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# Risk factors for maternal cardiac and obstetric outcomes in patients with and without CHD

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**Original Article**

**Cite this article:** Brown C, Voskamp S, Kube A, Cervantes L, Hibner S, Babbins N, and DeCampli W (2025) Risk factors for maternal cardiac and obstetric outcomes in patients with and without CHD. *Cardiology in the Young* **35**: 1663–1668. doi: 10.1017/S1047951125101017

Received: 26 March 2025
Revised: 25 June 2025
Accepted: 28 June 2025
First published online: 22 August 2025

**Keywords:**
cardio-obstetrics; CHD; pregnancy; morbidity

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## Abstract

*Background:* Physiologic changes in the peripartum period put women with CHD at increased risk for morbidity. This study examines factors associated with peripartum complications and length of stay compared to patients without CHD. *Methods:* This single-institution retrospective case-control study included women with CHD (2000–2017) and a control population without CHD. A review of clinical and echocardiographic data was used to assign baseline characteristics, disease severity, and adverse outcomes. Primary outcomes were composite variables of cardiac and obstetric adverse events, along with peripartum length of stay. The relationship between maternal CHD, baseline characteristics, and peripartum adverse events was evaluated by multivariable regression. *Results:* The cohort and control groups included 162 deliveries among 113 women and 321 deliveries among 321 women, respectively. Cardiac complications, including arrhythmia, heart failure, pulmonary oedema, and thromboembolic events, occurred in 8.6% of the cohort (RR 2.52, 95% CI 1.17–5.42), with the most common event being arrhythmia. Obstetric events, such as caesarean delivery, assisted vaginal delivery, preterm birth, and pre-eclampsia, occurred in 67.9% versus 56.1% in the control group (RR 1.21, 95% CI 1.05–1.40). In multivariable models, increasing age was associated with increased composite cardiac events. Length of stay was longer in the cohort group ($p < 0.001$) and significantly associated with modified World Health Organization classification ($p = 0.016$). *Conclusions:* Women with CHD experience increased cardiac and obstetric morbidity compared to controls during peripartum admission. Those with CHD have longer hospital stays around delivery, which is associated with disease severity.

## Introduction

CHD is the most common form of congenital abnormalities, occurring in about 0.8% of infants worldwide.[1] Over the last decades, the mortality rate of CHD has declined by over 30%, which is attributable to advances in medical and surgical care.[2] This subsequently has increased the population of diagnosed individuals surviving into adulthood and reaching reproductive age.

The peripartum period poses unique challenges for patients with CHD. Physiologic changes to circulation, including increased cardiac output and coagulability, place haemodynamic stress on the cardiac system and heighten the risk of complications such as arrhythmia and heart failure.[3] Previous studies have evaluated the impact of demographic and cardiac characteristics on maternal and neonatal outcomes. Findings demonstrate increased incidence of various adverse events, including preterm birth, surgical delivery, and infants born small for gestational age.[3,4] Furthermore, morbidity has been shown to increase with cardiac lesion severity.[3] Previously developed prediction models have also worked to stratify patients into risk categories based on various factors.

Navigating pregnancy and delivery among patients with CHD requires the care of a multidisciplinary team and assessment of each patient's risk for adverse events. The clinical guidelines for these decisions are continually evolving as we enhance our understanding of outcomes and modifiable risk factors. The aim of the current study is to evaluate cardiac and obstetric adverse outcomes associated with maternal CHD in a single centre compared to women without CHD. Additional objectives are to evaluate risk factors associated with increased length of peripartum hospital stay. Identifying risks associated with pregnancy in this population can aid in the shared decision-making process regarding management.

## Methods

### *Data source and study population*

This is a retrospective case-control study. The cohort group included parous patients with CHD who consulted with the anaesthesiology department at Winnie Palmer Hospital for Women and

Babies (WPH) during the course of their pregnancies from 1 January 2000 to 19 June 2017. Parous women normally have an anaesthesiology consult for epidural, caesarean section, or pain control with induction as part of their obstetric care; however, only parous patients with recorded CHD in their charts were included in the study. Previously compiled anaesthesia records provided an efficient way to identify the cohort. Heart disease diagnoses, demographic variables, and adverse events were identified via medical record review. Women with indications of acquired heart disease were excluded. Neonatal records were linked to maternal records for the cohort group based on delivery date and patient name. Multiple deliveries by the same patient were included if they fell within the study period.

