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Obstetric Comorbidity and Severe Maternal Morbidity Among Massachusetts Delivery Hospitalizations, 1998–2013

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Abstract

Objectives—The rate of severe maternal morbidity in the United States increased approximately 200% during 1993–2014. Few studies have reported on the health of the entire pregnant population, including women at low risk for maternal morbidity. This information might be useful for interventions aimed at primary prevention of pregnancy complications. To better understand this, we sought to describe the distribution of comorbid risk among all delivery hospitalizations in Massachusetts and its association with the distribution of severe maternal morbidity.

Methods—Using an existing algorithm, we assigned an obstetric comorbidity index (OCI) score to delivery hospitalizations contained in the Massachusetts pregnancy to early life longitudinal (PELL) data system during 1998–2013. We identified which hospitalizations included severe maternal morbidity and calculated the rate and frequency of these hospitalizations by OCI score.

Results—During 1998–2013, PELL contained 1,185,182 delivery hospitalizations; of these 5325 included severe maternal morbidity. Fifty-eight percent of delivery hospitalizations had an OCI score of zero. The mean OCI score increased from 0.60 in 1998 to 0.82 in 2013. Hospitalizations with an OCI score of zero comprised approximately one-third of all deliveries complicated by severe maternal morbidity, but had the lowest rate of severe maternal morbidity (22.8/10,000 delivery hospitalizations).

Conclusions—The mean OCI score increased during the study period, suggesting that an overall increase in risk factors has occurred in the pregnant population in Massachusetts. Interventions

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that can make small decreases to the mean OCI score could have a substantial impact on the number of deliveries complicated by severe maternal morbidity. Additionally, all delivery facilities should be prepared for severe complications during low-risk deliveries.

Keywords

Severe maternal morbidity; Obstetric comorbidity index; Population health; Massachusetts

Introduction

For every maternal death that occurs in the United States, approximately 50 women suffer from severe morbidity that is directly or indirectly related to pregnancy (Callaghan et al. 2012). The rate of these severe maternal morbidities in the United States increased approximately 200% during 1993–2014 (Severe Maternal Morbidity 2017). Research has focused on identifying women and pregnancies at high risk for severe maternal morbidity and other adverse pregnancy outcomes (Mhyre et al. 2011). This has led to coordinated efforts aimed at secondary prevention of severe morbidity and mortality among pregnant women at high risk, such as the American College of Obstetrics and Gynecology (ACOG) guidelines for maternal levels of care, the Council on Patient Safety in Women's Health patient safety bundles, and the work of collaboratives to improve perinatal quality (Preeclampsia and Hypertension, n.d.; D'Alton et al. 2014; Obstetric Care Consensus 2015; Henderson et al. 2014). With this focus on pregnant women at high risk, less attention has been given to the health profile of the entire pregnant population, which includes women at low risk for maternal morbidity. Such population level information could be important for the development of future public health interventions designed to improve maternal health, especially when it comes to primary versus secondary prevention efforts.

At the population level, a small to average individual risk for disease can account for a large portion of disease burden (Rose 1985, 2008). This is because people at low risk often account for a larger segment of the impacted population, compared with people at high risk. For a population of pregnant women, a significant portion of severe maternal morbidity might occur among pregnant women with low risk for adverse maternal health outcomes simply because the absolute numbers are higher, compared with the number of women at high risk. A study of severe maternal morbidity using 1998–2011 data from the National Inpatient Sample reported that the biggest increase in relative risk for severe maternal morbidity during the study period occurred among women with few risk factors for adverse maternal health outcomes, compared with women with more risk factors (Hehir et al. 2017).

A better understanding of the distribution of severe maternal morbidity along a continuum of risk might help to prioritize interventions aimed at reducing the greatest possible number of deliveries with severe complications. Thus, we sought to describe the distribution of comorbid risk among all delivery hospitalizations in Massachusetts and its association with severe maternal morbidity.

