Postpartum Cardiovascular Outcomes Among Women With Heart Disease from A Nationwide Study

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There is limited data on postpartum maternal postpartum major adverse cardiovascular and cerebrovascular events (MACCE) among women with heart disease (HD) in the US. Therefore, we aimed to determine the prevalence and predictors of MACCE in the US. The Nationwide Readmissions Databases (2010 to 2014) were screened for patients with and without HD undergoing delivery. HD subtypes included cardiomyopathy (CDM), congenital heart disease, valvular heart disease, and pulmonary hypertension. Rates and reasons of 42-day readmission were determined using weighted national estimates. Independent predictors of postpartum MACCE were determined using multivariable logistic regression for complex survey data. We found among 15,273,247 patients hospitalized for delivery, 33,827 had HD (CDM 22.78%, congenital heart disease 45.98%, valvular heart disease 24.81%, and pulmonary hypertension 6.41%). Of these, 5.2% of HD patients and 1.4% of No HD were readmitted. MACCE was higher in HD vs No HD (2.68% vs 0.17%, p <0.0001). Median time to MACCE was 5.6 days (interquartile range 3 to 15 days). CDM had >10% readmission at 42 days. Among HD patients, cardiovascular, infectious, hypertensive syndromes, and complications of pregnancy were the most common reasons for 42-day readmission. MACCE predictors in women with HD included HD subtype, age, insurance status, obesity, eclampsia, postpartum hemorrhage, MACCE during delivery, preterm delivery, and thrombotic complications. In conclusion, among a nationwide analysis, postpartum MACCE was more common among patients with HD especially within 1 week of discharge from delivery. Predictors can be easily screened for by clinicians, including presence of any HD, hypertensive syndromes, age, obesity, and obstetrical events during index hospitalization. **(Am J Cardiol 2019;123:2006−2014)**

Preventable cardiovascular complications and death from pregnancy occur on a global scale, and it is a worldwide priority to reduce maternal mortality and morbidity according the United Nations' Millennium Development Goals.[1] Indeed, the United States as a whole had the second-highest maternal mortality ratio among 31 members of the Organization for Economic Cooperation and Development. The most common causes of maternal mortality in the US appear to be cardiovascular disease, hypertensive disorders, and sepsis.[2−4] Other investigations suggest that there are substantial postpartum (within 42 days of delivery) and late (>42 days of delivery) maternal cardiovascular events from direct or indirect obstetric causes than those during pregnancy or labor and delivery.[5] However, maternal events may be underestimated, likely related to events falling outside the delivery hospitalization, and therefore, not captured.[6] To date, there is little data on the postpartum cardiovascular events among women with heart disease in the US. Therefore, we sought to determine the contemporary rates, reasons, and predictors of postpartum maternal cardiovascular events in the US.

Methods

Data were obtained from the 2010 to 2014 Nationwide Readmission Database (NRD), collected by the Healthcare Cost and Utilization Project (HCUP), the largest, publicly available, inpatient databank in the United States.[7] The NRD is comprised of multiple HCUP State Inpatient Databases that cover multiple geographically dispersed states and deliver annual information on nearly 15 million unweighted discharges (35 million weighted discharges) each year. As per US Census Bureau statistics, the NRD represents nearly half of all US hospitalizations and the US population.[8] The NRD uses a unique patient linkage identifier to associate the same patient across multiple hospitalizations across a given state, while maintaining the individual's privacy. These linkage identifiers, however, do

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not track a given patient across calendar years (December to January). To better generalize the multiple years of data analysis, the Agency for Healthcare Research and Quality, which oversees HCUP databases, has developed discharge weights for the NRD. Each record was associated with a weight which allows for national estimates. Discharge records related to labor and delivery were included in the study. *International Classification of Diseases, Ninth Revision* (ICD-9) codes were used to determine hospitalizations for delivery, defined as any record with a normal delivery or other indications for care in pregnancy, labor, and delivery-related diagnoses as previously described by our group (Appendix).[9]

From 2010 to 2014, a total of 64,997,906 records of women ≥18 years of age were extracted for delivery-related analysis. Deliveries with missing data on death or insurance status were excluded (n = 196,773). Patients that died during the index hospitalization were excluded from further analysis (n = 1,497,326). Patients were further excluded if they were not delivering or had another delivery record found within 42-days of the index hospitalization, or if the index hospitalization occurred in November or December, or if data on length-of-stay were missing (n = 56,696,098). The final analytic cohort was comprised of 6,607,709 (national estimate: n = 15,273,247) index hospitalizations for delivery (Figure 1).

