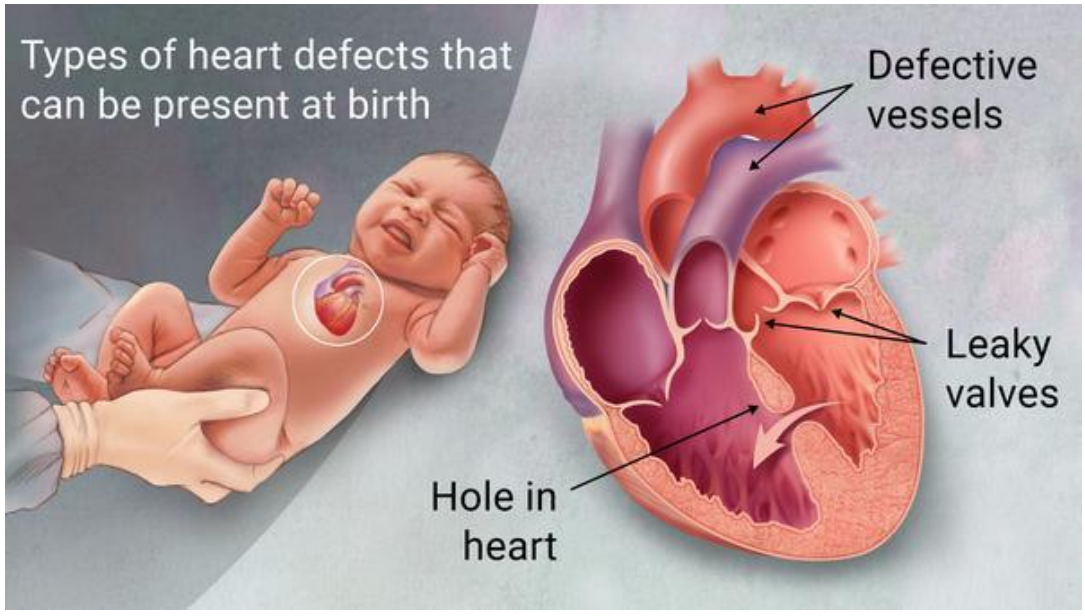


Fig1: Show That Types of Heart Defect That Can Be Present at Birth

Several studies have evaluated pregnancy outcomes in women with heart disease, focusing on CHD and repaired conditions. Prior research has identified risk factors for adverse outcomes and examined the risk for offspring. Studies have also sought to validate predictive models for cardiac and obstetric complications (Chu et al., 2020). Pregnancy management for women with complex CHD has garnered particular attention, with analyses of predictors of complications and cardiac outcomes after pregnancy. Large cohort studies document adverse pregnancy outcomes in women with heart disease; however, studies specifically addressing pregnant women with CHD remain limited. Few investigations compare fetal outcomes between women with and without heart disease or analyze the impact of surgery and cyanosis.