The control group was identified via a medical record query using the ELLIE database query function for deliveries at WPH between February 2023 and July 2023, including all patients without a history or diagnosis of acquired or CHD. Case-control matching was used to identify the control group from the large data pool of non-CHD patients. Two patients in the control group were matched to one patient in the cohort group based on gravidity, parity, and maternal age. Some matches were incomplete secondary to missing data or not meeting the inclusion criteria. Matching resulted in 162 deliveries among 113 women in the final cohort group and 321 deliveries among 321 women in the control group.

Baseline characteristics were collected for both the cohort and control groups. Demographic characteristics included maternal age at delivery, ethnicity, and pre-pregnancy body mass index as documented in peripartum medical records. Pre-pregnancy body mass index (BMI) was not available for all control group cases, and such cases were excluded from the adverse event analysis that evaluated BMI as a risk factor. Pregnancy-related factors were gravidity, parity, initiation of prenatal care within the first trimester, and history of smoking and alcohol use.

CHD severity was assigned using the modified modified World Health Organization (mWHO) classification, which accounts for structural and functional elements of CHD diagnoses and has previously been demonstrated as the best risk assessment tool for cardiovascular events.[5] Categories included mWHO I, II, II–III, III, and IV, with increasing maternal morbidity risk and cardiac event rate per category.[6] A review of clinical and echocardiographic data contributed to the assignment of cases into the appropriate category. In patients with multiple findings, classification was assigned according to the most severe finding. For example, single valve repairs were classified as mWHO I. Uncomplicated repaired transposition of great arteries was assigned mWHO II.

IRB approval was obtained from Orlando Health and the University of Central Florida. A consent waiver was granted by the IRB for this retrospective chart review; thus, informed consent was not obtained. De-identified data was recorded in password-protected databases for analysis.

### Outcome measures

The primary outcomes of this study are the cardiac and obstetric adverse event composite variables. Individual outcome variables within composite cardiac and maternal adverse events were determined a priori based on existing literature. Cardiac adverse events included arrhythmia, congestive heart failure, pulmonary oedema, and thromboembolic events mentioned during the peripartum admission or within 30 days of readmission. In this study, we did not assess changes in cardiac-related laboratory values, medications, or cardiac imaging or evaluate the impact of pregnancy or delivery on these aspects of the clinical course. Obstetric adverse events included peripartum pregnancy, labour, and delivery-related adverse events. Variables consist of caesarean delivery, assisted vaginal delivery (forceps or vacuum-assisted), preterm delivery, non-reassuring fetal status, pre-eclampsia, postpartum haemorrhage, intrauterine fetal demise, maternal mortality, and peripartum admission length of stay. Within the electronic medical record, various terminology was used that may refer to non-reassuring fetal status including fetal heart rate decelerations and decreased fetal movement. The outcome variable was positive, however, only if the terminology "non-reassuring fetal status" was explicitly stated in the medical record. The outcome variable pre-eclampsia was positive only if the patient received the diagnosis in their electronic medical record. Patients with preexisting hypertension or gestational hypertension but not meeting the criteria for pre-eclampsia were not included in this variable.

### Statistical analysis

Univariable analysis was used to generate descriptive statistics for identified cardiac and delivery complications. A chi-squared test was used to compare categorical variables between the cohort and control groups. The prevalence of cardiac and delivery adverse events was compared between groups using risk ratios and 95% confidence intervals. Risk factors for composite adverse event variables were determined using logistic regression. Univariable regression was used to determine the association between a prescribed outcome and each risk factor, and predictors with a $p$-value <0.15 were included in multivariable models. Odds ratios and confidence intervals were reported. ANOVA with Bonferroni post hoc test was used to explore the association between demographic characteristics (ethnicity), CHD severity, or pregnancy-related factors (including gravity, parity, cigarette or alcohol use, and trimester in which prenatal care was initiated) and peripartum admission length of stay. A $p$-value <0.05 was considered significant. Analysis was performed using SPSS version 29.0.0.0.

