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Pulmonary Hypertension During Pregnancy in New York State, 2003–2014

Jean Guglielminotti[1,2,3] · Ruth Landau[1] · Alexander M. Friedman[4] · Guohua Li[1,5]

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Abstract

Objectives This study examined the prevalence and temporal trends in (a) pulmonary hypertension (PH) during pregnancy and (b) mortality and morbidity during pregnancy with and without PH. *Methods* This was a retrospective observational study of the 2003–2014 New York State Inpatient Database. PH was categorized as primary or secondary and pregnancy as loss or termination of pregnancy, preterm birth, or term birth. The Centers for Disease Control and Prevention definition of maternal morbidity was used, including 17 diagnoses and 5 procedures. Changes were assessed using Cochran-Armitage trend tests. *Results* Of 2,940,868 pregnancy-related discharges, 746 indicated a diagnosis of PH (25/100,000; 95% CI 24–27). PH was secondary in 677/746 (91%) discharges and 488/746 were term births (65%). Prevalence of secondary PH increased from 17 to 30/100,000 between 2003– 2004 and 2013–2014 (+ 69%; P < 0.001), with an increase in the prevalence of heart valve disease, obesity, and systemic hypertension. Primary PH decreased 81% (P = 0.002). Term-birth PH discharges increased from 13 to 22/100,000 between 2003–2004 and 2013–2014 (+ 66%; P = 0.003), without change in preterm births and loss or termination of pregnancies. No change in morbidity in PH discharges was observed between 2003–2004 and 2013–2014, contrasting with a 64% increase in discharges without PH. *Conclusions for Practice* Prevalence of secondary PH during pregnancy markedly increased since 2003, underscoring the importance of screening for PH, especially in women with heart valve disease, obesity, or systemic hypertension.

Keywords Maternal morbidity · Pulmonary hypertension · Pregnancy

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✉ Jean Guglielminotti
jg3481@cumc.columbia.edu

[1] Department of Anesthesiology, Columbia University College of Physicians and Surgeons, 622 West 168th Street, PH5-505, New York, NY 10032, USA

[2] INSERM, UMR 1137, IAME, 16 rue Henri Huchard, 75018 Paris, France

[3] Département d'Anesthésie-Réanimation, APHP, Hôpital Bichat-Claude Bernard, 46 rue Henri Huchard, 75 877 Paris Cedex 18, France

[4] Division of Maternal Fetal Medicine, Department of Obstetrics and Gynecology, Columbia University College of Physicians and Surgeons, 622 West 168th Street, New York, NY 10032, USA

[5] Department of Epidemiology, Columbia University Mailman School of Public Health, 722 West 168th Street, New York, NY 10032, USA

Abbreviations

AHA	American Hospital Association
CDC	Centers for Disease Control and Prevention
CI	Confidence interval
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
OR	Odds ratio
PH	Pulmonary hypertension
WHO	World Health Organization

Significance

Prevalence of secondary PH during pregnancy markedly increased since 2003, emphasizing the importance of screening this diagnosis, especially in women with heart valve disease, obesity, or systemic hypertension.

Introduction

Pulmonary hypertension (PH) is an abnormal hemodynamic condition defined by a mean pulmonary artery pressure at rest greater than 25 mm Hg, as measured by right heart catheterization (Galie et al. 2009; McLaughlin et al. 2009). PH during pregnancy is considered as a rare disease (Bonnin et al. 2005; Obican and Cleary 2014). Estimated prevalence in the United States for primary PH (i.e. PH without a known cause) is 1.6/100,000 deliveries and for combined primary and secondary PH (i.e. PH resulting from other diseases) 22.5/100,000 deliveries (Chakravarty et al. 2008; Thomas et al. 2017). Prevalence of secondary PH may be increasing because of the increase in the prevalence of chronic comorbidities associated with secondary PH (e.g., congenital heart disease) (Kuklina and Callaghan 2011; Maxwell et al. 2013; Thompson et al. 2015). Healthcare providers may therefore be more likely to care for these very high-risk women.

