

ORIGINAL RESEARCH

# Delivery Timing and Associated Outcomes in Pregnancies With Maternal Congenital Heart Disease at Term

Thalia Mok , MD; Allison Woods, MD; Adam Small, MD; Mary M. Canobbio, RN, MN; Megha D. Tandel, MPH; Lorna Kwan, MPH; Gentian Lluri , MD, PhD; Leigh Reardon , MD; Jamil Aboulhosn , MD; Jeannette Lin , MD; Yalda Afshar , MD, PhD

**BACKGROUND:** Current recommendations for delivery timing of pregnant persons with congenital heart disease (CHD) are based on expert opinion. Justification for early-term birth is based on the theoretical concern of increased cardiovascular stress. The objective was to evaluate whether early-term birth with maternal CHD is associated with lower adverse maternal or neonatal outcomes.

**METHODS AND RESULTS:** This is a retrospective cohort study of pregnant persons with CHD who delivered a singleton after 37 0/7 weeks gestation at a quaternary care center with a multidisciplinary cardio-obstetrics care team between 2013 and 2021. Patients were categorized as early-term (37 0/7 to 38 6/7 weeks) or full-term ( $\geq 39$  0/7) births and compared. Multivariable logistic regression was conducted to calculate the adjusted odds ratio for the primary outcomes. The primary outcomes were composite adverse cardiovascular, maternal obstetric, and adverse neonatal outcome. Of 110 pregnancies delivering at term, 55 delivered early-term and 55 delivered full-term. Development of adverse cardiovascular and maternal obstetric outcome was not significantly different by delivery timing. The rate of composite adverse neonatal outcomes was significantly higher in early-term births (36% versus 5%,  $P < 0.01$ ). After adjusting for confounding variables, early-term birth remained associated with a significantly increased risk of adverse neonatal outcomes (adjusted odds ratio 11.55 [95% CI, 2.59–51.58]).

**CONCLUSIONS:** Early-term birth for pregnancies with maternal CHD was associated with an increased risk of adverse neonatal outcomes, without an accompanying decreased rate in adverse cardiovascular or obstetric outcomes. In the absence of maternal or fetal indications for early birth, induction of labor before 39 weeks for pregnancies with maternal CHD should be reserved for routine obstetrical indications.

**Key Words:** congenital heart disease ■ delivery timing ■ early-term birth ■ maternal cardiac disease

Significant advancements in medical care have allowed pregnant people with maternal congenital heart disease (CHD) to survive to childbearing age, resulting in an increased prevalence of cardiovascular disease in pregnancy.<sup>1,2</sup> Although pregnancy and its associated hemodynamic changes may be well tolerated in some, pregnancy may increase the risk of volume overload, development of arrhythmias,

and progressive cardiac dysfunction in others.<sup>3–5</sup> The presence of maternal CHD is also a major determinant for neonatal morbidity.<sup>3,6,7</sup> Overall, pregnancies complicated by maternal CHD are at an increased risk for adverse maternal and neonatal outcomes compared with the general obstetric population.<sup>5,8,9</sup>

Society guidelines on management of pregnancies with maternal CHD provide recommendations

Correspondence to: Yalda Afshar, MD, PhD, Division of Maternal-Fetal Medicine, Department of Obstetrics and Gynecology, University of California, 200 Medical Plaza, Suite 430, Los Angeles, CA 90095. Email: [yafshar@mednet.ucla.edu](mailto:yafshar@mednet.ucla.edu)

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## CLINICAL PERSPECTIVE

### What Is New?

- Early-term birth in pregnancies with maternal congenital heart disease was associated with a significantly increased rate of adverse neonatal outcomes, including neonatal intensive care unit admission and respiratory distress syndrome.
- Earlier delivery did not significantly decrease the rate of cardiovascular complications in pregnancies with underlying maternal congenital heart disease.
- In this retrospective cohort study, early-term birth in pregnancies with maternal congenital heart disease is associated with an increased risk for adverse neonatal outcomes without accompanying maternal benefit.

### What Are the Clinical Implications?

- In the absence of maternal or fetal indications and stable cardiovascular status, consideration may be taken to avoid early-term births in pregnancies complicated by maternal congenital heart disease outside of routine obstetrical indications.
- Further prospective clinical trials are needed to determine complete recommendations for delivery timing of pregnancies with maternal CHD, but the findings from this study begin to offer evidence to inform such studies and may be considered when coordinating delivery plans for these complex patients.

## Nonstandard Abbreviations and Acronyms

<b>FGR</b>	fetal growth restriction
<b>HDP</b>	hypertensive disorder of pregnancy

in an attempt to optimize maternal and neonatal outcomes.<sup>1,2</sup> However, there are limited data to guide delivery timing for this population. The American Heart Association stated that elective induction of labor for pregnant women with cardiovascular disease is recommended between 39 and 40 weeks of gestation in those without spontaneous onset of labor or clinical indications for preterm birth, citing the ARRIVE trial (A Randomized Trial of Induction Versus Expectant Management) for this recommendation.<sup>1,10,11</sup> However, this trial was completed on a low-risk nulliparous patient population, and patients with maternal medical conditions, including cardiac disease, were excluded.<sup>11</sup> It has also been suggested that induction of labor as early as 37 or 38 weeks of gestation can be considered for those with complex CHD because of the increased

cardiovascular strain and associated risks that may accompany prolonging pregnancy.<sup>1</sup>

Overall, there remains limited evidence assessing delivery timing of pregnancies with maternal CHD, and recommendations arise primarily from expert opinion. The objective of this study was to evaluate timing of delivery in women with CHD and associated rates of adverse maternal and neonatal outcomes to determine whether early-term birth is beneficial.