## Results

### Demographics

In total, 162 deliveries among 113 women with CHD and 321 deliveries among 321 women without CHD were identified for inclusion. Patient demographic and pregnancy-related characteristics are listed and compared between groups in Table 1. The obtained cohort and control group were ethnically diverse and had a mean [SD] age of 27.57 [6.4] for women with CHD and 28.11 [6.1] for women without CHD. The CHD cohort has a larger predominance of non-Hispanic White women compared to the control population and a less prevalence of Hispanic and non-Hispanic Black women. The BMI for the CHD cohort trended lower than the control group, with a larger proportion in the <18.5 and 18.5–24.9 categories and fewer in the 25.0–29.9 and >30 categories. Within the control group, 15 had unknown pre-pregnancy BMI. Furthermore, 47.4% of women in the control group initiated prenatal care after the first trimester or did not have prenatal care, whereas 16.7% of the CHD cohort initiated prenatal care after the first trimester. Gravidity and parity were

https://doi.org/10.1017/S1047951125101017 Published online by Cambridge University Press

**Table 1.** Baseline characteristics

| Variable | Winnie Palmer CHD Group N | % | Winnie Palmer Control Group N | % | Chi-square (p) |
|---|---|---|---|---|---|
| **Demographic characteristics** | | | | | |
| Age, *years* | 27.57 ± 6.4 Range = 15–43 | | 28.11 ± 6.1 Range = 16–42 | | – |
| Ethnicity | | | | | |
| White, non-Hispanic | 92 | 56.8 | 87 | 27.1 | 41.501 (<0.001) |
| Black, non-Hispanic | 17 | 10.5 | 63 | 19.6 | |
| Hispanic | 37 | 22.8 | 130 | 40.5 | |
| Other | 16 | 9.9 | 41 | 12.8 | |
| Body mass index[a] | | | | | |
| <18.5 | 19 | 11.7 | 11 | 3.4 | 22.053 (<0.001) |
| 18.5–24.9 | 69 | 42.6 | 98 | 30.5 | |
| 25.0–29.9 | 36 | 22.2 | 79 | 24.6 | |
| >30 | 38 | 23.5 | 118 | 36.8 | |
| **Pregnancy-related factors** | | | | | |
| Gravidity | | | | | |
| 1 | 53 | 32.7 | 142 | 44.2 | 8.310 (0.140) |
| 2 | 48 | 29.6 | 83 | 25.9 | |
| 3 | 26 | 16.0 | 52 | 16.2 | |
| 4 | 23 | 14.2 | 28 | 8.7 | |
| 5 | 8 | 4.9 | 10 | 3.1 | |
| >6 | 4 | 2.5 | 6 | 1.9 | |
| Parity | | | | | |
| 0 | 77 | 47.5 | 170 | 53 | 3.996 (0.407) |
| 1 | 56 | 34.6 | 88 | 27.4 | |
| 2 | 17 | 10.5 | 41 | 12.8 | |
| 3 | 8 | 4.9 | 18 | 5.6 | |
| >4 | 4 | 2.5 | 4 | 1.2 | |
| Prenatal care initiated after first trimester, *n(%)* | 27 | 16.7 | 152 | 47.4 | 57.807 (<0.001) |
| History of smoking, *n(%)* | | | | | |
| Denied | 133 | 83.6 | 297 | 92.5 | 11.519 (0.003) |
| Former | 13 | 8.2 | 17 | 5.3 | |
| Yes | 13 | 8.2 | 7 | 2.2 | |
| History of alcohol, *n(%)* (past or current use) | 12 | 7.4 | 138 | 43.0 | 63.668 (<0.001) |

[a]Pre-pregnancy body mass index was not available for all control group deliveries.

not significantly different between the CHD and control cohorts as these variables were included in the case-control match variables to select the control cohort.

## Cardiac outcomes

Figure 1 shows the distribution of CHD diagnoses in the cohort group and maternal cardiovascular risk stratified by the mWHO score. A majority fell into mWHO class I and II, comprising over two-thirds of the group ($n = 116$). The most common diagnosis within the cohort was arrhythmias ($n = 42$), followed by valvular defects (left-sided $n = 32$, right-sided $n = 27$).

Cardiac complications, defined as arrhythmia, heart failure, pulmonary oedema, and thromboembolic events, occurred in 8.6% of the cohort (CHD) group compared to 3.4% in the control group (RR 2.5, 95 CI 1.2–5.4). Most adverse cardiac events experienced were arrhythmias ($n = 8$), followed by congestive heart failure ($n = 3$) and thromboembolic event ($n = 3$). While each individual event type was more common among women with CHD, results did not reach statistical significance.

Table 2 shows the multivariable logistic regression models for the association between demographic and pregnancy-related variables and the composite outcome "any cardiac adverse event." In women with CHD, there were higher odds of a cardiac event with increasing age (OR 1.15/yr, $p = 0.013$). Additionally, the association between maternal gravidity and parity and any cardiac event approached significance ($p = 0.067$ and $p = 0.065$, respectively). In the cohort (CHD) group, increasing gravidity showed increased odds, while higher parity showed decreasing odds of any adverse event. The mWHO risk classification was notably not associated with cardiac events (OR 0.97, $p = 0.944$). The control group did not have a statistically significant association between any of the variables and increasing odds of having any adverse cardiac event.