The investigative arm of the study included patients with heart disease (HD), which was defined as the presence of pulmonary hypertension (PH), cardiomyopathy (CDM), valvular heart disease (VHD), or congenital heart disease (CHD). ICD-9 diagnosis codes were utilized to determine the presence of heart disease (Appendix). A control group was designated as "no heart disease (No HD)" and was comprised of hospitalization for pregnancy and delivery (none of the previously mentioned cardiac disease codes present). For patients with multiple ICD-9 codes for HD, the HD types were assigned according to the priority rule: CDM > VHD > CHD > PH in order to separate multiple diagnoses. Only a minority of cases (1.5%) had overlapping HD diagnoses. Subtypes of CDM (peripartum, hypertrophic, and all other) were investigated (data presented in Supplemental tables). For patients with multiple ICD-9 CDM codes, the subtypes were assigned according to the priority rule: peripartum > hypertrophic > all other as previously described.[9]

Demographics (except race, which is not available in the NRD), clinical characteristics, co-morbidities, and other covariates of interest associated with the index hospital admission were extracted from the NRD. Delivery hospital characteristics such as teaching status, location, and region were obtained. The length of stay and total hospital charges (which represent absolute total hospital charge) of both the index and readmission were also extracted.

The primary outcome of interest was 42-day postpartum major adverse cardiovascular and cerebrovascular events (MACCE), defined as a composite of in-hospital death (NRD variable Y/N), cardiac arrest (see Appendix for all ICD9 codes), cardiogenic shock, acute myocardial infarction, heart failure, arrhythmia, cardiac complications of anesthesia or other sedation in labor and delivery, stroke, pulmonary embolism, arterial embolism, atheroembolism, obstetrical pulmonary embolism, and respiratory failure or arrest, acute renal failure. Time to first postpartum MACCE is defined as the difference between the admission date of first postpartum MACCE and the discharge date of index events (derived by adding corresponding length-of-stay to the admission date of index events) within 42 days of index events.

Pregnancy-related covariates during the index hospitalization were examined. Covariates of interest included transient hypertension of pregnancy (ICD-9 codes in Appendix), mild preeclampsia, severe preeclampsia, eclampsia complicating labor and delivery, multiple gestation, gestational diabetes mellitus, delivery type, and antepartum hemorrhage, abruptio placentae, and placenta previa. Complications occurring mainly in the course of labor and delivery were included. The overall rate of and median time to readmission were calculated. If a patient had multiple readmissions within 42 days, only the first was included. Causes of 42-day postpartum MACCE and readmission were classified using ICD-9 codes.

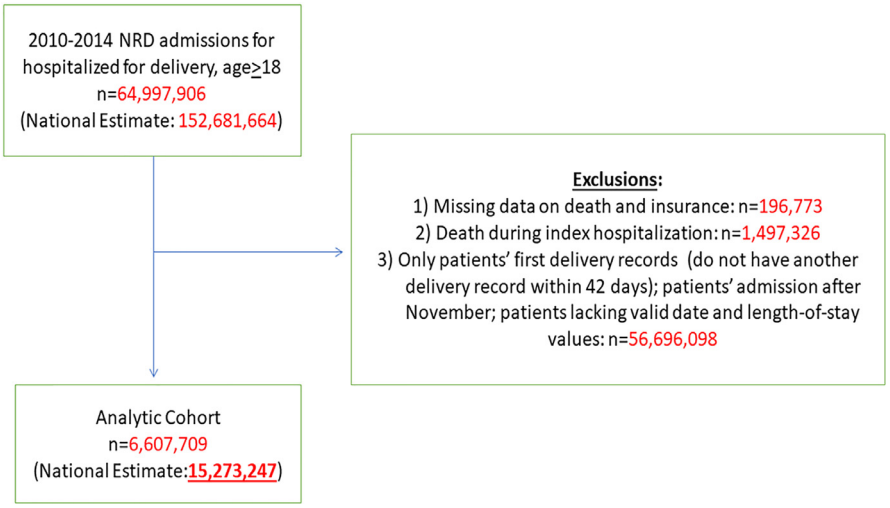

Figure 1. **Patient inclusion and exclusion criteria.** Flowchart of selection criteria for index labor and delivery hospitalizations. NRD = Nationwide Readmissions Database.