Methods

Study Sample

We included all delivery hospitalizations during 1998–2013 reported in the Massachusetts pregnancy to early life longitudinal data system (PELL). PELL is a relational data system that links infant birth and fetal death records to the corresponding maternal and infant hospital discharge administrative data for all delivery hospitalizations occurring in Massachusetts to resident women (Shapiro-Mendoza et al. 2008). PELL does not capture pregnancy terminations or pregnancies that end with miscarriage or stillbirth at ≤ 20 weeks gestation or ≤ 350 g because no fetal death records are produced for those events. For the purposes of analysis, multiple deliveries to the same woman during the study period were treated as separate observations. This study was approved by the Massachusetts Department of Public Health Human Subjects Review Board; the Centers for Disease Control and Prevention (CDC) reviewed this study for human subjects protection and deemed it non research.

Severe Maternal Morbidity

We defined the outcome of severe maternal morbidity using an algorithm previously published by Callaghan et al. (2012) and validated by others (Main et al. 2016; Sigakis et al. 2016). This definition uses a set of *International Classification of Disease, Ninth Revision Clinical Modification* (ICD-9-CM) codes to identify 25 lifesaving procedures or life-threatening events from delivery hospitalization administrative data (Online Resource Table). The severe maternal morbidity algorithm does not consider hospitalizations with implausibly short lengths of stay as hospitalizations in which severe morbidity occurred. This algorithm was applied to each of the delivery hospitalizations identified in the PELL data system. The rate of delivery hospitalizations complicated by severe maternal morbidity/ 10,000 delivery hospitalizations was calculated without the ICD-9-CM code for blood transfusion, because of concerns about its low specificity for severe morbidity relative to other ICD-9-CM codes in the algorithm (Main et al. 2016).

Maternal Risk

To operationalize a continuum of maternal risk for an adverse health outcome during delivery hospitalization, we used the obstetric comorbidity index (OCI) previously published by Bateman et al. (2013). OCI was developed and validated using Medicaid claims and enrollment data, and was externally validated for use in hospital discharge administrative data (Metcalfe et al. 2015). OCI assigns a weight of 1–5 to each of 20 conditions identified from ICD-9-CM codes at delivery and maternal age ≥ 35 years old (Online Resource Table). Conditions with higher weights were the more predictive of maternal end-organ injury or death during OCI development. Each delivery hospitalization could have multiple conditions, and the weights of each were summed with the age range score to assign a final score of 0–45 to each delivery hospitalization. Two modifications of the scoring algorithm were made to adapt OCI for the study context. ICD-9-CM codes related to two conditions, sickle cell anemia with crisis (282.6×) and eclampsia (642.6×), were omitted from the OCI algorithm because they are also used to define severe maternal morbidity, a study outcome. We have maintained the broader OCI algorithm categories that contained these codes, sickle

cell disease and severe preeclampsia or eclampsia, in OCI because they contain diagnosis codes other than the two above that do not overlap with the severe maternal morbidity algorithm. Additionally, birth certificate data concerning method of delivery in PELL was used to supplement ICD-9-CM codes in OCI when determining previous cesarean delivery status.

Analysis

We applied both the OCI and the severe maternal morbidity algorithm to all PELL delivery hospitalizations during 1998–2013. Delivery hospitalizations were described using PELL demographic information, including maternal race/ethnicity, delivery payer source, and method of delivery. Age groups were < 20, 20–24, 25–29, 30–34, 35–39, 40–44, and ≥ 44 years. Rates of severe maternal morbidity were calculated overall, by age group, race/ethnicity, payer source, method of delivery, year, and by OCI score. The total number of delivery hospitalizations and the number complicated by severe maternal morbidity were tallied by OCI score. The mean population OCI score was calculated by year. All analyses performed in SAS 9.4.