## Delivery outcomes

Women with CHD were more likely to have an adverse delivery event (110 (67.9%) with CHD, 180 (56.1%) without CHD (risk ratio [RR] 1.21, 95% CI 1.05–1.40). Figure 2 demonstrates risk ratios for adverse delivery events amongst women with CHD compared to those without. Caesarean and assisted vaginal deliveries were more likely in women with CHD (RR 1.42, 95% CI 1.1–1.8, and RR 3.6, 95% CI 1.8–7.3). As compared to controls, the cohort group had a lower risk of pre-eclampsia (RR 0.35, 95% CI 0.19–0.64). All other adverse delivery events, with the exception of intrauterine fetal demise, were lower in women with CHD compared to controls, although the associations were not significant.

In the multivariable logistic model for pregnancies with maternal CHD, other non-Hispanic ethnicity was associated with lower odds of any adverse delivery event. All other variables included in the model, including mWHO classification, trimester of initiation of prenatal care, and cigarette or alcohol use, were not significantly associated. Among women without CHD, increasing age and BMI were associated with higher odds of any adverse delivery events.

## Length of stay

The mean length of stay was approximately twice as long for women with CHD compared to those without (4.41 days vs 2.15 days, $p < 0.001$ [CI 1.85–2.49]). Significant differences were identified in hospital length of stay (days) across mWHO risk classifications (I = 4.36, II = 3.81, II–III = 5.14, III = 6.00, IV = 5.00, $p = 0.016$). The mWHO classification of IV contained one

https://doi.org/10.1017/S1047951125101017 Published online by Cambridge University Press

| Modified WHO Classification | N (%) |
|---|---|
| I | 47 (28.8) |
| II | 69 (42.3) |
| II-III | 35 (21.5) |
| III | 11 (6.7) |
| IV | 1 (0.7) |