Statistical analysis software (SAS) using PROC SURVEYFREQ and SURVEYREG were used to generate estimates for the national populations to compare the distribution of patients' characteristics, complications, co-morbidities, obstetric outcomes, during-delivery MACCE, and postpartum MACCE between groups with and without heart diseases, and with different types of heart diseases. Categorical variables are presented as frequencies and percentages; continuous variables are presented as mean ± standard deviation or median with interquartile range as appropriate. Year and stratum identifiers in the NRD files were used as stratification variables, while hospital identifiers and discharge weight were used as the cluster and weight variable, respectively. Total discharges of each stratum in the original national discharge database were used to calculate finite population correction factors in order to get corrected variance estimate and hence valid inference.[10] In order to correctly account for variations between clusters and make accurate inferences about the national population, all records in the NRD remaining in the analysis and interested subgroup analysis were carried out using the domain options in PROC SURVEYFREQ and SURVEYREG.[11]

Possible predictors for postpartum MACCE among patients with heart disease were selected using ANOVA under the assumption of unequal variance and Pearson's chi-squared test with p values from Monte Carlo simulation to compare patients' characteristics, complications, co-morbidities, obstetric outcomes and during-delivery MACCE between HD patients with and without postpartum MACCE. These possible risk factors were further studied in the final multivariable survey logistic regression model using PROC SURVEYLOGISTIC, which was appropriate to draw conclusions about national populations. Similar models were used to compare the risk of postpartum MACCE between patients with and without HD or patients with a specific HD type and without HD. All adjusted ORs along with corresponding 95% confidence intervals are reported. Statistical significance was set at 0.05 and analysis was done using SAS 9.4 (SAS Institute Inc., Cary, NC).

Results

Among the nationally weighted analytical cohort of 15,273,247 patients hospitalized for delivery, there were 33,827 patients with HD (0.22% of the overall cohort) and 15,239,420 with no HD. Among the HD subtypes, there were 7,708 with CDM (22.78% of HD), 15,556 with CHD (45.98% of HD), 8,394 with VHD (24.81% of HD), and 2,169 with PH (6.41% of HD). Patient characteristics and demographics are described in Table 1. The HD group was older than No HD. The HD group was an overall a sicker cohort with higher rates of medical co-morbidities such as asthma, chronic obstructive pulmonary disease and bronchiectasis, complicated and noncomplicated diabetes mellitus, complicated and essential hypertension, and thyroid disease. The HD group also had higher rates of obesity, tobacco, alcohol and other substance use.

Complications during the index hospitalization for delivery are listed in Table 2. Compared to women with No HD, MACCE was more common in women with HD, predominantly due to higher rates of heart failure, arrhythmia, and respiratory arrest or failure. MACCE rates varied among the HD groups, with the highest rates noted in the CDM and PH groups, followed by VHD and least among patients with CHD.

Obstetric complications during delivery (Table 3) were overall more common among women with HD compared with No HD. Early onset of delivery was over twofold higher among patients with HD. CDM and PH had the highest rates of obstetrical complications during the index hospitalization. Over 10% of CDM and PH groups had severe preclampsia.

The overall median time to postpartum MACCE was 5.6 days (interquartile range 3 to 15 days). Postpartum MACCE was more prevalent among patients with HD compared with No HD, mostly due to heart failure, arrhythmia, and respiratory failure or arrest. Among the subtypes of HD, the CDM group had more than twofold higher postpartum MACCE than the PH group (Table 4 and Figure 2).

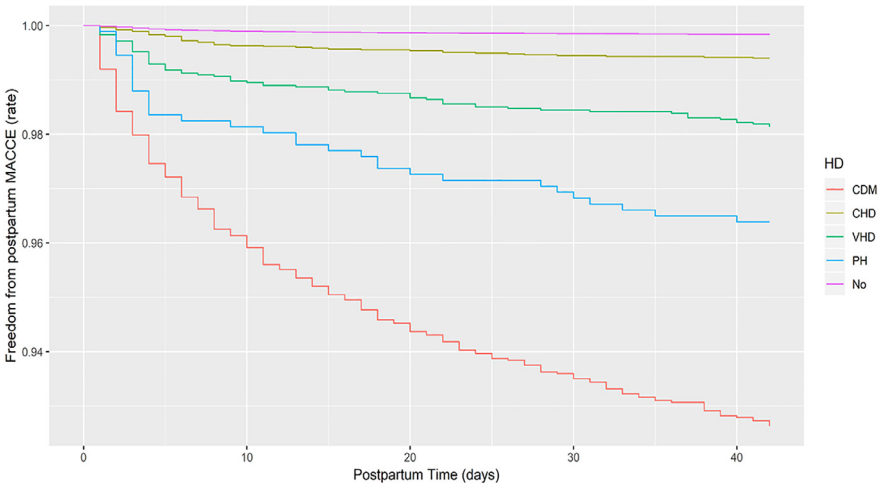

Figure 2. **Time to post-partum MACCE.** Kaplan-Meir curves. Numbers in parenthesis represent 95% confidence interval. CHD = congenital heart disease; CDM = cardiomyopathy; MACCE = major adverse cardiovascular and cerebrovascular events; No = no heart disease; PH = pulmonary hypertension; VHD = valvular heart disease.