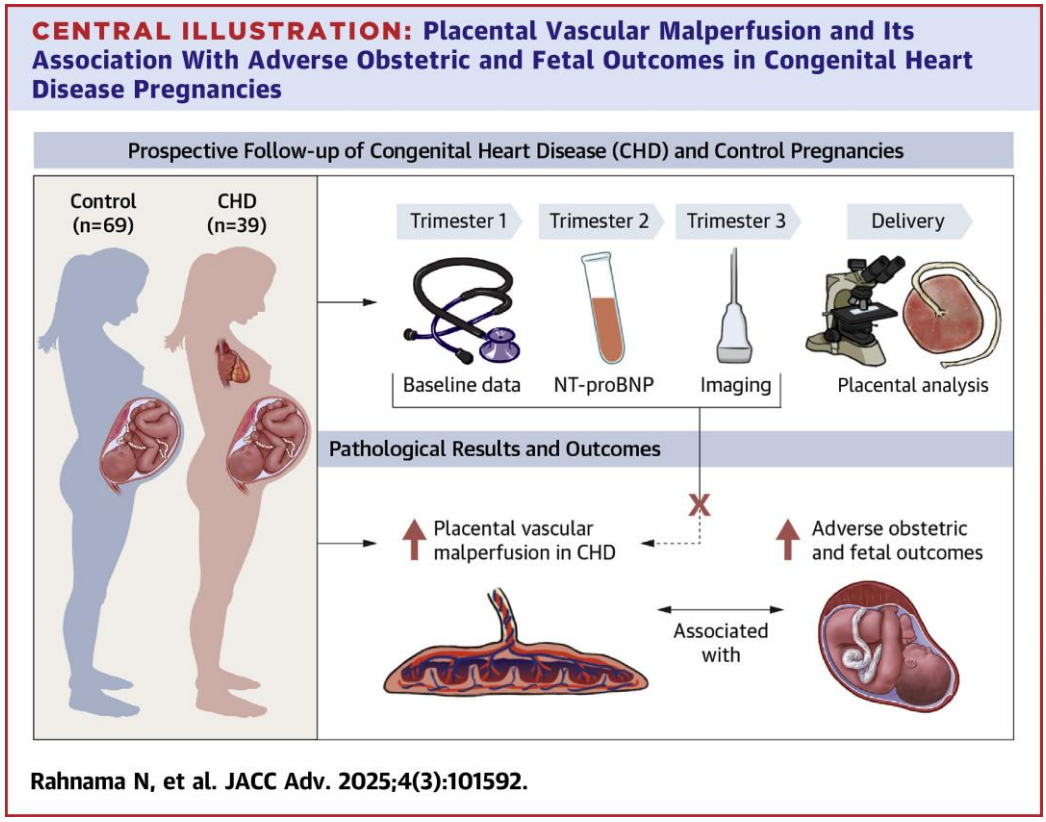
Epidemiology

The occurrence of congenital heart disease (CHD) in India is estimated at approximately 8.73 per 1,000 live births, while the global birth prevalence is reported as 9.41 per 1,000 live births (Wu et al., 2022). Pregnancy in women with CHD is associated with an elevated risk for mother and fetus, necessitating enhanced surveillance to improve outcomes. The reported risk of major adverse cardiac events (MACE) such as decompensated heart failure, arrhythmia, stroke, need for cardiac intervention, or death among pregnant women with CHD is 11–16% (Dhiman et al., 2024).

Pregnancy and Congenital Heart Disease

Increasingly, more women with congenital heart disease (CHD) are reaching reproductive age and contemplating pregnancy (Chu et al., 2020). Although pregnancy is not contraindicated for all patients with CHD, they remain at an elevated risk for adverse maternal and neonatal events compared to the general population. Certain features—including advanced New York Heart Association (NYHA) class, Eisenmenger syndrome, pulmonary hypertension, reduced left ventricular ejection fraction, sinus tachycardia, low arterial oxygen saturation, and shorter pregnancy duration—are predictive of poor maternal outcomes, while Eisenmenger syndrome,

preeclampsia, and low oxygen saturation predict adverse neonatal outcomes. Maternal cardiac pathologies complicate approximately 4% of pregnancies worldwide (Dhiman et al., 2024). Although women with CHD in particular are increasingly choosing to become pregnant, their offspring have an elevated risk of congenital heart disease or other anomalies, and they experience higher incidences of adverse pregnancy outcomes. Furthermore, these women themselves face heightened risks during pregnancy, including heart failure, stroke, arrhythmia, and myocardial infarction.



They are also more likely to experience preterm labor, preterm birth, and deliver infants small for gestational age and to undergo operative deliveries such as cesarean sections. Numerous large series have documented pregnancy outcomes among women with heart disease, yet specific data focusing solely on those with CHD are uncommon. Few investigations have compared fetal outcomes between women with CHD and healthy controls, or have stratified the data to examine the influence of surgical correction or cyanotic status. To address these gaps, a retrospective analysis was conducted to evaluate and compare fetal and cardiac outcomes in pregnant women with CHD and those without heart disease, with subgroup analyses examining cyanotic versus non-cyanotic disease and operated versus non-operated defects.

Physiological Changes During Pregnancy

Pregnancy influences women with congenital and acquired heart disease, affecting outcomes and long-term health. Pregnancy in women with heart disease requires specialized obstetric management. Women with heart disease encounter more pregnancy complications, especially when conceiving through fertility therapy. Women with valve prostheses face specific

pregnancy risks, including structural valve deterioration. Women with Marfan syndrome need close monitoring due to potential impacts on aortic growth and mortality. Outcomes vary based on the type of heart defect and previous surgical repairs, such as atrial switch operations. Pregnancy may contribute to systemic right ventricular dysfunction and deterioration over time. Long-term studies indicate that the effects of pregnancy on ventricular function and overall health depend on individual conditions and disease severity (Niwa, 2018).

During pregnancy, the common haemodynamic changes experienced by pregnant women before delivery include (i) a significant increase in plasma volume, stroke volume and cardiac output, with an elevation of heart rate and a reduction in systemic vascular resistance; and (ii) changes in the local cardiac environment, such as inflammation, with the over-production of reactive oxygen species. These changes impose an additional load on the heart, and, as a result, the size, weight and volume of chambers all increase and for women with or at risk of cardiovascular disease, they can impact cardiac function and ultimately cause cardiac dysfunction. The degree of cardiac adaptation to pregnancy depends mainly on the maternal cardiovascular status, which often can be complicated for women with CHD. Because the physical and physiological influences of pregnancy can vary according to the different CHD anomalies, the overall management of pregnant women with CHD should be based on consideration of the pathology, anatomical abnormality and haemodynamics.