PH is aggravated during pregnancy and delivery. Consequently, risks of maternal morbidity and mortality are markedly increased in pregnant women with PH. The World Health Organization (WHO) classification categorizes PH during pregnancy in the highest class of cardiovascular risk (class IV) (Regitz-Zagrosek et al. 2011). Recent reports indicate a mortality rate for PH during pregnancy ranging between 8 and 16% (Meng et al. 2017; Mhyre et al. 2011; Pieper et al. 2014; Ruys et al. 2014; UK Obstetric Surveillance System 2013). Poor maternal prognosis associated with this diagnosis has resulted in considering PH as a relatively strong contraindication for pregnancy and medical or surgical termination of pregnancy is often recommended (Galie et al. 2009; Regitz-Zagrosek et al. 2011). It has been suggested that mortality of pregnant women with PH has decreased over the last two decades (Bedard et al. 2009; Duarte et al. 2013; Pieper et al. 2014). However, such improvement in maternal prognosis can be questioned because studies have mainly analyzed small series from academic centers. Furthermore, no study has specifically examined maternal morbidity in pregnant women with PH.

Based on a census of hospital discharges records from New York State from 2003 to 2014, this study aimed to examine the prevalence and time trends in (a) PH during pregnancy and (b) mortality and morbidity during pregnancy with and without PH.

Materials and Methods

The study protocol was reviewed by the Institutional Review Board of Columbia University Medical Center and was granted exemption under 45 Code of Federal Regulation 46 (not human subjects research). The Strengthening The Reporting of OBservational studies in Epidemiology (STROBE) and the Reporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statements were followed.

Study Sample and Definition of Pregnancy

Hospital discharge records of the State Inpatient Database for New York from 2003 to 2014 were analyzed. State Inpatient Databases are part of the Healthcare Cost and Utilization Project sponsored by the Agency for Healthcare Research and Quality (HCUP 2018). They capture all inpatient discharges from non-federal acute care community hospitals, including tertiary and academic centers. For each discharge, the State Inpatient Database include patient characteristics, one hospital identifier, and up to 15 procedural and 25 diagnostic codes defined in the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM). Hospital characteristics were obtained from the State Inpatient Database and from the American Hospital Association (AHA) file.

Based on ICD-9-CM codes, pregnancy was categorized into 3 mutually exclusive groups: (1) loss or termination of pregnancy (including molar or ectopic pregnancy, abortion, intra-uterine death, aspiration, curettage, and abortive intra-amniotic injection), (2) preterm birth (delivery before 37 completed weeks of gestation), and (3) term birth (delivery after 37 completed weeks of gestation) (Supplemental Digital Content Table 1).

Two groups of pregnant women were defined: (1) pregnant women without a diagnosis PH, and (2) pregnant women with a diagnosis of PH. In the ICD-9-CM, PH is categorized as either primary or secondary (Supplemental Digital Content Table 2). For consistency, we used this classification in this study rather than the 1998 updated classification or the 2013 WHO classification (Galie et al. 2009; Simonneau et al. 2013). The following possible etiologies of secondary PH were analyzed: congenital heart disease, heart valve disease, obesity, systemic hypertension, and connectivitis (Supplemental Digital Content Table 3). Connectivitis include systemic lupus erythematosus, systemic sclerosis, sicca syndrome, dermatomyositis, polymyositis, eosinophilia myalgia syndrome.

Maternal Mortality and Morbidity Outcomes

The outcomes analyzed included in-hospital maternal mortality and morbidity. In-hospital mortality was recorded directly from the State Inpatient Database. The composite outcome maternal morbidity was defined using the definition of the United States Centers for Disease Control and Prevention (CDC) and categorized into diagnoses and procedures

(Supplemental Digital Content Table 4). The 17 following diagnoses were included: (1) acute myocardial infarction, (2) aortic aneurysm and dissection, (3) acute renal failure, (4) adult respiratory distress syndrome, (5) amniotic fluid embolism, (6) cardiac arrest and ventricular fibrillation, (7) conversion of cardiac rhythm, (8) disseminated intravascular coagulation, (9) eclampsia, (10) heart failure or arrest during surgery or procedure, (11) puerperal cerebrovascular disorders, (12) pulmonary edema and acute heart failure, (13) anesthesia-related complications, (14) sepsis, (15) shock, (16) sickle cell disease with crisis, and (17) air and thrombotic embolism. Morbidity diagnoses were defined as severe if associated with in-hospital death or with hospital length-of-stay greater than the 90th percentile. The 4 following procedures were included: (1) transfusion of blood products, (2) hysterectomy, (3) tracheostomy, (4) and ventilation. Cesarean delivery was added to the 4 CDC procedures. The CDC definition of maternal morbidity based on administrative data used in this study was previously validated against direct chart review and have a sensitivity of 77% and a specificity of 99% (Main et al. 2016).