Table 1
Demographics and clinical characteristics during index hospitalization

Variable	Heart disease (n = 33,827)	No heart disease (n = 15,239,420)	p value	CDM (n = 7,708)	CHD (n = 15,556)	VHD (n = 8,394)	PH (n = 2,169)	p value
Age (±SD)	28.9 (± 0.06)	28.3 (± 0.03)	<0.0001	30.2 (± 0.10)	28.1 (± 0.08)	29.1 (± 0.11)	29.9 (± 0.22)	<0.0001
Age groups (years):			<0.0001					<0.0001
<=25	10652 (31.49%)	5269290 (34.58%)		1948 (25.27%)	5622 (36.14%)	2485 (29.61%)	597 (27.52%)	
26-35	18017 (53.26%)	8168675 (53.60%)		4140 (53.71%)	8179 (52.58%)	4569 (54.43%)	1130 (52.08%)	
>=36	5158 (15.25%)	1801455 (11.82%)		1620 (21.02%)	1755 (11.28%)	1340 (15.96%)	443 (20.40%)	
Insurance Status:			0.0005					<0.0001
Medicaid / Medicare	15202 (44.94%)	6502901 (42.67%)		4102 (53.22%)	6105 (39.25%)	3743 (44.59%)	1252 (57.71%)	
Private Insurance	17001 (50.26%)	7987874 (52.42%)		3205 (41.58%)	8688 (55.85%)	4254 (50.68%)	854 (39.36%)	
Other	1624 (4.80%)	748646 (4.91%)		401 (5.20%)	764 (4.91%)	397 (4.72%)	64 (2.93%)	
Asthma	3072 (9.08%)	570470 (3.74%)	<0.0001	776 (10.07%)	1338 (8.60%)	661 (7.87%)	297 (13.68%)	<0.0001
Chronic Obstructive Pulmonary Disease and Bronchiectasis	77 (0.23%)	7025 (0.05%)	<0.0001	26 (0.34%)	27 (0.17%)	6 (0.07%)	18 (0.82%)	<0.0001
Diabetes mellitus:			<0.0001					<0.0001
With complications	300 (0.89%)	22678 (0.15%)		165 (2.15%)	55 (0.35%)	37 (0.44%)	43 (2.00%)	
Without complications	708 (2.09%)	121013 (0.79%)		319 (4.14%)	162 (1.04%)	138 (1.64%)	89 (4.12%)	
Hypertension:			<0.0001					<0.0001
Essential	974 (2.88%)	89000 (0.58%)		488 (6.33%)	154 (0.99%)	166 (1.98%)	165 (7.62%)	
With complications and secondary type	560 (1.65%)	7306 (0.05%)		384 (4.99%)	44 (0.28%)	70 (0.84%)	62 (2.84%)	
Obesity	3793 (11.21%)	800719 (5.25%)	<0.0001	1468 (19.04%)	1112 (7.15%)	748 (8.91%)	465 (21.44%)	<0.0001
Smoker	2871 (8.49%)	844231 (5.54%)	<0.0001	872 (11.31%)	1157 (7.44%)	678 (8.08%)	164 (7.57%)	<0.0001
Alcohol abuse	100 (0.30%)	16830 (0.11%)	<0.0001	44 (0.57%)	21 (0.14%)	24 (0.28%)	11 (0.52%)	0.0017
Other substance abuse	1210 (3.58%)	255361 (1.68%)	<0.0001	460 (5.96%)	352 (2.26%)	293 (3.50%)	105 (4.86%)	<0.0001
Thyroid disorder	2008 (5.94%)	461856 (3.03%)	<0.0001	588 (7.64%)	822 (5.28%)	435 (5.18%)	163 (7.50%)	<0.0001