Impact of Congenital Heart Disease on Pregnancy Outcomes

Maternal heart disease complicates up to 4% of pregnancies and remains a major contributor to maternal mortality worldwide (Dhiman et al., 2024). Prevalence of pregnancy in women with congenital heart disease (CHD) is rising due to improved healthcare, medical treatment, and longevity. Such women are at heightened risk of congestive heart failure, CVA/stroke, arrhythmia, and myocardial infarction during pregnancy. Pregnancies complicated by maternal CHD demonstrate increased susceptibility to preterm labour, operative delivery, and maternal mortality. Neonates of mothers with CHD are similarly vulnerable to small-for-gestational age, preterm birth, and recurrence of CHD or other congenital anomalies. Although diverse studies detailing pregnancy in women with heart disease have been published, relatively few focus specifically on the CHD subgroup. Comparisons of fetal outcomes between women with and without CHD are scarce, as are assessments of the influence of prior cardiac surgery or cyanotic status. A retrospective analysis was therefore undertaken to contrast fetal and cardiac outcomes between pregnant women with CHD and a matched cohort without heart disease. The study also investigated variations between cyanotic and non-cyanotic CHD and between operated and unoperated defects.

Risk Assessment Framework

Pregnant patients with congenital heart disease are far more likely to have adverse events than other groups. However, clinical risk models for this population are rarely developed and poorly validated, with the majority based on small retrospective cohorts. This study analyzed the aggregate data resulting from a meta-analysis on the adverse cardiac events of pregnant patients with congenital heart disease, and developed a hierarchical Bayesian model for predicting adverse cardiac events outcomes of pregnant patients, which was then integrated into an online risk assessment framework for pregnant patients. Given that pregnancy is a significant burden on the cardiovascular system for women with congenital heart disease, they carry a substantially higher risk of adverse cardiac events. To better assess the risk of adverse cardiac events for pregnant patients with congenital heart disease (Chu et al., 2020) , a meta-analysis was

conducted and a hierarchical Bayesian model was developed for describing distributions of diverse adverse cardiac events outcomes (Dhiman et al., 2024). It was incorporated as an online assessment framework, which quantified the risks of adverse cardiac events for pregnant patients with congenital heart disease.

Definition of Risk Assessment

In cardiology, risk assessment denotes a thorough evaluation designed to estimate the likelihood of adverse outcomes in patients with heart conditions. The term holds particular prominence in the context of pregnant women with congenital heart disease (CHD), where the prediction of potential complications and the probable development of life-threatening events is crucial (Chu et al., 2020). Risk assessment can be categorized according to the severity of associated events. Efforts to accurately determine the level of risk also make use of the risk stratification approach, through which individuals at higher or lower levels of risk are isolated for the purposes of more tailored progress or control.

In pregnancy, risk assessment often aims to foresee the likelihood that a pregnant woman with a specific condition might develop a particular complication during gestation (Dhiman et al., 2024). Similar methodologies have been applied to the general population, having produced a candidate classifier for the identification of individuals at high risk of myocardial ischemia based on sociodemographic and laboratory data. Predictors of adverse outcomes in pregnancies involving women with CHD have been defined through the analysis of multicenter prospective and retrospective datasets. Validation of the pre-existing modified WHO classification has also been conducted, alongside the proposition of alternatives whenever deemed stabilized clinical markers are lacking. There remains, however, a heavy emphasis on supplementary studies to further assess and expand the obtained findings. Risk assessment, at present, constitutes a multifaceted approach of considerable relevance, addressing a subject of increased interest in a setting of particularly heightened concern—the risk of cardiac patients facing adverse cardiac events during pregnancy.

Importance of Risk Assessment in Pregnant Women

Risk assessment is an essential part of the care of pregnant women with congenital heart disease. Congenital heart disease (CHD) is the most common congenital malformation, with an estimated prevalence of 0.8% of live births worldwide. Due to advances in medical and surgical treatments, 85% of these patients are expected to survive into adulthood, but they frequently remain only partially cured or may become reoperated during childhood. Consequently, the proportion of women with CHD who conceive and reach childbearing potential has risen dramatically (Chu et al., 2020).