## METHODS

This study was a retrospective cohort study of singleton gestations with maternal CHD that delivered after 37 0/7 weeks between 2013 (implementation of an electronic medical record) and 2021 at a single quaternary care center with a multidisciplinary cardio-obstetrics team, which included maternal–fetal medicine, adult congenital heart disease, obstetric anesthesia, and nursing. A clinical database of all pregnant persons with maternal cardiac disease who receive care at our institution is maintained by the cardio-obstetrics team. The cohort of pregnant persons with CHD was selected from this database. Exclusion criteria included acquired heart disease, pregnant persons who did not receive continual prenatal care at our facility or did not deliver at our institution, preterm birth, and multiple gestations. This study was approved by the Institutional Review Board (IRB #17–000778), and informed written consent was waived. The lead author (T. M.) had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. The data that support the findings of this study are not publicly available at this time but may be available from the corresponding author upon reasonable request.

Data were abstracted from the maternal and neonatal records. Data abstraction was performed by the lead and second authors (T. M., A. W.). All abstracted data were reviewed by the lead author (T. M.) to ensure accuracy and uniformity in interpretation. Maternal demographics, baseline characteristics, medical comorbidities, and cardiac lesion were collected. Race and ethnicity are self-reported and were included in this study because of prior association of race and ethnicity with obstetric morbidity.<sup>12</sup> Based on the Adult Congenital Heart Disease Anatomic and Physiological classification (ACHD AP) system, the complexity of the anatomic lesion and the physiological stage were used to categorize patients into 1 of 12 categories and assess overall risk of morbidity and mortality.<sup>2</sup> Baseline New York Heart Association (NYHA) functional class was recorded along with cardiovascular risk stratification scores from 3 different models: CARPREG (Cardiac Disease in Pregnancy) risk score, ZAHARA

(Zwangerschap bij Aangeboren HARTafwijking-II) score, and modified World Health Organization (mWHO) classification.<sup>4,5,13–16</sup>

Pregnancies were categorized into 2 groups by gestational age at delivery: early-term birth (delivery at 37 0/7 to 38 6/7 weeks) or full-term birth (delivery at 39 0/7 weeks and beyond). The primary outcomes included development of a composite adverse cardiovascular outcome, composite adverse maternal obstetric outcome, and composite adverse neonatal outcome. The composite adverse cardiovascular outcome was defined as having 1 or more of the following: new or worsening congestive heart failure, sustained or symptomatic arrhythmia, new or worsening valvular dysfunction, embolic complication, endocarditis, need for cardiac intervention or treatment, cardiac arrest, or cardiac death. Congestive heart failure was diagnosed by symptoms and physical examination findings, as defined by the American College of Cardiology/American Heart Association guideline, and whether they required hospital admission or treatment.<sup>17</sup> Worsening valvular dysfunction was defined as an increase in valvular gradient (>20 mmHg) or worsening valvular regurgitation ( $\geq 2$  grades). Cardiac intervention was defined as requiring any surgical or transcatheter intervention, while need for cardiac treatment included initiation of supplemental oxygen or medication, such as a diuretic,  $\beta$ -blocker, or antibiotic, for management of worsening cardiovascular disease or complication.

The composite adverse maternal obstetric outcome was defined as 1 or more of the following: postpartum hemorrhage, blood transfusion, intensive care unit admission, endometritis or intra-amniotic infection, or emergency hysterectomy. Postpartum hemorrhage was defined, according to the American College of Obstetricians and Gynecologists guidelines, as a cumulative blood loss of  $\geq 1000$  mL or blood loss accompanied by signs or symptoms of hypovolemia.<sup>18</sup> Adverse cardiovascular and maternal obstetric outcomes were assessed for development during pregnancy and throughout the postpartum period, defined as up to 6 months after delivery.

A composite adverse neonatal outcome was defined as having 1 or more of the following: 5-minute Apgar score of <7, respiratory distress syndrome, small for gestational age (SGA), transient tachypnea of the newborn, sepsis, necrotizing enterocolitis, intraventricular hemorrhage, hypoxic ischemic encephalopathy, seizure, neonatal death before 28 days of life, or neonatal intensive care unit admission. SGA infants were defined by birthweight percentiles using the World Health Organization growth standards.<sup>19</sup> Secondary outcomes included development of pregnancy complications: hypertensive disorder of pregnancy (HDP), fetal growth restriction (FGR), and gestational diabetes. Additional secondary outcomes evaluated were intrapartum and delivery characteristics: indication