Table 2
Complications during index hospitalization

Variable	Heart disease (n = 33,827)	No heart disease (n = 15,239,420)	p value	CDM (n = 7,708)	CHD (n = 15,556)	VHD (n = 8,394)	PH (n = 2,169)	p value
MACCE:	6986 (20.65%)	74828 (0.49%)	<0.0001	3804 (49.36%)	1236 (7.95%)	1315 (15.66%)	631 (29.07%)	<0.0001
Death*	0 (0.0%)	0 (0.0%)	–	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	–
Cardiac arrest	124 (0.37%)	587 (0.00%)	<0.0001	86 (1.12%)	<10	26 (0.31%)	8 (0.37%)	<0.0001
Cardiogenic shock	133 (0.39%)	90 (0.00%)	<0.0001	124 (1.61%)	<10	<10	<10	<0.0001
Heart failure	3294 (9.74%)	2301 (0.02%)	<0.0001	2631 (34.13%)	154 (0.99%)	339 (4.04%)	170 (7.85%)	<0.0001
Acute myocardial infarction	130 (0.38%)	348 (0.00%)	<0.0001	88 (1.14%)	11 (0.07%)	17 (0.20%)	13 (0.61%)	<0.0001
Arrhythmia	3138 (9.28%)	55725 (0.37%)	<0.0001	1097 (14.23%)	976 (6.27%)	835 (9.95%)	230 (10.60%)	<0.0001
Cardiac complications of anesthesia in L&D	27 (0.08%)	869 (0.01%)	<0.0001	<10	<10	13 (0.15%)	<10	<0.0001
Stroke	121 (0.36%)	967 (0.01%)	<0.0001	41 (0.53%)	55 (0.35%)	12 (0.14%)	14 (0.63%)	0.2379
Obstetrical pulmonary embolism	236 (0.70%)	3067 (0.02%)	<0.0001	88 (1.14%)	32 (0.20%)	44 (0.52%)	72 (3.32%)	<0.0001
Pulmonary embolism	27 (0.08%)	281 (0.00%)	<0.0001	11 (0.14%)	0 (0.0%)	12 (0.14%)	<10	–
Respiratory failure/arrest	1771 (5.24%)	10251 (0.07%)	<0.0001	1208 (15.67%)	99 (0.64%)	216 (2.58%)	248 (11.43%)	<0.0001
Acute renal failure	457 (1.35%)	5458 (0.04%)	<0.0001	329 (4.27%)	32 (0.21%)	43 (0.51%)	52 (2.40%)	<0.0001

Table 3
Obstetrical characteristics and complications during index hospitalization

Variable	Heart disease (n = 33,827)	No heart disease (n = 15,239,420)	p value	CDM (n = 7,708)	CHD (n = 15,556)	VHD (n = 8,394)	PH (n = 2,169)	p value
Antepartum Hemorrhage, Abruptio Placentae and Placenta Previa	1009 (2.98%)	284522 (1.87%)	<0.0001	275 (3.57%)	339 (2.18%)	284 (3.38%)	112 (5.14%)	<0.0001
Delivery Type:			<0.0001					<0.0001
Cesarean	16603 (49.08%)	5159752 (33.86%)		4838 (62.77%)	6402 (41.15%)	3997 (47.61%)	1366 (62.98%)	
Vaginal	17224 (50.92%)	10079669 (66.14%)		2870 (37.23%)	9155 (58.85%)	4397 (52.39%)	803 (37.02%)	
Early onset of delivery	4883 (14.43%)	1022066 (6.71%)	<0.0001	1665 (21.61%)	1626 (10.45%)	1111 (13.23%)	481 (22.18%)	<0.0001
Eclampsia:			<0.0001					<0.0001
Eclampsia complicating L&D	120 (0.36%)	9836 (0.06%)		54 (0.70%)	11 (0.07%)	35 (0.42%)	20 (0.93%)	
Mild preeclampsia	1270 (3.75%)	334739 (2.20%)		516 (6.70%)	392 (2.52%)	225 (2.68%)	136 (6.27%)	
Severe preeclampsia	1840 (5.44%)	226526 (1.49%)		922 (11.96%)	327 (2.10%)	362 (4.31%)	229 (10.56%)	
Gestational diabetes mellitus	1578, 3637 (10.75%)	504146, 1129894 (7.41%)	<0.0001	1257 (16.31%)	1289 (8.29%)	699 (8.33%)	391 (18.04%)	<0.0001
Multiple gestation	1169 (3.46%)	271079 (1.78%)	<0.0001	405 (5.25%)	375 (2.41%)	253 (3.01%)	137 (6.30%)	<0.0001
Premature Rupture of Membranes	1716 (5.07%)	651492 (4.28%)	0.0003	281 (3.64%)	898 (5.77%)	429 (5.12%)	108 (4.97%)	0.0023
Thrombotic Event	132 (0.39%)	5939 (0.04%)	<0.0001	61 (0.79%)	16 (0.10%)	37 (0.45%)	18 (0.85%)	<0.0001
Transient hypertension of pregnancy	1364 (4.03%)	556299 (3.65%)	0.0536	373 (4.84%)	536 (3.44%)	318 (3.79%)	137 (6.33%)	0.0014
Uterine rupture	62 (0.18%)	9575 (0.06%)	<0.0001	23 (0.30%)	27 (0.17%)	9 (0.11%)	4 (0.17%)	<0.0001
Laceration (3rd or 4th degree)	667 (1.97%)	338974 (2.22%)	0.1584	108 (1.40%)	395 (2.54%)	151 (1.80%)	13 (0.61%)	0.0007
Postpartum hemorrhage	1812 (5.36%)	440463 (2.89%)	<0.0001	519 (6.74%)	717 (4.61%)	392 (4.66%)	184 (8.47%)	<0.0001
Postpartum infection	573 (1.69%)	49975 (0.33%)	<0.0001	268 (3.47%)	115 (0.74%)	90 (1.07%)	100 (4.63%)	<0.0001