Preconception counseling constitutes an important aspect of cardiac care in females with CHD and should be initiated early, ideally in adolescence, by cardiologists in conjunction with maternal-fetal medicine specialists experienced in pregnancy and congenital heart disease. Women who have not received regular cardiac care before conception should undergo re-assessment by a cardiologist in the early stages of pregnancy. Counseling should include general recommendations for a healthy pregnancy, such as weight control, smoking cessation, and periconceptional folic acid supplementation. Additionally, the discussion should encompass a detailed obstetric history and an evaluation of the risk of complications like pregnancy-induced hypertension and diabetes mellitus, both of which may affect cardiovascular function (Niwa, 2018).

Patients with CHD should receive pre-pregnancy counseling addressing the risks to both mother and fetus, the hereditary transmission potential, the possible course of the pregnancy, and considerations regarding sexual activity and infant care. It is common for women with CHD to experience heart failure and/or arrhythmia during pregnancy and the postpartum period, which can impair their ability to care for the newborn. Although the New York Heart Association (NYHA) classification is frequently employed to determine the advisability of pregnancy, reliance solely on this metric is inadequate for forecasting the individual prognosis. Specific congenital heart defects and conditions that require careful monitoring or preclude pregnancy are identified due to their association with high maternal and fetal risk, including complications such as cardiac failure, arrhythmias, thromboembolism, cardiac ischemia, aortic dissection, and exacerbated cyanosis. Maternal health constitutes a critical determinant of fetal and neonatal outcomes, and the incidence of adverse events varies according to the particular cardiac lesion. Furthermore, the risk of transmitting congenital heart disease to offspring depends on whether the cardiac condition originates maternally or paternally.

Methodology of the Meta-Analysis

This meta-analysis aims to evaluate the associations between congenital heart disease (CHD) and pregnancy outcomes in women with and without CHD. A comprehensive search was conducted in Web of Science, Scopus, ScienceDirect, EMBASE, PubMed, and Google Scholar databases for studies published until November 2023. Both prospective and retrospective observational cohorts met the eligibility criteria. Case-control and cross-sectional studies were excluded. Data extraction and quality assessment were independently performed by two reviewers using Microsoft Excel. A random-effects meta-analysis synthesized odds ratios and risk ratios, while R software computed the pooled estimates with 95% confidence intervals. Statistical heterogeneity was assessed using the Cochran Q test and I\0B2 statistic, and Egger\0B4s test evaluated publication bias. Large cohort investigations have linked heart disease to adverse pregnancy outcomes and have offered risk assessments. However, few studies focus exclusively on pregnant women with CHD or compare their fetal outcomes to those of women without heart disease. Building on a retrospective analysis conducted at an apex institute, the meta-analysis seeks to compare fetal and cardiac outcomes between these groups. Subgroup analyses consider cyanotic versus non-cyanotic CHD and operated versus non-operated defects (Dhiman et al., 2024). Electronic searches of PubMed, Web of Science/Scopus, Cochrane library, and Google Scholar databases were undertaken to identify relevant publications up to March 2021. Independent data extraction employed Microsoft Excel. STATA version 14 calculated pooled effect sizes with 95% confidence intervals for the influence of maternal periconceptional folic acid supplementation on CHD risk using the DerSimonian and Laird random-effects model. Statistical heterogeneity was evaluated through the Cochran Q test, I\0B2 statistic, and funnel plot inspection (Taye Wondemagegn & Afework, 2022).

Search Strategy

A stringent search was undertaken in PubMed and Cochrane Library databases, covering all reports in English published through August 2020. Core search terms included Pregnancy AND Heart Defect(s)/Disease(s)/Condition(s)/Abnormality(ies)/Failing, Congenital Heart Defect/Disease/Condition/Abnormality, and Pregnancy Outcome. The references of key studies were manually reviewed for additional relevant sources. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Taye Wondemagegn & Afework, 2022) directed the process. Reports were screened for observational studies involving

pregnant women with congenital heart disease (CHD) and at least one of the following outcomes: maternal mortality, arrhythmia, heart failure, stroke/transient ischemic attack (TIA), aortic dissection, cesarean section, postpartum hemorrhage, preterm birth (<37 weeks), small for gestational age, and perinatal mortality. When outcomes were stratified by diagnosis, data were extracted only for the first pregnancy if a study included multiple pregnancies per patient. Two investigators conducted the searches independently, resolving conflicts by consensus.

Inclusion and Exclusion Criteria

The selection criteria for studies included in the review were as follows: (a) retrospective or prospective studies, (b) published in English language, and (c) studies published between 2011 and 2022. Studies not within these parameters were excluded from analysis. The inclusion and exclusion criteria thus ensured that the corpus reflected contemporary research articulated in English.