Patients and Hospitals Variables

The following patient- and hospital-level variables were directly recorded or calculated from the State Inpatient Database: maternal age, race or ethnicity, insurance type, admission during weekend, admission type (elective or non-elective), and annual volume of delivery. In the State Inpatient Database, Hispanic ethnicity is considered as a distinct racial group. Charlson comorbidity index was calculated using an ICD-9-CM algorithm previously described (Quan et al. 2011). Other patient characteristics were identified with ICD-9-CM codes (Supplemental Digital Content Table 3). The following hospital-level variables were recorded from the AHA data: hospital location (rural or urban), teaching status, and neonatal level-of-care designation (1, 2 or 3). Rural hospital location included micropolitan or rural areas based on the Core Based Statistical Areas. A teaching hospital had an affiliation to a medical school or residency training accreditation.

Statistical Analysis

Results are expressed as numerator/denominator (%; per 10,000 for mortality and morbidity; per 100,000 for prevalence), median (interquartile range), or mean (1 standard deviation). Statistical analysis was performed with R version 3.4.1 (R Foundation for Statistical Computing, Vienna, Austria). The unit of analysis was the discharge record and not the patient.

Comparisons of discharges with and without PH used Student t or Wilcoxon test for continuous variables and Chi square or Fisher exact test for categorical variables. Unadjusted odds ratios were calculated using univariable logistic regression. Adjusted odds ratios were calculated using multivariable logistic regression with the following variables for adjustment: age, race, Charlson comorbidity index, outcome of pregnancy (loss or termination versus birth), and year of hospitalization.

Prevalence and Rates

The prevalence of PH in pregnant women was calculated for each 2-year period according to the type of PH (primary or secondary) and to the outcome of pregnancy (loss or termination of pregnancy, preterm birth, or term birth). Two-year prevalence rates were also calculated for the possible etiologies of secondary PH: congenital heart disease, heart valve disease, obesity, systemic hypertension, and connectivitis. The crude rates of maternal morbidity including morbidity diagnoses, severe morbidity diagnoses, and procedures in pregnant women with and without PH were calculated for each 2-year period of the study period.

The percent change in prevalence (rate) over the 12-year study period was calculated as the difference between the prevalence (rate) in 2013–2014 and the prevalence (rate) in 2003–2004 divided by the prevalence (rate) in 2003–2004. The 95% CI for the percent change was calculated. The Cochran–Armitage test for trends was used to assess the statistical significance of changes of prevalence and rates over time.

Multivariable Logistic Regression Model

One multivariable logistic regression model was fitted for risk factors for maternal morbidity diagnoses in discharges with PH. Univariable analysis used Chi square tests or Fisher exact tests for categorical variables and Student t tests or Wilcoxon test for continuous variables. Variables with a P-value < 0.2 in the univariable analysis were entered in a logistic regression without selection (full model). Type of PH (primary or secondary) and outcome of pregnancy (loss or termination of pregnancy or birth) were forced in the models. Missing values were handled with multiple imputations. Discrimination of the model was assessed with the c-index.

Results

During the study period, 30,891,478 discharges were available in the New York State Inpatient Database (Supplemental Digital Content Fig. 1). Of 2,940,868 pregnancy-related discharges, 746 included a PH diagnosis (25.4/100,000

pregnancies; 95% CI 23.6–27.2). PH was secondary in 677 of 746 cases (90.7%).

Characteristics and Outcomes of Discharges with and Without PH

Compared to discharges without a diagnosis of PH, discharges with a diagnosis of PH were older (31 versus 29 year-old), more frequently black (33.3% versus16.5%), more frequently covered by Medicaid or Medicare (59.7% versus 43.5%), and had a higher Charlson comorbidity index score (Table 1). In discharges with a diagnosis of PH, pregnancy loss or termination (10.3% versus 3.0%) and preterm birth (24.3% versus 6.9%) were both more common than in discharges without a diagnosis of PH.