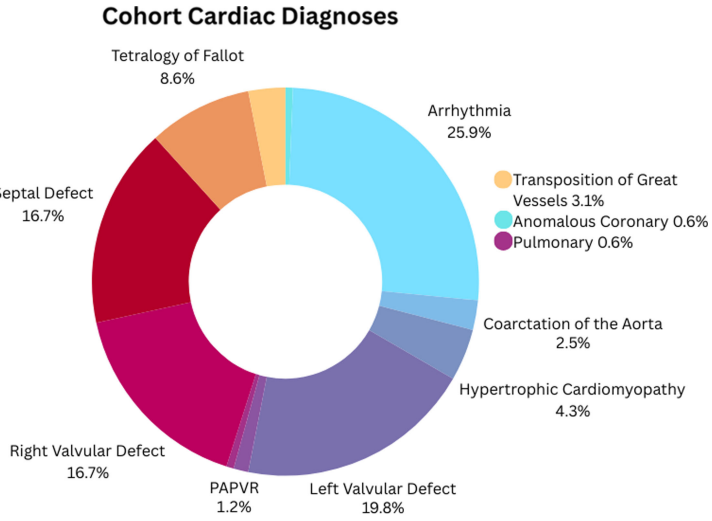


**Figure 1.** Cardiac cohort diagnoses.

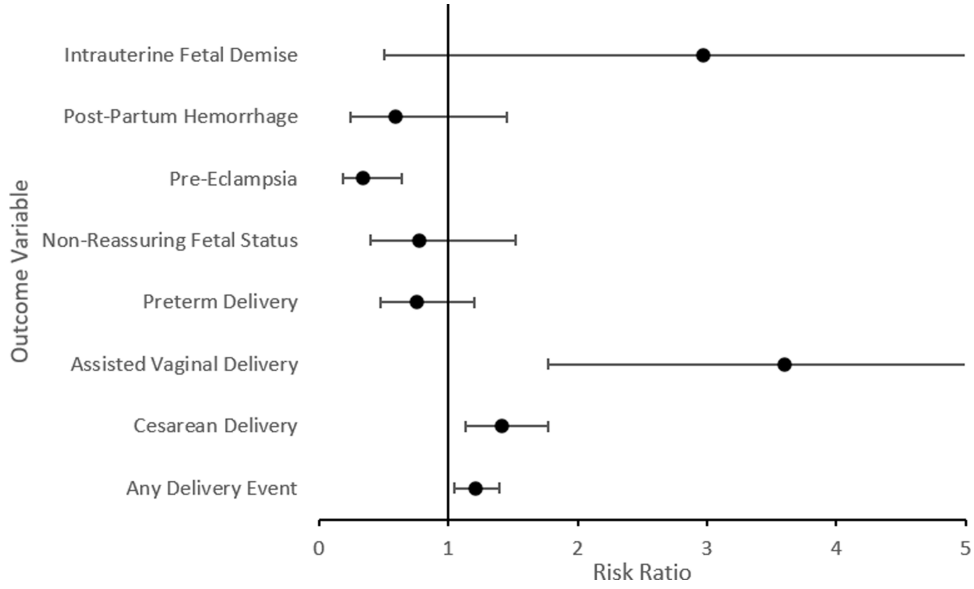


**Figure 2.** Risk ratio for adverse delivery events.

patient and thus was removed from further analysis. A mean difference of 2.2 days was found between patients within mWHO class III and class II ($p = 0.059$). Length of stay differed by 1.3 days between those with diagnoses in class II–III and class II ($p$ 0.084). A parity of 2 had a significantly increased length of stay compared to nulliparous patients (ANOVA $p = 0.017$, 1.733 days, $p = 0.045$).

## Discussion

The increasing number of women with CHD surviving to reproductive age and considering pregnancy is a testament to the advances in CHD treatments and care but provides new challenges and risks. Previous studies have constructed predictive systems to provide guidelines to bridge this gap and stratify risk in pregnant women with CHD. However, prenatal counselling regarding pregnancy risk must be guided by individually specialised care. Herein, we present a single-institution investigation of maternal cardiac and delivery adverse outcomes in women with CHD compared to controls without CHD.

Overall, our study had similar findings as previous studies, demonstrating that women with heart disease experience significantly increased peripartum morbidity compared to women without heart disease, although mortality was a rare outcome. This is highlighted in a meta-analysis of Hardee et al., which found 26 studies across 1347 women with CHD and only 9 reports of mortality.[3] Women with CHD diagnoses had an increased prevalence of adverse cardiac events compared to the control group, occurring in 8.6% of pregnancies. While individual adverse events, such as arrhythmias and congestive heart failure, did not reach significance (perhaps in part due to sample size limitation), our data does suggest a higher incidence of "any adverse event" in the cohort compared to controls.

Within the cohort group, analysis of demographic variables found that increasing age was associated with adverse maternal cardiac events. Age has also been identified as an associated factor in other studies, including CARPREG II.[7] Notably, our results did not reflect an association between cardiac events and mWHO classification, gravidity, or parity.

https://doi.org/10.1017/S1047951125101017 Published online by Cambridge University Press

**Table 2.** Multivariable logistic regression model for any adverse cardiac event

| Adverse cardiac events | | | | | | |
|---|---|---|---|---|---|---|
| | CHD cohort (*N* = 162) | | | Control (*N* = 306) | | |
| | **Odds ratio** | **95% confidence interval** | ***p*-value** | **Odds ratio** | **95% confidence interval** | ***p*-value** |
| Age, *per 1 year* | 1.15 | 1.03–1.27 | 0.013 | 1.00 | 0.90–1.12 | 0.974 |
| Gravidity | 1.61 | 0.97–2.68 | 0.067 | 1.47 | 0.73–2.96 | 0.287 |
| Parity | 0.38 | 0.14–1.06 | 0.065 | 0.61 | 0.22–1.66 | 0.332 |
| BMI | 0.98 | 0.89–1.09 | 0.759 | 1.02 | 0.94–1.10 | 0.716 |
| mWHO classification | 0.97 | 0.38–2.46 | 0.944 | – | – | – |
| **Adverse delivery events** | | | | | | |
| Age, *per 1 year* | 0.976 | 0.920–1.036 | 0.423 | 1.056 | 1.010–1.104 | 0.015 |
| Gravidity | 1.127 | 0.792–1.603 | 0.506 | 0.967 | 0.674–1.386 | 0.853 |
| Parity | 0.847 | 0.498–1.439 | 0.539 | 1.027 | 0.646–1.633 | 0.909 |
| BMI | 0.947 | 0.894–1.003 | 0.065 | 1.069 | 1.030–1.109 | <0.001 |
| Ethnicity | | | | | | |
| White, non-Hispanic* | 1 | | | 1 | | |
| Black, non-Hispanic | 1.016 | 0.299–3.451 | 0.980 | 1.118 | 0.543–2.299 | 0.763 |
| Hispanic | 0.571 | 0.239–1.360 | 0.206 | 0.727 | 0.402–1.312 | 0.290 |
| Other, non-Hispanic | 0.317 | 0.101–0.997 | 0.049 | 0.775 | 0.334–1.744 | 0.538 |
| Smoking history | | | | | | |
| None* | 1 | | | 1 | | |
| Past use | 4.939 | 0.593–41.121 | 0.140 | 1.00 | 0.314–3.184 | 1.00 |
| Current use | 0.698 | 0.192–2.541 | 0.585 | 1.152 | 0.222–5.965 | 0.866 |
| mWHO classification | 1.281 | 0.851–1.928 | 0.234 | – | – | – |