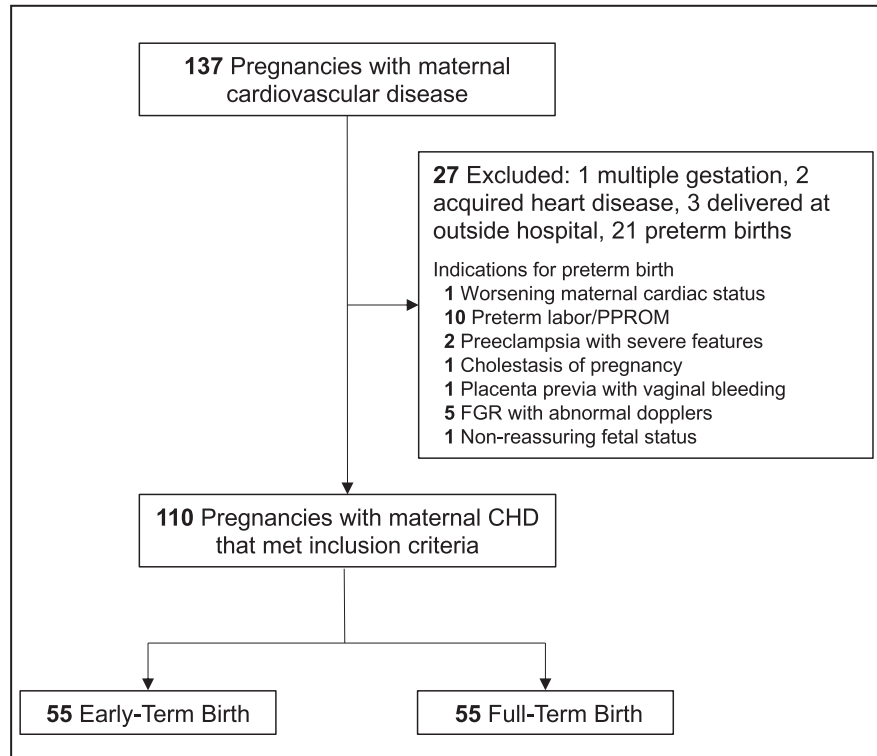
for delivery, type of labor (spontaneous or induced/scheduled), length of labor (hours), type of anesthesia, estimated blood loss, mode of delivery, and neonatal birthweight.

Patient characteristics and demographics, primary outcomes, and secondary outcomes were compared between the 2 gestational age at delivery groups with a  $\chi^2$  (or Fisher exact) and Wilcoxon rank-sum test. Data were presented with means with SDs, medians with interquartile ranges, and counts with percentages, as appropriate. Multivariable logistic regression analyses were conducted to calculate the adjusted odds ratio for development of adverse outcomes for gestational age at delivery. Statistical analyses were performed using SAS 9.4 (Cary, NC), and statistical significance was set at a *P* value of <0.05.

## RESULTS

For initial analysis, 137 pregnancies complicated by maternal cardiovascular disease that received care with our facility's cardio-obstetrics team were identified. A total of 27 pregnancies were excluded: 1 had a multiple gestation, 2 had acquired heart disease not congenital heart disease, 3 did not deliver at our institution, and 21 pregnancies delivered preterm (<37 weeks). Of the preterm births, only 1 was for worsening maternal cardiac status with decompensated heart failure in the setting of maternal unrepaired Tetralogy of Fallot at 35 weeks. The remainder of preterm births were for routine obstetric indications or presentation in preterm labor. A total of 110 pregnancies were complicated by maternal CHD and delivered after 37 weeks of gestation with known neonatal outcomes meeting criteria for analysis. Of these, 55 (50%) delivered at early-term, and 55 (50%) delivered at full-term (Figure 1).

The demographics and clinical characteristics of patients included in the study by gestational age at delivery are shown in Table 1. Patients with early-term births were less likely to be nulliparous than those with full-term births (44% versus 69%, *P*<0.01). There was no significant difference between the groups with respect to maternal age at delivery, race, prepregnancy body mass index, or maternal comorbidities. Cardiac lesions and ACHD-AP classification for those who delivered early-term were not significantly different from those who delivered full-term. The most common cardiac diagnosis was transposition of the great arteries (22%) for the early-term group and a left-sided lesion, such as bicuspid aortic valve, aortic stenosis, aortic regurgitation, or left ventricular outflow tract obstruction (29%) for patients who delivered at full-term. Prepregnancy echocardiogram measurements, baseline New York Heart Association class, and history of prior adverse cardiac event did not differ by delivery timing. Full-term births were more likely to have a lower



**Figure 1. Flow diagram of patients.**

CHD indicates congenital heart disease; FGR, fetal growth restriction; and PPROM, preterm premature rupture of membranes.

mWHO classification than those who had an early-term birth ( $P<0.01$ ), but the CARPREG II and ZAHARA risk stratification scores did not differ by delivery timing.