The in-hospital mortality rates were 147/10,000 in discharges with a diagnosis of PH and 1/10,000 in discharges without this diagnosis (P < 0.001) (Table 2). The mortality rate was not significantly different between primary and secondary PH. Rates of morbidity diagnoses and procedures were also significantly higher in discharges with a diagnosis of PH, without a difference between primary and secondary PH. The crude odds ratio (OR) for morbidity diagnoses was 53.0 (95% CI 45.0–62.4) and the adjusted OR (aOR) 21.5

Table 1 Characteristics of discharges with and without a diagnosis of pulmonary hypertension (PH) in the State Inpatient Database for New York 2003–2014

	No PH (N = 2,9401,22)	PH (N = 746)	P-value
General characteristics			
Outcome of pregnancy			< 0.001
Loss or termination of pregnancy	89,094 (3.0%)	77 (10.3%)	
Preterm birth	201,975 (6.9%)	181 (24.3%)	
Term birth	2,649,053 (90.1%)	488 (65.4%)	
Age (year) (missing = 1)	29 (6)	31 (7)	< 0.001
Race and ethnicity (missing = 78,772)			< 0.001
White	1,361,222 (47.6%)	194 (26.5%)	
Black	472,140 (16.5%)	244 (33.3%)	
Hispanic	494,266 (17.3%)	161 (22.0%)	
Asian and Pacific Islander	204,689 (7.2%)	36 (4.9%)	
Other	329,046 (11.5%)	98 (13.4%)	
Insurance			< 0.001
Medicare and Medicaid	1,279,758 (43.5%)	445 (59.7%)	
Private insurance	1,474,907 (50.2%)	254 (34.0%)	
Self-pay	126,377 (4.3%)	34 (4.6%)	
Other	59,080 (2.0%)	13 (1.7%)	
Comorbidities			
Charlson comorbidity index	0 (0–0)	1 (1–1)	< 0.001
Diabetes mellitus	20,369 (0.7%)	23 (3.1%)	< 0.001
Hypertension	46,984 (1.6%)	152 (20.4%)	< 0.001
Heart valve disease	20,330 (0.7%)	257 (34.5%)	< 0.001
Heart congenital disease	2025 (0.1%)	70 (9.4%)	< 0.001
Obesity	81,192 (2.8%)	95 (12.7%)	< 0.001
Sickle cell disease	2469 (0.1%)	25 (3.4%)	< 0.001
Connectivitis	5068 (0.2%)	21 (2.8%)	< 0.001
Asthma	112,978 (3.8%)	84 (11.3%)	< 0.001
Chronic kidney disease	6753 (0.2%)	24 (3.2%)	< 0.001
Hospital			
Urban hospital (missing = 72,813)	2,718,800 (94.8%)	692 (99.0%)	< 0.001
Teaching hospital (missing = 72,813)	2,798,535 (97.6%)	689 (98.6%)	0.12
Neonatal level-of-care designation (missing = 584,248)			< 0.001
1	530,978 (22.5%)	86 (14.4%)	
2	405,768 (17.2%)	36 (6.0%)	
3	1,419,277 (60.2%)	475 (79.6%)	
Volume of delivery	2482 (1571–4013)	2765 (1830–4481)	< 0.001

Results expressed as median (interquartile range) or count (%)

Table 2 Outcomes for discharges with and without a diagnosis of pulmonary hypertension (PH) in the State Inpatient Database for New York 2003–2014

	No PH (N = 2,9401,22)	PH (N = 746)	P-value	Unadjusted OR (95% CI)	Adjusted OR* (95% CI)
Death (missing = 20)	313 (1/10,000)	11 (147/10,000)	< 0.001	140.6 (76.7-257.6)	15.6 (6.8–35.7)†
Maternal morbidity					
Morbidity diagnoses	19,907 (68/10,000)	198 (2654/10,000)	< 0.001	53.0 (45.0-62.4)	21.5 (17.8–25.9)
Morbidity diagnoses with prolonged hospital stay or death	8150 (28/10,000)	157 (2105/10,000)	< 0.001	95.9 (80.3-114.5)	25.8 (20.8–32.0)
Procedures	963,201 (3276/10,000)	458 (6139/10,000)	< 0.001	3.3 (2.8–3.8)	2.9 (2.4–3.3)

CI confidence interval, *OR* odds ratio

Results expressed as number (per 10,000)

*Adjusted for age, race, Charlson comorbidity index, outcome of pregnancy (loss or termination versus birth), and year of hospitalization

†Because of the low number of events in the PH group, the adjusted odds ratio may be potentially unreliable

(95% CI 17.8–25.9). The crude OR for procedures was 3.3 (95% CI 2.8–3.8) and the aOR 2.9 (95% CI 2.4–3.3). Similar results were observed for the rate of morbidity diagnoses with prolonged hospitalization or death.