Data Extraction and Quality Assessment

Two independent investigators separately extracted information on study characteristics and outcomes (Chu et al., 2020) (Dhiman et al., 2024). Disagreement was resolved by repeated review and consensus among all investigators. Extracted data included author names, year of publication, region, study period, study design, demographic and clinical characteristics of patients, and clinical outcomes. The Newcastle-Ottawa Scale was employed to assess risk of bias in observational studies.

The case group comprised pregnant women with congenital heart disease who delivered at a tertiary care hospital, whereas the control group consisted of pregnant women without heart disease who delivered during the same timeframe. Relevant patient information, such as demographic profiles, obstetric history, delivery details, and neonatal data, was collected. Specific heart disease data encompassed signs and symptoms, New York Heart Association functional class, cyanotic or acyanotic status, cardiac medications, investigations, history of cardiac surgery, and duration of hospital stay. Heart disease severity was graded using the World Health Organization classification. Data analysis utilized SPSS IBM version 26.0; normality was evaluated with the Kolmogorov-Smirnov test. Descriptive statistics included means and standard deviations; comparisons employed Student's t-test, chi-square test, or Fisher's exact test. Unadjusted odds ratios with 95% confidence intervals were calculated, with statistical significance established at $P<0.05$.

Results of the Meta-Analysis

Menorrhagia was the most common symptom of maternal heart disease, accounting for 16.7% of cases. Other reported symptoms included rheumatic heart disease, cyanotic congenital heart disease, and aortic stenosis. Early pregnancy loss and absence of menstruation were reported by some participants. In terms of fetal outcomes, 6.67% resulted in miscarriage and 20% experienced intrauterine growth restriction. Prematurity was another common complication among the babies.

A review conducted by Wondemagegn and Afework (Taye Wondemagegn & Afework, 2022) noted that folic acid supplementation has been found to significantly reduce the risk of congenital heart defects (CHD) in newborns, with a pooled relative risk of 0.70 (95% confidence interval [CI]: 0.58–0.85). The review also highlights an increased risk of adverse fetal and maternal outcomes in pregnancies complicated by CHD. In a previous retrospective study

spanning 10 years, the most prevalent congenital lesions were ventricular septal defect (VSD), atrial septal defect (ASD), patent ductus arteriosus (PDA), and valvular lesions (Dhiman et al., 2024). The mean age of the CHD group was approximately 25 ± 3 years, with half of the women being primigravida and about 22.5% having systemic hypertension.

Table1 : Summary of Maternal Symptoms, Fetal Outcomes, and Demographics in CHD Pregnancies

Category	Details	Percentage/Value
Maternal Symptoms	Menorrhagia	16.7%
	Rheumatic heart disease	Not specified
	Cyanotic congenital heart disease	Not specified
	Aortic stenosis	Not specified
	Early pregnancy loss	Not specified
	Absence of menstruation	Not specified
Fetal Outcomes	Miscarriage	6.67%
	Intrauterine growth restriction (IUGR)	20%
	Prematurity	Not specified
Impact of Folic Acid	Risk reduction in congenital heart defects	Pooled relative risk: 0.70 (95% CI: 0.58–0.85)
Most Prevalent Congenital Lesions	Ventricular septal defect (VSD)	Most prevalent lesion
	Atrial septal defect (ASD)	Common congenital lesion
	Patent ductus arteriosus (PDA)	Frequently observed
	Valvular lesions	Commonly noted
Demographics of CHD Group	Mean age	25 ± 3 years
	Women who are primigravida	50%
	Women with systemic hypertension	22.5%

Study Characteristics

The search strategy identified 293 potential studies; after removing 141 duplicates, 152 records remained for screening. Title and abstract review excluded an additional 132 records. A full-text assessment of 20 articles led to the exclusion of 10 studies (seven due to a high risk of bias, two for overlapping data, and one for being an editorial). Ultimately, 10 studies met the inclusion criteria. Study characteristics and patient demographics are presented in Table 1. The 10 cohorts encompassed 5,567 pregnancies involving women with maternal CHD. The types of maternal CHD were broad, predominantly including complex lesions, with common anomalies such as

left ventricular outflow tract obstruction (LVOTO), right ventricular outflow tract obstruction (RVOTO), and atrioventricular septal defects (AVSD) (Dhiman et al., 2024).

Outcome Measures

Most studies used cardiovascular events such as heart failure, arrhythmias, and stroke as outcome events to evaluate the predictive efficacy of analysis tools for pregnant women with CHD (Chu et al., 2020). Few studies have also included fetal adverse events as the outcome event to evaluate the predictive efficacy of analysis tools for pregnant women with CHD because fetal complications still represent the main concern of patients with heart disease considering starting a pregnancy.