Table 2 summarizes the labor and intrapartum characteristics of the cohort. Of the entire cohort, 34% (37/110) presented in spontaneous labor and 66% (73/110) underwent an induction of labor or scheduled cesarean birth and did not differ between groups. The indication for delivery also did not differ between those who delivered early-term or full-term. The most common indication for a scheduled delivery was presence of maternal cardiac disease. Of these patients who had a scheduled delivery for the presence of maternal cardiac disease, 52.5% (21/40) were delivered early-term and 47.5% (19/40) were delivered full-term. Four of the patients underwent scheduled delivery because of worsening maternal cardiac status, all at early-term, and the remainder were considered elective deliveries for the presence of a maternal CHD diagnosis. Mode of delivery and length of labor did not significantly differ between the cohorts. The rate of cesarean birth was 26% in the early-term group and 33% in the full-term group, and the median length of labor was 17 hours for the early-term group and 20 hours for the full-term group. The median length of labor for those who presented in spontaneous labor was 16 hours, compared with 22 hours for those who underwent an induction

of labor. The rate of conversion to cesarean birth after induction of labor was 14% for the early-term group and 20% for the full-term group. A majority of patients received neuraxial anesthesia (91%); 3 (3%) patients required general anesthesia and 7 (6%) patients had an unmedicated birth.

Overall, 39 (35%) patients had a composite adverse cardiovascular outcome, 18 (16%) had a composite adverse maternal obstetric outcome, and 23 (21%) had a composite adverse neonatal outcome (Table 3). Development of composite adverse cardiovascular outcome was not significantly different between early-term and full-term births (40% versus 31%,  $P=0.32$ ). In the early-term birth group, 7 (13%) developed new or worsening congestive heart failure, 9 (16%) developed sustained or symptomatic arrhythmia, 1 (2%) developed valvular dysfunction, and 21 (38%) required cardiac intervention or treatment. In the full-term birth group, 5 (9%) developed new or worsening congestive heart failure, 4 (7%) developed sustained or symptomatic arrhythmia, and 17 (31%) had a need for cardiac intervention or treatment. The most common treatment required was initiation of a diuretic (22/110, 20%) followed by a  $\beta$ -blocker (15/110, 14%).

There was no significant difference in development of a composite adverse maternal obstetric outcome by delivery timing (13% early-term versus 20% full-term,

**Table 1. Patient Characteristics by Gestational Age at Birth**

	Early-term birth (n=55)	Full-term birth (n=55)	P value
Maternal age at delivery, y, median (IQR)	33 (28–36)	31 (28–35)	0.49*
Advanced maternal age†	19 (34)	16 (29)	0.54
Race/ethnicity			0.35
African American/Black	4 (7)	2 (4)	
Asian/Pacific Islander	9 (16)	5 (9)	
Hispanic/Latino	8 (15)	15 (27)	
White	29 (53)	26 (47)	
Other‡	5 (9)	7 (13)	
Gravida, median (IQR)	2 (1–3)	1 (1–2)	0.14*
Nulliparous	24 (44)	38 (69)	<0.01
Pre-pregnancy BMI			0.42§
Underweight (<18.5)	5 (9)	2 (4)	
Normal (18.5–24.9)	26 (47)	34 (62)	
Overweight (25–29.9)	13 (24)	10 (18)	
Obese (≥30)	11 (20)	9 (16)	
History of smoking	5 (9)	5 (9)	0.99
Maternal comorbidity	18 (33)	13 (24)	0.29
Pregestational diabetes	2 (4)	0 (0)	
Chronic hypertension	7 (13)	3 (5)	
Asthma	6 (11)	3 (5)	
Thyroid disease	5 (9)	2 (4)	
Autoimmune	2 (4)	1 (2)	
Other comorbidity	3 (5)	5 (9)	
Cardiac diagnosis			0.05§
Intracardiac shunt lesion	9 (16)	12 (22)	
Bicuspid aortic valve/aortic stenosis/aortic regurgitation/LVOT obstruction	9 (16)	16 (29)	
Mitral stenosis	1 (2)	1 (2)	
Mitral valve prolapse and/or mitral regurgitation	0 (0)	3 (5)	
Tetralogy of Fallot or pulmonary valve disease	7 (13)	12 (22)	
D-TGA (atrial switch)	8 (15)	2 (4)	
D-TGA (arterial switch)	4 (7)	2 (4)	
Single ventricle physiology	2 (4)	0 (0)	
Double outlet right ventricle	1 (2)	1 (2)	
Pulmonary hypertension	0 (0)	0 (0)	
Marfan syndrome	2 (4)	1 (2)	
Ebstein anomaly	2 (4)	0 (0)	
Other	10 (18)	5 (9)	
Prepregnancy echocardiogram subaortic ventricular dilation or dysfunction	5/42 (12)	3/35 (9)	0.72§
Prepregnancy echocardiogram subpulmonic ventricular dilation or dysfunction	3/42 (7)	3/35 (9)	0.99§

(Continued)