Time Trends in Prevalence of Recorded PH in Pregnant Women

During the study period, the prevalence of recorded PH during pregnancy increased from 22/100,000 (95% CI 18–27) in 2003–2004 to 31/100,000 (95% CI 28–36) in 2013–2014 (+38% increase; 95% CI 4–72; P = 0.003) (Fig. 1). The prevalence of secondary PH increased from 17/100,000 (95% CI 14–22) in 2003–2004 to 30/100,000 (95% CI 25–35) in 2013–2014 (+69% increase; 95% CI 24–114; P < 0.001). The prevalence of primary PH decreased from 5/100,000 (95% CI 3–7) in 2003–2004 to 1.0/100,000 (95% CI 0.2–2.2) in 2013–2014 (81% decrease; 95% CI 62–101; P = 0.002) (Fig. 1a). Among the possible etiologies of secondary PH, an increase was observed in the prevalence of heart valve disease (from 6.2 to 9.4/100,000 between 2003–2004 and 2013–2014), obesity (from 0.6 to 7.3/100,000 between

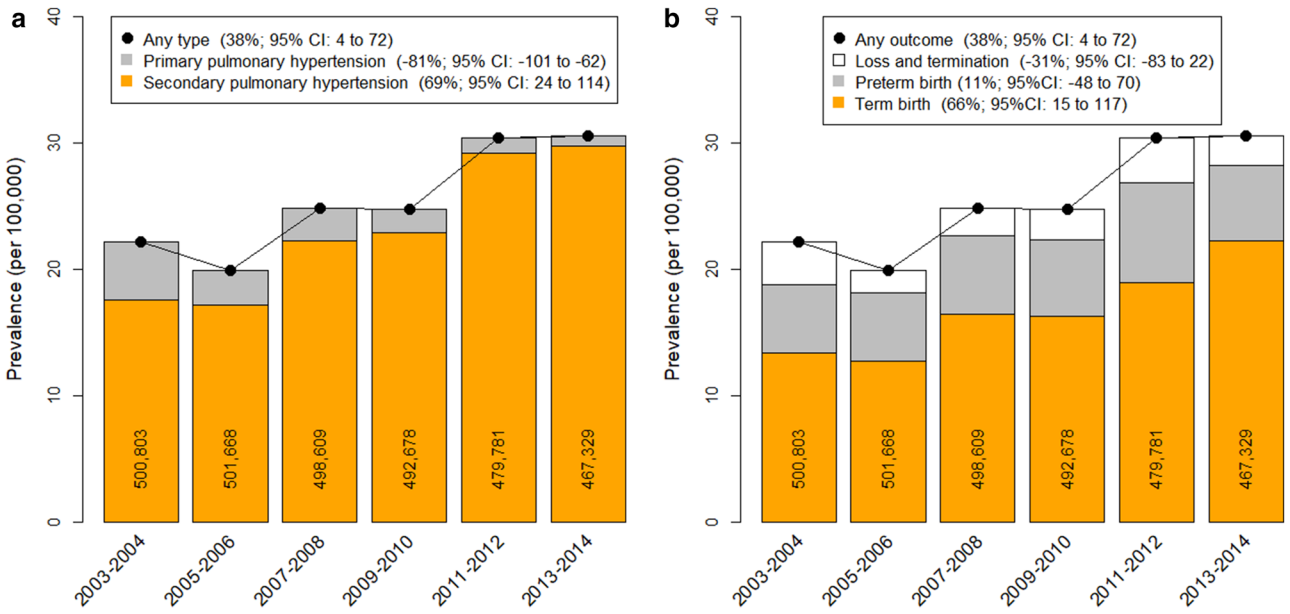

Fig. 1 Prevalence of recorded pulmonary hypertension (PH) in pregnancy in the State Inpatients Database for New York 2003–2014. Prevalence is presented for 2-year intervals. The legend indicates the percent change from 2003–2004 to 2013–2014 (95% confidence interval (CI). The italic number in each box indicates the number of discharges indicating pregnancy for each 2-year period. **a** Prevalence according to the etiology of PH. **b** Prevalence according to the outcomes of pregnancy

2003–2004 and 2013–2014), and systemic hypertension (from 3.4 to 6.8/100,000 between 2003–2004 and 2013–2014).