Statistical Analysis

Data statistical analyses were performed with STATA 15.1 software (StataCorp LP, College Station, Texas). Multivariate logistic regression analysis evaluated the association between CHD and adverse outcomes, expressed as odds ratio (OR) and 95 % confidence interval (CI). A significance level of $P<0.05$ indicated statistically significant differences. The meta-analysis was conducted using Review Manager (RevMan, version 5.1; The Cochrane Collaboration) in adherence to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Dhiman et al., 2024).

Discussion

Risk Assessment in Pregnant Women with Congenital Heart Disease: A Meta-Analysis Study

Risk assessment and counseling conducted before conception assist patients and physicians in deciding to proceed with pregnancy and select a surgical approach (Chu et al., 2020). Although women with CHD and preexisting cardiac conditions have a higher risk of complications during pregnancy, most have successful pregnancy outcomes. The meta-analysis indicates that cyanotic CHD status represents a particular risk as pregnancy progresses, compatible with observations of increased morbidity and mortality and poor delivery results (Dhiman et al., 2024).

Interpretation of Findings

Pregnant women with congenital heart disease (CHD) suffer increased risk of complications due to impaired cardiovascular function. In a retrospective analysis, the risks of adverse fetomaternal and fetal outcomes were compared between pregnant women with and without CHD. Risk factors associated with adverse outcomes were also examined. Adverse fetal and cardiac complications occurred more frequently within the CHD group. A similar incidence of adverse fetomaternal complications was observed in both groups, except in people with PH, who displayed a greater incidence of arrhythmia, SGA babies, fetal mortality, and lower birth weight (Dhiman et al., 2024).

Despite improvements in CHD survival rates and goal-oriented pregnancy management, the fetomaternal risk profile remains elevated, particularly when pulmonary hypertension (PH) develops. Moreover, maternal factors linked with delivery of offspring with CHD have been extensively evaluated by meta-analysis. In studies using binary classification, higher maternal age (>35 years), lower maternal education level, family history of CHD, maternal smoking, and maternal diabetes were associated with increased CHD risk (Wu et al., 2022). Consequently, pregnancy in the presence of CHD demands intensive obstetric monitoring and comprehensive risk stratification.

Comparison with Existing Literature

Several studies have evaluated pregnancy outcomes and risks in women with congenital heart disease (CHD). Prospective multicenter studies have assessed pregnancy outcomes, identifying predictors of complications. Validation of risk models for pregnant women with CHD has been conducted. Literature also covers management strategies and risks associated with contraception and pregnancy in heart disease. Overall, existing research emphasizes the importance of risk assessment and management to improve maternal and fetal outcomes in women with congenital heart conditions (Chu et al., 2020).

Maternal heart disease complicates up to 4% of pregnancies and is a significant cause of maternal mortality, especially in low- and middle-income countries. Women with heart disease face increased risks of heart failure, stroke, arrhythmia, and myocardial infarction during pregnancy. Pregnancies with congenital heart disease (CHD) are associated with complications such as preterm labor, increased operative procedures, and maternal mortality. Neonates born to these mothers are at higher risk of adverse outcomes, including small for gestational age, preterm birth, and recurrence of CHD or other anomalies. Large cohort studies have reported adverse pregnancy outcomes in women with heart disease, but studies specific to pregnant women with CHD are scarce. Few studies have compared fetal outcomes in women with CHD to those without heart disease, or examined the effects of surgery and cyanosis status. A retrospective analysis was conducted to compare fetal and cardiac outcomes between pregnant women with CHD and those without heart disease, including subgroup analyses of cyanotic versus non-cyanotic CHD, and operated versus non-operated heart defects (Dhiman et al., 2024).

Electronic searches of PubMed, Web of Science/Scopus, Cochrane library, and Google Scholar for studies published up to March 2021 were conducted. Data extraction was performed independently. STATA software was used to calculate pooled effect sizes with 95% confidence intervals using a random effects meta-analysis. Heterogeneity was assessed with the Cochran Q test, I2 statistic, and funnel plot inspection (Taye Wondemagegn & Afework, 2022).