**Table 1. Continued**

	Early-term birth (n=55)	Full-term birth (n=55)	P value
Prepregnancy echocardiogram aortic or subaortic atrioventricular valve regurgitation	4/42 (10)	3/35 (9)	0.99§
Prepregnancy echocardiogram pulmonic or subpulmonic atrioventricular valve regurgitation	5/42 (12)	5/35 (14)	0.99§
Prior adverse cardiac event	19 (35)	16 (29)	0.68
NYHA functional class			0.52§
I	50 (91)	53 (96)	
II	3 (5)	2 (4)	
III	2 (4)	0 (0)	
Modified WHO classification			<0.01§
I	9/53 (17)	19 (35)	
II	10/53 (19)	18 (33)	
II–III	22/53 (41)	15 (27)	
III	12/53 (23)	3 (5)	
IV	0/53 (0)	0 (0)	
CARPREG II score			0.15§
0–1	28/53 (53)	42 (76)	
2	6/53 (11)	3 (5)	
3	11/53 (21)	6 (11)	
4	2/53 (4)	1 (2)	
>4	6/53 (11)	3 (5)	
ZAHARA score			0.21§
0–0.5	22/53 (41)	29 (52)	
0.51–1.5	21/53 (40)	22 (40)	
1.51–2.5	4/53 (8)	1 (2)	
2.51–3.5	6/53 (11)	2 (4)	
>3.5	0/53 (0)	1 (2)	
ACHD AP classification			0.50§
IA	2/51 (4)	4/50 (8)	
IB	5/51 (10)	6/50 (12)	
IC	1/51 (2)	1/50 (2)	
IIA	1/51 (2)	2/50 (4)	
IIB	12/51 (23)	18/50 (36)	
IIC	12/51 (23)	11/50 (22)	
IIIA	0/51 (0)	0/50 (0)	
IIIB	8/51 (16)	4/50 (8)	
IIIC	10/51 (20)	4/50 (8)	

Data presented as n (%) unless otherwise indicated. If values were missing for certain parameters, denominator is indicated. ACHD AP indicates Adult Congenital Heart Disease Anatomic and Physiological; BMI, body mass index; CARPREG, Cardiac Disease in Pregnancy; LVOT, left ventricular outflow tract; NYHA, New York Heart Association; TGA, transposition of the great arteries; WHO, World Health Organization; and ZAHARA, Zwangerschap Bij Aangeboren Hartafwijking-II.

\*Wilcoxon rank-sum.

†Advanced maternal age defined as maternal age of 35 years or older at the time of delivery.

‡“Other” was an option in the medical record for self-reported race and ethnicity.

§Fisher exact.

**Table 2. Intrapartum Characteristics by Gestational Age at Birth**

	Early-term birth (n=55)	Full-term birth (n=55)	P value
Labor type			0.42
Spontaneous	20 (36)	16 (29)	
Planned	35 (64)	39 (71)	
Indication for delivery			0.72*
Labor	20 (37)	16 (29)	
Maternal cardiac disease	21 (38)	19 (35)	
Obstetric indication	9 (16)	11 (20)	
Fetal indication	3 (5)	4 (7)	
Other	2 (4)	5 (9)	
Elective induction† (n=73)	17 (49)	22 (58)	0.61
Mode of delivery			0.44
Vaginal delivery	32 (58)	32 (58)	
Cesarean delivery	14 (26)	18 (33)	
Assisted delivery (forceps/vacuum)	9 (16)	5 (9)	
Length of labor (h), median (IQR)	17 (4, 25)	20 (10, 38)	0.16‡
Anesthesia			0.19*
None	5 (9)	2 (4)	
Neuraxial	50 (91)	50 (91)	
General	0 (0)	3 (5)	

Data presented as n (%) unless otherwise indicated. IQR indicates interquartile range.

\*Fisher exact.

†Only included patients who underwent induction of labor.

‡Wilcoxon rank-sum.

$P=0.30$ ). The rate of HDP was higher in those who delivered at early-term compared with full-term, but the difference was not statistically significant (22% early-term versus 14% full-term,  $P=0.32$ ). Of those who developed HDP, 3 had a history of chronic hypertension: 2 who had an early-term birth, and 1 who had a full-term birth. A majority developed HDP intrapartum or postpartum with 8/12 (66.7%) in the early-term group and 7/8 (87.5%) in the full-term group. HDP was the indication for earlier delivery in 4/12 (33.3%) of those who delivered early-term compared with 2/8 (25.0%) in those who delivered full-term. FGR was also higher in those who delivered at early-term compared with full-term, but the difference was not statistically significant (14% early-term versus 5% full-term,  $P=0.11$ ). FGR was the indication for delivery in 3/8 (37.5%) in the early-term cohort. The rate of gestational diabetes did not significantly differ between patients who delivered at early-term versus full-term.

Composite adverse neonatal outcome was significantly higher in early-term compared with full-term births (36% early-term versus 5% full-term,  $P<0.01$ ). Specifically, early-term births were associated with a significantly higher rate of neonatal intensive care

unit admissions (18% early-term versus 2% full-term,  $P<0.01$ ) and SGA infants (25% early-term versus 2% full-term,  $P<0.01$ ) compared with full-term births. Of the 15 neonates with SGA, just over half (8/15, 53.3%) were diagnosed with FGR in-utero (7 early-term birth, 1 full-term birth). There was also a higher rate of respiratory distress syndrome in those who had an early-term birth compared with full-term birth, which was approaching statistical significance (7% early-term versus 0% full-term,  $P=0.06$ ).