Table 4
Postpartum MACCE and readmission rate

Variable	Heart disease (n = 33,827)	No heart disease (n = 15,239,420)	p value	CDM (n = 7,708)	CHD (n = 15,556)	VHD (n = 8,394)	PH (n = 2,169)	p value
Readmission rate:								
42-day	5.2%	1.4%	<0.0001	10.3%	2.5%	4.9%	7.5%	<0.0001
Postpartum MACCE:	906 (2.68%)	25660 (0.17%)	<0.0001	585 (7.60%)	92 (0.59%)	161 (1.92%)	67 (3.10%)	<0.0001
Death	24 (0.07%)	328 (0.00%)		19 (0.25%)	<10	0 (0.0%)	<10	–
Cardiac arrest	16 (0.05%)	275 (0.00%)	<0.0001	16 (0.21%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	–
Cardiogenic shock	22 (0.07%)	190 (0.00%)	<0.0001	22 (0.29%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	–
Heart failure	659 (1.95%)	8385 (0.06%)	<0.0001	488 (6.33%)	54 (0.34%)	78 (0.93%)	39 (1.80%)	<0.0001
Acute myocardial infarction	23 (0.07%)	736 (0.00%)	<0.0001	17 (0.22%)	<10	0 (0.0%)	0 (0.0%)	–
Arrhythmia	267 (0.79%)	7749 (0.05%)	<0.0001	149 (1.94%)	35 (0.23%)	68 (0.80%)	15 (0.69%)	<0.0001
Cardiac complications of anesthesia in labor and delivery	0 (0.0%)	21 (0.00%)	–	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	–
Stroke	27 (0.08%)	1376 (0.01%)	<0.0001	16 (0.21%)	<10	<10	<10	0.0024
Obstetrical pulmonary embolism	49 (0.14%)	4341 (0.03%)	<0.0001	24 (0.31%)	<10	16 (0.19%)	<10	0.0477
Pulmonary embolism	30 (0.09%)	1138 (0.01%)	<0.0001	14 (0.18%)	<10	9 (0.11%)	<10	0.075
Respiratory failure/arrest	155 (0.46%)	4745 (0.03%)	<0.0001	115 (1.49%)	14 (0.09%)	13 (0.15%)	14 (0.64%)	<0.0001
Acute renal failure	115 (0.34%)	2941 (0.02%)	<0.0001	36, 77 (1.00%)	<10	20 (0.24%)	13 (0.62%)	<0.0001

Rate of 42-day readmission was low for both patients with HD and No HD, though higher in those with HD. The CDM group had over 10% readmission rate at 42 days (Table 4). Most common primary causes for readmission at 42 days are shown in Figure 3. Among women with HD, cardiovascular causes were the most common reason for readmission at 42 days, followed by infection, complications of pregnancy, obstetrical surgery, or surgical wound, and eclampsia or preeclampsia.

Among the CDM subtypes, peripartum CDM had the highest rates of index hospital MACCE, obstetrical complications, 42-day readmission, and postpartum MACCE (Supplemental Tables 1−4).

Multivariable survey logistic regression modeling of predictors for postpartum MACCE among patients with HD is shown in Table 5. The presence of any HD was associated with over fourfold increased risk of postpartum MACCE. Among the HD subtypes CDM carried the highest risk for postpartum MACCE, followed by VHD, subsequently followed by PH, and lastly CHD. Older age groups (26 to 35 years) was significantly associated with increased risk of postpartum MACCE compared with age <25 years. Insurance status and obesity were other covariates associated with postpartum MACCE. Obstetrical complications during the index hospitalization that were significant predictors for postpartum MACCE included mild preeclampsia, postpartum hemorrhage, early onset of delivery, and thrombotic event.

Discussion

In this contemporary, nationally representative population of patients hospitalized for delivery, we found the rate of postpartum MACCE at 42-days was over 15-fold higher among women with HD compared with those without. Among the subgroups of HD, patients with CDM had the highest rates of postpartum MACCE. Heart failure, arrhythmia, and respiratory complications were the most common components of MACCE noted in the postpartum period. Cardiovascular causes were among the leading reasons for readmission among women with HD, typically within 1 week of discharge. We found the presence of any heart disease (particularly CDM), increased age, insurance status, and obesity predictive of postpartum MACCE at 42-days. Clinical events during the index hospitalization such as mild preeclampsia, postpartum hemorrhage, early onset of delivery, and thrombotic complications during the labor and delivery were predictive of postpartum MACCE. To our knowledge, this is the first study of its kind to investigate the postpartum outcomes of patients with HD and different subgroups of HD.