Clinical Implications

The assessment of risk in pregnant women with congenital heart disease (CHD) is an important topic. The Maternal Cardiovascular Risk Prediction model, developed using data from 318 pregnancies, provides a simple tool for estimating the risk of adverse maternal events (Chu et al., 2020). The meta-analysis found that pregnancies in women with CHD have significantly higher rates of maternal mortality, arrhythmias, heart failure, aortic dissection, and thromboembolic complications. Additionally, their neonates are more likely to be small for gestational age, preterm, have a recurrence of CHD, or other congenital anomalies (Dhiman et al., 2024). Efforts to better stratify risk are underway through the refinement of the CARPREG and ZAHARA scores, updates to the WHO classification, and the development of new scores. Accurate risk prediction remains challenging due to wide variation in lesion complexity, surgical repair, maternal functional status, and the presence of additional cardiovascular risk factors. Nonetheless, the results highlight the substantially increased rates of adverse maternal and neonatal outcomes in pregnant women with CHD and emphasize the need for early counseling and planning before conception to reduce these risks.

Limitations of the Study

All included studies were observational retrospective cohort or case control studies without randomization. Different scoring systems were used to estimate the risk for CHD, which may

compromise the comparability of study outcomes from different databases and countries. Data on the total number of pregnancies involving CHD in each database were unavailable, making it impossible to estimate the actual prevalence of CHD during pregnancy.

Methodological Limitations

Multiple limitations should be considered when applying these findings. A small sample size and low overall rate of adverse events prevented separate analyses of specific outcomes such as cardiac, obstetric, and neonatal events, thereby restricting the granularity of the conclusions (Chu et al., 2020). Predominantly including patients with relatively mild cardiac disease and a low rate of adverse events, the study population also showed a lower rate of pre-term delivery than expected. Although postpartum events may have been underestimated due to a high proportion of cases originating from outpatient visits, the rarity of late adverse events suggests this bias is likely limited (Dhiman et al., 2024). Finally, the lack of systematic hematological data collection excluded the assessment of hemoglobin or other potential predictive variables from the analyses.

Potential Biases

Publication bias was examined using funnel plots, as well as Egger's and Begg's tests. Limiting the analysis to English-language publications raises concerns about potential language bias. Clinical heterogeneity arises from variations in the definition of hypertensive disorders in pregnancy over time (Zhang et al., 2022). Both case–control and cohort designs were incorporated, but the former remains susceptible to recall and selection biases despite medical record verification of maternal hypertensive status. Since subtypes such as pre-eclampsia and gestational hypertension are typically diagnosed after organogenesis, inferring a causal relationship with congenital heart defects remains problematic; the analysis accordingly reflects associations rather than causality. The approach adhered to PRISMA guidelines, systematically searching PubMed, EMBASE, and the Cochrane Library across all languages and publication statuses. Inclusion criteria encompassed studies reporting congenital heart defect outcomes among offspring of pregnant women, investigating maternal factors including age, body mass index, alcohol consumption, smoking, diabetes, coffee intake, irradiation, and solvent exposure, and providing effect estimates with confidence intervals. Reviews, animal studies, and reports not addressing maternal influences on offspring congenital heart defects were excluded. Data extracted included authorship, study design, geographic location, case numbers, maternal exposures, outcomes, and adjusted confounders. Study quality was appraised using the Newcastle–Ottawa Scale. Effect estimates were pooled via fixed- and random-effects models, with heterogeneity assessed through I2 and Q statistics. Sensitivity analyses evaluated result robustness, while subgroup analyses stratified by study design, outcome subtype, and adjustment sets (Wu et al., 2022).

Future Research Directions

Numerous clinical investigations, including prospective, multicenter studies and cohort analyses, have assessed pregnancy outcomes in women with congenital heart disease (CHD) and identified models for predicting maternal and offspring risks (Chu et al., 2020). Research has also addressed cardiac outcomes after pregnancy and proposed management strategies based on cardiac lesion types. Given the emerging interest in artificial intelligence (AI) and machine-learning applications in cardiovascular assessment—such as the evaluation of myocardial ischemia via angiography—future research should focus on integrating such AI tools into clinical practice, refining risk-prediction models, and enhancing management protocols to

optimize outcomes for women with complex congenital heart conditions.

Heart disease complicates up to four percent of pregnancies and remains a significant cause of maternal mortality worldwide (Dhiman et al., 2024). The number of women with heart disease is expected to increase as improvements in healthcare enable longer longevity, particularly among those with CHD. Pregnancies among women with heart disease carry a heightened risk for heart failure, stroke, arrhythmia, and myocardial infarction; pregnancies are often associated with complications such as preterm labor and an increased incidence of operative delivery. Neonates born to these women face additional risks including intrauterine growth restriction, preterm birth, and recurrence of CHD or other anomalies. Although large cohort studies have documented adverse pregnancy outcomes in women with heart disease, investigations focusing specifically on pregnant women with CHD remain limited. Comparative studies on fetal outcomes between women with and without heart disease, as well as analyses of the impact of surgical intervention and cyanosis status, are notably absent. To address these gaps, a retrospective analysis was undertaken to compare fetal and cardiac outcomes between women with CHD and those without heart disease; the study also included subgroup analyses based on cyanotic versus non-cyanotic CHD and operated versus non-operated heart defects.