After adjusting for maternal age at delivery, mWHO classification, whether labor was spontaneous or induced/scheduled, and FGR in a multivariable logistic regression, early-term birth remained independently associated with an increased risk of composite adverse neonatal outcome ([aOR] 11.49 [95% CI, 2.57–51.36],  $P<0.01$ ) (Table 4). With 32% of the cohort entering spontaneous labor, a sensitivity analysis was performed restricting to pregnancies with maternal CHD that underwent induction of labor or a scheduled cesarean delivery ( $n=73$ ). This subset analysis demonstrated similar results with an increased risk of composite aOR with early-term birth (aOR, 7.96 [95% CI, 1.92–32.95],  $P<0.01$ ) but no significant difference in composite adverse cardiovascular outcome (aOR, 1.16 [95% CI, 0.41–3.25],  $P=0.78$ ) or composite adverse maternal obstetric outcome (aOR, 1.29 [95% CI, 0.35–4.77],  $P=0.71$ ). An additional sensitivity analysis on pregnancies with more severe disease defined as mWHO classification of II, II-III, III, or IV ( $n=80$ ) also demonstrated no significant difference in composite adverse cardiovascular outcome (aOR, 1.85 [95% CI, 0.72–4.77],  $P=0.20$ ) or composite adverse maternal obstetric outcome (aOR, 0.68 [95% CI, 0.19–2.48],  $P=0.56$ ) with early-term birth but a significantly increased risk for composite aOR (aOR, 8.10 [95% CI, 2.10–31.03],  $P<0.01$ ).

## DISCUSSION

There is limited evidence guiding delivery timing for pregnancies complicated by maternal CHD, and current recommendations are based primarily on expert clinical opinion. This retrospective cohort study of women with CHD evaluated adverse outcomes by timing of delivery and begins to evaluate delivery timing for this high-risk population. Our findings demonstrated that in maternal CHD pregnancies, delivery before 39 weeks was associated with a significantly higher incidence of an adverse neonatal outcome without significantly decreasing the incidence of an adverse cardiovascular or maternal obstetric outcome (Figure 2).

It is well established that early-term birth is associated with increased neonatal morbidity and mortality when compared with delivery at or beyond 39

**Table 3. Maternal Cardiovascular and Obstetric Outcomes and Neonatal Outcomes by Gestational Age at Birth**

	Early-term birth (n=55) n (%)	Full-term birth (n=55) n (%)	P value
<b>Maternal outcomes</b>			
Composite adverse cardiovascular outcome	22 (40)	17 (31)	0.32
Congestive heart failure	7 (13)	5 (9)	
Arrhythmia	9 (16)	4 (7.2)	
Thromboembolism	0 (0)	0 (0)	
Valvular dysfunction	1 (2)	0 (0)	
Endocarditis	0 (0)	0 (0)	
Cardiac intervention or treatment	21 (38)	17 (31)	
Surgical or transcatheter intervention	0 (0)	0 (0)	
Supplemental oxygen	1 (2)	1 (2)	
Diuretic	10 (18)	12 (22)	
β-blocker	12 (22)	4 (7)	
Antibiotics	0 (0)	0 (0)	
Other cardiovascular medications	0 (0)	1 (2)	
Cardiac arrest	0 (0)	0 (0)	
Cardiac death	0 (0)	0 (0)	
Hypertensive disorder of pregnancy	12 (22)	8 (14)	0.32
Gestational hypertension	7 (13)	4 (7)	
Preeclampsia without severe features	1 (2)	1 (2)	
Preeclampsia with severe features/HELLP	4 (7)	3 (5)	
Fetal growth restriction	8 (14)	3 (5)	0.11
Gestational diabetes	7 (13)	6 (11)	0.77
Estimated blood loss (mL), median (IQR)	300 (200–600)	300 (200–600)	0.89*
Composite adverse maternal obstetric outcome	7 (13)	11 (20)	0.31
Postpartum hemorrhage	2 (4)	7 (13)	0.16
Blood transfusion	0 (0)	4 (7)	0.12
Emergent hysterectomy	0 (0)	1 (2)	0.99
Peripartum infection	4 (7)	5 (9)	0.99
ICU admission	2 (4)	2 (4)	0.99
<b>Neonatal outcomes</b>			
Birthweight (g), median (IQR)	2910 (2570–3190)	3250 (3010–3535)	<0.01*
Composite adverse neonatal outcome	20 (36)	3 (5)	<0.01
SGA	14 (25)	1 (2)	<0.01
5-min Apgar score <7	1 (2)	0 (0)	0.99
NICU admission	10 (18)	1 (2)	<0.01
Respiratory distress syndrome	4 (7)	0 (0)	0.06
Sepsis	1 (2)	0 (0)	0.50
Antibiotics	2 (4)	1 (2)	0.62

Data presented as n (%) unless otherwise indicated. Only components of the composite adverse neonatal outcome that occurred in 1 or more neonate are reported in this table. HELLP indicates hemolysis, elevated liver enzymes, and low platelet count; ICU, intensive care unit; IQR, interquartile range; NICU, neonatal intensive care unit; and SGA, small for gestational age.

\*Wilcoxon rank-sum.

0/7 weeks.<sup>20–23</sup> As a result, elective early-term births should be avoided.<sup>21</sup> However, there are conditions that warrant early-term births because of risks associated with further continuation of the pregnancy.<sup>24</sup> Pregnant women with CHD are at an increased risk for both maternal cardiac and neonatal complications,<sup>6</sup>

but it has not been established whether an early-term birth would provide sufficient benefit to outweigh the risks of an earlier delivery.