*Control group.

In looking at obstetric-related events, women with CHD were more likely to have C-sections or assisted vaginal deliveries. The predominant reasons for C-sections within our cohort were a history of a previous surgical delivery and obstetric complications. This is consistent with clinical guidelines, which recommend that women with stable cardiac disease can undergo vaginal delivery at 39 weeks with C-section delivery reserved for obstetric indications. Previous evidence has suggested that there is no improvement of maternal outcomes by planned C-section over vaginal delivery. Ruys et al. showed that perinatal mortality and low APGAR scores were not significantly different between the two groups.[8] In exploring other obstetric events, our study notably found lower rates of preterm delivery and pre-eclampsia in women with CHD. The incidence of these outcomes within our cohort approximated rates seen in other studies, though they occurred more often in women without CHD.[9] While deducing the reasoning is beyond the scope of our study, it should be noted that the control group includes patients who may have an array of other clinical conditions and predisposing factors for these outcomes. The comparisons, additionally, are likely impacted by the limited sample size.

Among women with CHD, the multivariable model for variables associated with adverse delivery events revealed only other non-Hispanic ethnicity as a significant risk. BMI approached significance, and again, diagnosis severity, measured via mWHO classification, was not associated. Within the control group, increasing age and BMI were associated with increased risk.

Despite CHD diagnosis severity not having a significant association with cardiac and obstetric adverse outcomes in regression models, it was found to be positively associated with length of stay. Our regression results suggest that our selected outcomes may not have captured the clinical reasons for these differences. There may be other contributors or clinical precautions that influenced admission duration that were not investigated by our study. Regardless of the underlying cause, the finding does highlight an important difference related to healthcare costs. On average, women with CHD had nearly twice the length of stay compared to controls. Furthermore, within the CHD cohort, there was an overall trend of increasing length of stay with more severe CHD diagnosis.

## Limitations

Although the study reflects consistent findings with existing literature on the outcomes of pregnancies in women with CHD, there are limitations to our study. First, by including only patients who received an anaesthesia consultation, the study did not capture potential patients with severe CHD diagnoses who were advised against carrying pregnancies to term and therefore did not deliver. Additionally, patients with CHD diagnoses who had a pregnancy loss prior to consultation were not captured in the study collection method, possibly resulting in a decreased number of patients in higher mWHO categories included for analysis. Second, while there are strengths in our use of matched controls, control cases were selected from a different year range than our cohort, a consequence of a change in medical record systems with archiving of older records. The impact of the differing eras is likely small but could result from practice changes between the eras. Lastly, our cohorts were taken from a single-institution obstetric practice, limiting the sample size and therefore our ability to delineate the significance of more subtle associations.

In conclusion, this study of a single institution over a 17-year period demonstrates that women with CHD are more likely to encounter both cardiac- and obstetric-related morbidities in their peripartum admission. They were more likely to undergo caesarean or assisted vaginal deliveries. In women with CHD, increasing age was a significant predictor of any adverse cardiac outcome. No predictors were identified for adverse delivery events, however. Those with CHD had a longer peripartum length of stay, which was significantly influenced by CHD severity. Reassuringly, mortality remains a rare outcome. These results add to growing data aimed at improving the clinical management of pregnancies in women with CHD.

**Acknowledgements.** We acknowledge co-author Noah Babbins, MD, who passed away during the course of this study. Dr Babbins was passionate about understanding risks during delivery in patients with CHD. He collected the original records of the patients in the study's cohort group.

**Financial support.** This research received no specific grant from any funding agency, commercial, or not-for-profit sectors.

**Competing interests.** The authors declare none.

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https://doi.org/10.1017/S1047951125101017 Published online by Cambridge University Press