Among obstetric-related discharges, the prevalence of term births with PH increased from 13/100,000 in 2003–2004 (95% CI 10–17) to 22/100,000 (95% CI 18–27) in 2013–2014 (+66% increase; 95% CI 15–117; P = 0.003). The prevalence of preterm birth and loss or terminations of pregnancy associated with PH did not change during the study period (Fig. 1b).

Temporal Trends in Maternal Morbidity in Pregnant Women with and Without PH

In obstetric-related discharges with PH, the 4 most frequent morbidity diagnoses recorded were (1) acute pulmonary edema or acute heart failure, (2) adult respiratory distress syndrome, (3) acute renal failure, and (4) air and thrombotic embolism (Supplemental digital content Table 5). The rate of morbidity diagnoses among discharges with PH was 2342/10,000 (95% CI 1591–3241) in 2003–2004 and 2937/10,000 (95% CI 2206–3756) in 2013–2014 with no statistically significant changes over the 12-year period. Similar results were observed for the rate of morbidity diagnoses with prolonged hospitalization or death. In the multivariable analysis, 2 factors were associated with a significant risk of morbidity diagnoses in discharges with PH: primary PH (aOR 2.19; 95% CI 1.10–4.37) and Charlson comorbidity index (aOR 2.98/1-point increase; 95% CI 2.45–3.64) (Supplemental digital content Table 6).

In discharges without PH, the 4 most frequent morbidity diagnoses recorded were (1) disseminated intravascular coagulation, (2) adult respiratory distress syndrome, (3) acute renal failure, and (4) eclampsia. Contrary to discharges with PH, morbidity diagnoses in discharges without PH increased from 52/10,000 (95% CI 50–54) in 2003–2004 to 85/10,000 (95% CI 82–87) in 2013–2014(+64% increase; 95% CI 56–72; P < 0.001). The rate of morbidity diagnoses with prolonged hospitalization or death increased 21% (95% CI 11–30; P < 0.001).

In discharges with PH, the 2 most frequent procedures were (1) cesarean delivery and (2) blood transfusion (Supplemental Digital Content Table 5). Procedures utilization increased from 4775/10,000 in 2003–2004 (95% CI 3818–5744) to 6853/10,000 (95% CI 6024–7603) in 2013–2014 (+44%; 95% CI 11–76; P = 0.006). This increase was mostly driven by an increase in the cesarean delivery rate.

In discharges without PH, the 2 most frequent procedures were also (1) cesarean delivery and (2) blood transfusion. Similar to discharges with PH, procedures utilization in discharges without PH increased 17% (95% CI 16–18; P < 0.001) during the study 12-year period from 2904/10,000 (95% CI 2891–2916) in 2003–2004 to 3402/10,000 (95% CI 3388–3416) in 2013–2014. This increase was mostly driven by an increase in blood transfusion.

Discussion

In this study, we observed that the prevalence of secondary PH during pregnancy is increasing over time, driven by an increase in the prevalence of women with heart valve disease, obesity, and systemic hypertension, while the prevalence of secondary PH is decreasing. Both primary and secondary obstetric PH patients have an increased risk of death and morbidity compared to patients without PH but the temporal trends are more favorable for women with PH than without PH.

The very marked increases in the odds of death and morbidity associated with both primary and secondary PH during pregnancy underscore the need for thorough screening and diagnosis of this condition in women before conception or early pregnancy and for transferring these women in a timely manner to tertiary centers with the required level of maternal care (The American College of Obstetricians and Gynecologists and The Society for Maternal Fetal Medicine 2015) PH is often recognized late in pregnancy or after delivery with delays in diagnosis associated with worse maternal outcomes (Weiss et al. 1998). In the 2016 report on PH during pregnancy from the Registry Of Pregnancy and CArdiac disease (ROPAC) of the European Cardiology Society, 25% of women had a diagnosis of PH made during pregnancy (Sliwa et al. 2016). Clinical decision making and patient counseling related to pregnancy continuation versus termination should take into consideration disease severity, the natural history of the disease during pregnancy, and patient choice. Administrative data do not provide information about the severity of the disease such as the WHO functional status or the mean arterial pulmonary pressure, which are strong predictors of adverse maternal outcomes (Galie et al. 2009). Nevertheless, the very high increase in the odds of death or morbidity associated with PH observed in this study suggests that this disease should be viewed as a major risk factor requiring timely evaluation and ongoing, coordinated management by a multidisciplinary team including cardiologists, maternal fetal medicine specialists, and obstetric anesthesiologists.