Neonatal complications occur in 20% to 30% of pregnancies with maternal CHD.<sup>5,6</sup> The rate of an aOR occurring in our cohort of women with CHD was

**Table 4. Association of Early-Term Birth With Composite Cardiovascular, Maternal Obstetric, and Neonatal Outcomes**

	Unadjusted OR among early-term birth (95% CI)	P value	Adjusted OR among early-term birth* (95% CI)	P value
Composite adverse cardiovascular outcome	1.49 (0.68–3.27)	0.32	1.29 (0.55–3.02)	0.56
Composite adverse maternal obstetric outcome	0.58 (0.21–1.64)	0.31	0.77 (0.26–2.27)	0.63
Composite adverse neonatal outcome	9.91 (2.74–35.87)	<0.01	11.55 (2.59–51.58)	<0.01

OR indicates odds ratio; and WHO, World Health Organization.

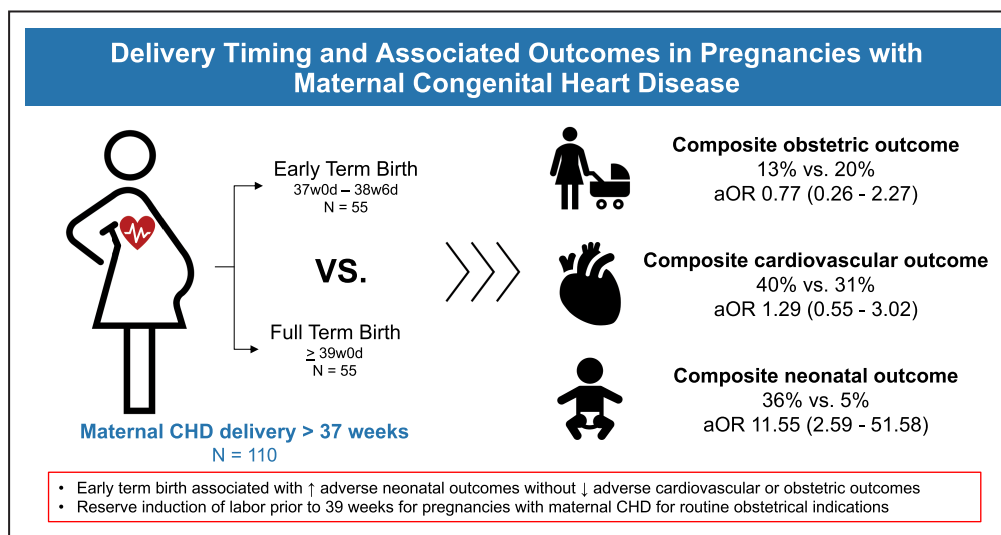
\*Adjusted for maternal age (<35 vs >35), modified WHO classification (II/II–III/IV vs I), type of labor, and fetal growth restriction.

comparable at a rate of 21%. The most common neonatal complication in pregnancies with CHD is premature births followed by SGA birthweight.<sup>6</sup> Even with the exclusion of premature births, there was a significantly increased risk of aOR in those who delivered at early-term compared with full-term. The primary driver for neonatal complications in the early-term cohort was an increased rate of neonatal intensive care unit admissions and SGA infants followed by increased rates of respiratory distress syndrome. The rate of obstetric complications associated with increased neonatal risks, including HDP, FGR, and gestational diabetes, did not significantly differ by timing of delivery. As a result, the increase in rate of aOR appears to be primarily associated with earlier delivery rather than the presence of alternative obstetric complications. Overall, the increased neonatal risks associated with elective early-term birth were confirmed in our study evaluating pregnancies with maternal CHD.

From the perspective of maternal risks, pregnancy leads to multiple hormonally mediated physiologic changes, including an increase in blood volume and heart rate and a decrease in systemic vascular

resistance.<sup>1</sup> These changes in underlying cardiac disease lead to an increased susceptibility to complications, such as arrhythmias, heart failure, or cardiac dysfunction.<sup>3–5</sup> Because of the cumulative stress of pregnancy over time, it may be theorized that earlier delivery leads to maternal benefit and avoids the development of adverse cardiovascular outcomes.

In contrast, in our cohort of pregnancies with CHD there was no significant difference in incidence of composite adverse cardiovascular outcome by timing of delivery, demonstrating no significant benefit with early-term birth. An alternative interpretation is that earlier delivery avoided the eventual development of an adverse cardiovascular outcome. However, although not statistically significant, the rate of adverse cardiovascular outcome was slightly higher in the early-term cohort at 40% compared with 31% at full term. In addition, the highest risk for decompensation or worsening maternal cardiac status is thought to be in the late second and early third trimester because of the substantial physiologic changes that occur during this time period.<sup>1</sup> It is unclear whether or not there is a significant difference in risk of cardiovascular



**Figure 2. Early-term birth for pregnancies with maternal congenital heart disease increased risk of neonatal morbidity without significant maternal benefit.**

aOR indicates adverse neonatal outcomes; and CHD, congenital heart disease.



complications in stable CHD during the 2 weeks between an early-term and full-term birth. It would theoretically be less because of the plateau of physiologic changes that may cause cardiac stress in the late third trimester.<sup>1</sup> This uncertain maternal benefit of earlier delivery contrasted with the clear neonatal risks associated with elective early-term births argues that care should be taken when deciding whether or not to proceed with an early-term birth, weighing all risks and benefits along with patient characteristics and disease status.