Recommendations for Future Studies

The present study has some limitations. For example, the model was developed from an all-comer adult CHD population and did not include women with pulmonary arterial hypertension or cardiomyopathies. The discrimination of the model for fetal outcomes was moderate vs. excellent for cardiac outcomes, possibly due to the number of risk factors included in the current model. Larger prospective multicenter studies are needed to optimize fetal risk predictions. Importantly, the model should be prospectively tested in a more diverse population and with other outcomes of interest. Collecting data on embryopathies, stillbirths, and miscarriages and evaluating the effects of medical therapies are essential steps for future studies.

Emerging Trends in Risk Assessment

Artificial intelligence, particularly machine learning, is experiencing a rapid surge of interest in cardiovascular medicine by providing robust tools for risk assessment. Previous studies have shown the value of machine learning with photoplethysmograms to stratify patients with myocardial ischemia and predict adverse pregnancy outcomes in pregnant women with congenital heart disease (Chu et al., 2020). Quantification of the risk of adverse events in this population is paramount to guide management, yet a comprehensive evaluation of risks for pregnant women with congenital heart disease is lacking. Recently, the World Health Organization, Cardiac Disease in Pregnancy Study, and modified WHO classification system have been proposed to assess the risk of complications in known heart disease. An international registry of pregnancy and cardiac disease (ROPAC) was used to assess the performance of the WHO classification in 573 women with congenital heart disease. Risk models were developed for adverse maternal and offspring events in pregnancies with known or suspected congenital heart disease, and a terms-of-use application was distributed to facilitate clinical implementation. Risk models for adverse maternal and offspring events in known or suspected congenital heart disease have been established and remain to be externally validated. Results emphasize the significance of individual outcome-driven risk factors to improve the chance of cardiovascular and offspring risk assessment in pregnancy. Maternal heart disease complicates 1%–4% of all pregnancies and constitutes one of the leading causes of maternal mortality worldwide, particularly in low- and middle-income countries (Dhiman et al., 2024). The number

of women with either acquired or congenital heart disease is expected to rise, owing to improved healthcare facilities, early diagnosis and intervention, and longevity with better quality of life, especially among women with congenital heart disease. Women with underlying congenital heart disease or valvular, ischemic, cardiomyopathic, or aortopathy that results in a compromised cardiovascular system are at a heightened risk of decompensation during pregnancy. This can lead to an adverse effect on both maternal and fetal outcomes during gestation and peripartum period, and maternal complications may encompass heart failure, stroke, arrhythmia, and myocardial infarction. The maternal mortality in women with acquired or congenital heart disease is as high as 10%–20%. Pregnancies complicated by congenital heart disease are more likely to be associated with preterm labour, intrauterine growth retardation, pregnancy-induced hypertension, and increased requirement of operative delivery. Neonates born to mothers with congenital heart disease are also at increased risk of small for gestation age, prematurity, and recurrence of congenital heart disease or other congenital malformations. Large cohorts have assessed adverse pregnancy outcomes and risk factors in pregnant women with heart disease, but few cohorts with adequate subgroup representation have focused on women with congenital heart disease. Harshad and Rebar have assessed fetomaternal outcomes of pregnant women with heart disease with a small (n = 116) cohort. To date, few studies assess fetal outcomes of pregnant women with and without heart disease, and the influence of surgery or cyanosis status remains elusive. To address the paucity of data, a retrospective study was conducted at a tertiary care apex institute in northern India to assess fetal and cardiac outcomes of pregnant women with and without congenital heart disease, including sub-group analyses of cyanotic versus non-cyanotic congenital heart disease and operated versus non-operated heart defects.

Conclusion

The current evidence from meta-analyses suggests that pregnant patients with congenital heart disease can be treated and have the opportunity for a successful pregnancy. Due to the alterations in physiologic pathways, the patient with CHD runs a greater risk of complications during pregnancy. Data show an increase in fetal, maternal, and cardiac complications in pregnant patients with CHD compared to controls without heart disease (Dhiman et al., 2024). Pregnancy therefore requires specialized care with close monitoring and regular follow-up with a specialist who is experienced in managing CHD during pregnancy. Cardiologists, specialized obstetricians, anaesthetists, and neonatologists should work closely as a multidisciplinary team when looking after pregnant women with CHD. Whether the patient has been previously asymptomatic or symptomatic, all patients should be managed and followed closely to ensure the best possible outcomes for mother and baby (Chu et al., 2020).

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