With the NRD we were able to longitudinally track the same patient to 42-days postdischarge from their corresponding labor and delivery hospitalization. We demonstrated that pregnant women with HD are at increased risk for deterioration requiring re-hospitalization in the postpartum period. Due to the hemodynamic challenges of pregnancy, pregnancy is known to cause or worsen cardiac conditions such as CDM and CHD,[12−15] with mortality rates of about 10% to 25% within 6 months after diagnosis. Although, because these events can occur outside the

Table 5
Risk of post-partum MACCE among patients with heart disease

	OR (95% CI)	p value
Heart disease (vs No HD)	4.38 (3.88-4.96)	<0.0001
Heart disease subtypes (vs No HD)		<0.0001
CDM	5.88 (4.99, 6.93)	
PH	2.95 (2.21, 3.94)	
CHD	2.30 (1.69, 3.12)	
VHD	4.56 (3.46, 5.99)	
Heart disease subtypes (vs other subtype):		<0.0001
CDM (vs CHD)	5.58 (3.79-8.22)	
CDM (vs PH)	2.17 (1.61-2.92)	
CDM (vs VHD)	2.26 (1.69-3.03)	
CHD (vs PH)	0.39 (0.25-0.60)	
CHD (vs VHD)	0.41 (0.27-0.60)	
VHD (vs PH)	0.96 (0.66-1.39)	
Age:		
26-35 (vs ≤25)	1.90 (1.47-2.45)	
26-35 (vs ≥36)	0.94 (0.71-1.24)	
≤25 (vs ≥36)	0.50 (0.36-0.68)	
Insurance:		<0.0001
Medicaid/Medicare (vs Other)	1.10 (0.72-1.67)	
Medicaid/Medicare (vs Private Insurance)	1.78 (1.37-2.31)	
Other (vs Private Insurance)	1.62 (1.13-2.33)	
Asthma	1.22 (0.90-1.66)	0.2070
Diabetes:		0.1157
With Complication	2.14 (0.97-4.71)	
With Complication (vs without Complication)	2.16 (0.96-4.87)	
Without Complication	0.99 (0.49-1.99)	
Hypertension:		0.5846
Essential Hypertension vs Hypertension with Complications and Secondary Hypertension	1.13 (0.59-2.17)	
Essential Hypertension	1.29 (0.79-2.11)	
Hypertension with Complications and Secondary Hypertension	1.14 (0.65-1.98)	
Obesity	1.34 (1.03-1.75)	0.0286
Schizophrenia and Other Psychotic Disorders	1.59 (0.41-6.10)	0.5025
Smoking	1.21 (0.89-1.64)	0.2221
Substance-related Disorders	1.05 (0.69-1.62)	0.8087
Laceration (3rd or 4th Degree)	0.76 (0.14-4.21)	0.7529
Postpartum Hemorrhage	1.43 (1.06-1.94)	0.0202
Antepartum Hemorrhage, Abruptio Placentae and Placenta Previa	1.11 (0.65-1.88)	0.7108
Cesarean (vs Vaginal)	1.08 (0.84-1.39)	0.5562
Early Onset of Delivery	1.32 (1.05-1.65)	0.0152
Eclampsia:		0.0008
Eclampsia Complicating Pregnancy/Childbirth (vs Mild Preeclampsia)	0.93 (0.23-3.74)	
Eclampsia Complicating Pregnancy/Childbirth	1.82 (0.46-7.20)	
Eclampsia Complicating Pregnancy/Childbirth (vs Severe Preeclampsia)	1.87 (0.46-7.50)	
Mild Preeclampsia	1.95 (1.40-2.72)	
Mild Preeclampsia (vs Severe Preeclampsia)	2.00 (1.34-2.98)	
Severe Preeclampsia	0.97 (0.73-1.30)	
Gestational Diabetes Mellitus	0.82 (0.52-1.28)	0.3767
Thrombotic Event	1.98 (1.04-3.78)	0.0375
Uterine Rupture	1.95 (0.72-5.28)	0.1908

Note: There are two separate multivariate models listed above separated by the thick borderline.
CDM = cardiomyopathy; CHD = congenital heart disease; MACCE = major adverse cardiovascular and cerebrovascular events; PH = pulmonary hypertension; VHD = valvular heart disease.

hospitalization for delivery, women who deteriorate from CDM or other forms of HD can be missed. This is of concern because regardless of how late these events occur, they are pregnancy-related.