The prevalence of recorded PH in this study was 25.4/100,000 pregnancies and is consistent with previous research (Thomas et al. 2017). The prevalence of PH during pregnancy increased 38% overall during the study period while the prevalence of secondary PH decreased. Importantly, we observed a 69% increase in secondary PH. The increase in secondary PH was driven by an increase in the prevalence of pregnant women with heart valve disease,

obesity, and systemic hypertension. This increase in these comorbid conditions in women with PH mirrors the increase in chronic comorbidities observed in the general obstetric population, especially heart disease and obesity (Kuklina and Callaghan 2011; Admon et al. 2017). It suggests that screening and diagnosis of pulmonary hypertension in women before conception or early pregnancy should target women with these conditions.

In our analysis, the pattern of complications differed between pregnant women with and without PH. In pregnant women with PH, cardiac complications, respiratory complications, and pulmonary embolism constituted the majority of severe maternal complications. These findings are in agreement with the expected course of the disease in the general population including non-pregnant women, which is characterized by cardio-respiratory failure and venous thromboembolic complications (Fuster et al. 1984; McLaughlin et al. 2009; Rubin 1997). The multivariate analysis of the risk of severe morbidity indicates that this risk is increased in women with primary PH or additional comorbidities. This result differs from previous research indicating that primary PH has a lower risk of death (Bedard et al. 2009; Weiss et al. 1998). This discrepancy may be explained by the analysis of morbidity in our study whereas other studies only examined "death" as an outcome.

Contrasting with a 64% increase in morbidity diagnoses in women without PH, we did not observed a change in morbidity in women with PH over the 12-year study period. This may suggest an improvement in outcome for pregnant women with PH or a least a stability (Callaghan et al. 2012; CDC 2018). This improvement in outcomes for women with PH is also suggested by the low 1.5% in-hospital mortality rate for this women in this study, contrasting with the 8 to 16% mortality rates recently reported (Meng et al. 2017; Pieper et al. 2014; UK Obstetric Surveillance System 2013). We have to acknowledge that the mortality rate in the current study may be underestimated because we limited our analysis to delivery or abortive hospitalizations; 60% of maternal deaths occur before delivery or after the 6th postpartum day (Creanga et al. 2017). We observed a 44% increase in procedure utilization in women with PH driven by an increase in the cesarean delivery rate. It suggest that obstetrical practice tends to increasingly favor cesarean delivery for these patients. The choice of the mode of delivery in women in PH is debated and some teams favor vaginal delivery in women with medically controlled PH (Meng et al. 2017; Olsson and Channick 2016).

We acknowledge several limitations in our analysis. First, the analysis was limited to New York State and our findings may not be generalizable to the rest of the country. State variation in the prevalence of PH is likely given the marked between-state variation in age-standardized death rates for PH (George et al. 2014). Socioeconomic characteristics of New York State are different from the rest of the United States and may influence maternal outcomes and utilization of resources since disparities in both treatment and outcomes of PH are possible (Al-Naamani et al. 2017; Parikh et al. 2017). For example, New York State has a higher proportion of non-White population compared with the US average (43% versus 39%) and a lower proportion of uninsured (6% versus 9%). Second, we cannot exclude that the increase in the prevalence of secondary PH could be related to a better detection of the condition (i.e. ascertainment bias) or changes in diagnostic criteria (Galie et al. 2009; Simonneau et al. 2013). Third, the State Inpatient Database does not include information on outpatient procedures. Since some outpatient procedures were used to define loss or termination of pregnancy, we may have underestimated the prevalence.

In conclusion, we observed an increase in secondary PH during pregnancy and in term births. The very high odds of mortality or morbidity associated with PH underscore the importance for healthcare providers to screen and recognize this diagnosis in women in childbearing age or in early pregnancy, especially in women with heart valve disease, obesity, or systemic hypertension.

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Compliance with Ethical Standards

Conflict of interest The authors report no conflict of interest.

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