It is important to note that maternal cardiac events prompted delivery in 4 early-term patients, indicating that poor tolerance of pregnancy remains a clear indication for earlier delivery. When the analysis excluded these 4 patients who had a maternal cardiac indication for early-term birth, the rate of adverse cardiovascular outcome remained nonsignificant between groups. Thus, for stable pregnancies complicated by maternal CHD, full-term and early-term births had comparable incidences of adverse cardiovascular outcomes. Our findings on pregnancies with CHD support that of a prior study evaluating delivery timing in women with all forms of heart disease and that early-term birth in women with cardiovascular disease, who are clinically stable without worsening cardiovascular symptoms, does not provide significant maternal benefit in the peripartum period.<sup>25</sup>

Patients in the early-term cohort were more likely to be mWHO class II or higher, whereas patients in the full-term cohort were more likely to be mWHO class I. We hypothesize that this is because of the prevailing practice pattern during this era, in which the mWHO classification was used as the main risk stratification tool and providers preferentially delivering patients with higher mWHO risk earlier because of concern for potential cardiac deterioration. After adjusting for mWHO classification, there remained no significant difference in the rate of adverse cardiovascular outcomes between early-term and full-term births. The subset analysis of only those with more severe disease defined as mWHO classification of II or higher demonstrated similar results of no significant difference in risk for cardiovascular complications by delivery timing. Pregnancies with CHD consist of a heterogeneous population with different levels of associated risks based on the complexity of the underlying cardiac lesion and baseline physiologic status.<sup>26</sup> Additional studies should explore further stratification to determine whether earlier delivery is protective for pregnancies complicated by high-risk cardiac lesions.

### Strengths and Limitations

A strength of our study was the inclusion of only pregnancies with CHD, whereas a prior study by Rouse

et al evaluated timing of delivery for all forms of heart disease.<sup>25</sup> As a result, our study findings are specific for the CHD population, a group in which advances in medicine have led to an increased rate of successful pregnancies, but there remain limited data on best practices with respect to care throughout pregnancy. An additional strength is that the patients were cared for at a single quaternary care center by a well-established multidisciplinary team, providing a uniform approach to high-risk subspecialty care. However, the single-center study also serves as a limitation, decreasing the generalizability of our findings. These results may not apply to centers with limited resources.

Although our study is specific to pregnancies with CHD, this population is heterogeneous with a range of types and severity of cardiac lesions. This results in significantly different baseline maternal cardiac status and risk for development of adverse pregnancy outcomes. This heterogeneity limits the conclusions based on the findings. An additional limitation of this study is its smaller sample size. The lower prevalence of pregnancies with CHD, even in the setting of our institution's large cardio-obstetric center, led to this inherently small sample size. This may have limited the ability to detect smaller but potentially clinically relevant differences in adverse cardiovascular or maternal obstetric outcomes associated with timing of delivery. The multivariable models for adverse cardiovascular and neonatal outcomes were limited by wide confidence intervals, and the nonsignificant results and conclusions drawn from these findings should be interpreted with caution. Lastly, the retrospective design meant that missing data was inherent and may have led to unidentified confounding factors or bias. An adequately powered randomized control trial to evaluate timing of delivery for maternal CHD is needed to determine the most beneficial gestational age for delivery, but the lower prevalence of maternal CHD limits the feasibility of this trial.

### CONCLUSIONS

Within our cohort, early-term birth in pregnancies with maternal CHD was associated with an increased risk for adverse neonatal outcomes without an accompanying decrease in the risk of adverse maternal cardiac or obstetric outcomes. The findings from this study begin to offer evidence evaluating timing of delivery for pregnancies complicated by maternal CHD, suggesting that maternal cardiac outcomes are similar by delivery timing and that earlier delivery is not necessarily beneficial and may increase neonatal risks. Pregnant persons with maternal CHD remain a heterogeneous population that continues to require nuanced and individualized

multidisciplinary care for optimal maternal and neonatal outcomes. The decision on delivery timing should remain individualized for each patient, taking into consideration underlying cardiac diagnosis and baseline status, maternal and fetal status throughout the pregnancy, along with social factors including patient support systems and distance from a tertiary care hospital that is able to provide care for these complex cases. However, based on these study findings, in the absence of maternal or fetal indications and stable cardiovascular status, consideration may be taken to avoid early-term births in pregnancies complicated by maternal CHD outside of routine obstetric indications. Further prospective clinical trials are needed to determine recommendations for delivery timing and management of pregnancies with maternal CHD. This study begins to offer evidence to inform such studies and may be considered when coordinating delivery plans for these complex patients.

## ARTICLE INFORMATION

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### Affiliations

Division of Maternal-Fetal Medicine, Department of Obstetrics and Gynecology (T.M., Y.A.), Department of Anesthesiology and Perioperative Medicine (A.W.), Division of Cardiology, Department of Medicine, Ahmanson/UCLA Adult Congenital Heart Disease Center (M.M.C., G.L., L.R., J.A., J.L.), UCLA School of Nursing (M.M.C.), and Department of Urology (M.D.T., L.K.), University of California, Los Angeles, CA; and Division of Cardiology, Department of Medicine, New York University Langone Health, New York, NY (A.S.).

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### Disclosures

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