Surveillance data has shown cardiovascular disease to be among the leading causes of postpartum maternal deaths and its incidence rate is increasing.[16,17] CDM is a significant contributor to cardiovascular maternal morbidity and mortality in the US[9]. Previous investigations have shown CDM to be associated with approximately 12% of postpartum deaths in the US from 2006 to 2009.[18,19] Herein, HD of any type was associated with postpartum MACCE, while CDM had the highest risk by nearly sixfold and incurred the highest mortality during readmission. This

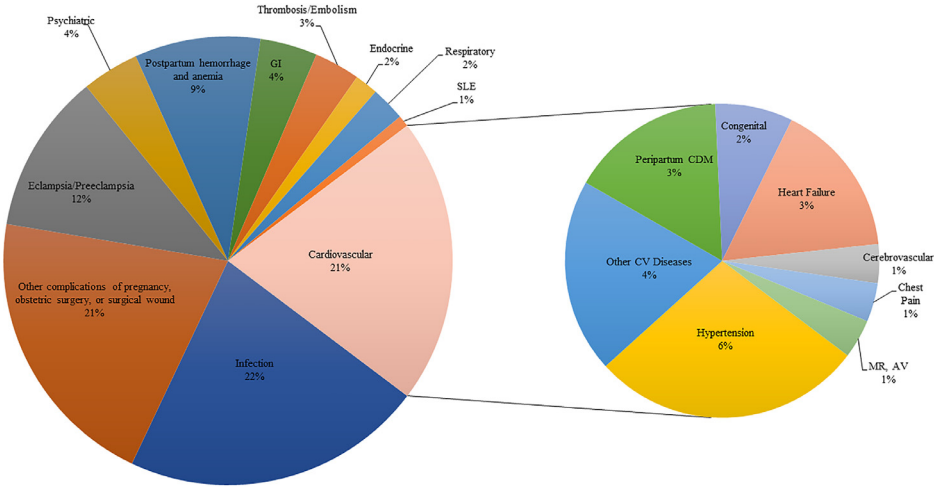

Figure 3. **Reasons for 42-day readmission in patients with heart disease after delivery.** The smaller pie chart shows distribution of readmissions for cardiovascular events. AV = aortic valve disorder; CDM = cardiomyopathy; Endocrine = endocrine conditions; GI = gastrointestinal conditions; MR = mitral valve regurgitation; Other CV Diseases = other cardiovascular diseases of mother, postpartum condition, or complication; Psychiatric = psychiatric conditions; SLE = systemic lupus erythematosus.

data should heighten awareness of readmission and postpartum risk in patients with CDM or any HD subtype presenting for labor and delivery.

Previous studies have described a high rate of patients losing insurance coverage in the postpartum periods.[20] Nearly half of the HD population in our study was ensured with Medicaid/Medicare and logistic regression modeling noted public, compared with private insurance, was more likely to experience postpartum MACCE. Most practices in the US offer a single follow-up visit at 6-weeks (42 days) postdischarge from delivery.[21] However, loss of healthcare coverage has been demonstrated previously as a barrier to postpartum follow-up and treatment.[22,23] This raises concern since patients with HD require more, rather than less, intensive monitoring in the postpartum period. Index hospital complications, clinical characteristics, and demographics could be easily screened for, which represent an opportunity for hospital systems and clinicians to identify patients to track closely in the postpartum period in order to deter complications. A multidisciplinary team, inclusive of cardiology, obstetrics/gynecology, and primary care should be closely involved with following patients early in the postpartum period, as most readmissions occur in the first week postpartum.

Our analysis should be interpreted within the context of several limitations. The retrospective nature of the data collection exposes the data to sampling bias and biases implicit in the limitations of the medical record and possible coding errors. Our assessment of postpartum MACCE only extended up to 42 days from the index hospitalization (delivery) discharge. Due to restrictions in the follow-up analysis in the NRD, a large proportion of records were eliminated from the study analysis, although this is common practice in this type of study.[24,25] Thus, patients presenting to the hospital beyond this time period were not captured. Since the NRD does not capture data on race, outpatient data, vital status between index hospitalization discharge and readmission, these important data were unattainable. Unfortunately, out-of-hospital maternal events and mortality were not included. Although coding errors are possible, ICD-9 coding has been shown to be associated with low error rates and hold high specificity and positive predictive value among cardiovascular conditions.[26–30]

In a contemporary, nationwide cohort of pregnant patients with HD and no HD, postpartum MACCE at 42-days was found to be over 15-fold higher among women with HD compared with those without. Median time to cardiovascular events occurred within 1 week of discharge. Patients with cardiomyopathy incurred the highest rate of postpartum MACCE among all studied subgroups. The HD subtype, age, insurance status, obesity, mild preeclampsia, postpartum hemorrhage, early onset of delivery, and thrombotic complications during the labor and delivery predicted postpartum MACCE among patients with HD. These risk factors can be screened for by clinicians during the index-hospitalization for labor and delivery and efforts aimed at monitoring these patients closely after hospital discharge should be implemented.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amjcard.2019.03.012.

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