Results

The PELL data system contained 1,185,182 delivery hospitalizations reported during 1998–2013. Twenty-two percent of deliveries were to women aged ≥ 35 years of age, 69% were to non-Hispanic white women, 61% were covered by private insurance, and 68% were vaginal births among women without a prior cesarean section (Table 1).

The overall rate of severe maternal morbidity among all delivery hospitalizations during 1998–2013 was 44.9/10,000 delivery hospitalizations (Table 1). Severe maternal morbidity rates were highest among the oldest age groups, non-Hispanic black women, deliveries classified as self-pay or billed to public insurance, and deliveries by cesarean section.

The frequency distribution of OCI scores is shown as bars in Figs. 1 and 2. Fifty-eight percent of delivery hospitalizations (n = 691,044) were assigned an OCI score of zero and the number of hospitalizations assigned to each score decreased with increasing score. Among the 5325 deliveries complicated by severe maternal morbidity, 1579 (30%) were among deliveries with an OCI score of zero (Fig. 1, Table 2). Deliveries with an OCI score of zero had the lowest rates of severe morbidity, with a rate of 22.8/10,000 delivery hospitalizations (Fig. 2, Table 2). Deliveries with OCI scores of ≥ 10 had the highest rates of severe morbidity at 1,383.6/10,000 delivery hospitalizations.

The population wide rate of severe maternal morbidity among delivery hospitalizations increased steadily during 1998–2013 (Fig. 3). The yearly mean OCI score among delivery hospitalizations also rose steadily during the study period, from 0.60 in 1998 to 0.82 in 2013 (Fig. 3). The rise in mean OCI score coincided with a 14.1% decrease in the proportion of deliveries with an OCI score of 0 and a 24.1% increase in the proportion of deliveries with an OCI score of ≥ 1.

Discussion

We have taken a population-level approach to describe the distribution of comorbid risk factors among Massachusetts deliveries using hospital administrative discharge data linked to infant birth certificates and fetal death records. An increase in the burden of comorbidities complicating deliveries, as illustrated by the increase in mean OCI score, accompanied the rising population wide rate of severe maternal morbidity. We found that deliveries with no identified comorbid risk factors had the lowest rate of severe maternal morbidity, but that they comprised one-third of those deliveries complicated by severe maternal morbidity. This finding is consistent with a growing body of research that reports a significant portion of adverse maternal outcomes occur among women with few diagnosed risk factors (Danilack et al. 2015; Friedman et al. 2016; Hehir et al. 2017).

Our findings are consistent with the idea that a small, individual risk among a large number of persons can account for a large portion of total disease (Rose 1985, 2008; Keyes and Galea 2016). The overall comorbid risk among deliveries in Massachusetts remained small during 1998–2013, with a yearly mean delivery OCI score of < 1, but increased steadily. This finding suggests that there has been an overall increase in risk factors among the pregnant population in Massachusetts, which might in part explain the rising rate of severe maternal morbidity among deliveries. The small increase in average OCI could be secondary to relatively small increases in the burden of high-scoring conditions (such as severe preeclampsia), but could also stem from larger increases in low-scoring conditions (such as previous cesarean delivery). More research is needed to investigate the changes in OCI distribution over time. Interventions that can make decreases to the mean population score, while not readily noticeable at the individual or facility level might in turn have a substantial impact on the total number of deliveries complicated by severe maternal morbidity (Rose 1985, 2008). In the future, identifying OCI components that are most closely associated with the rising average OCI score may help to prioritize public health interventions to decrease maternal morbidity in Massachusetts.

An example of an intervention that might address the average OCI score is an effort by the Massachusetts perinatal quality collaborative (MPQC) to decrease the overall state cesarean section rate. Having had a previous cesarean delivery is one of the comorbidities included in OCI and, because cesarean deliveries are relatively common across the Massachusetts pregnant population, one possible driver of the increasing average OCI score (Massachusetts Births 2014). MPQC began its work in 2007 with a goal of decreasing the number of cesarean deliveries in participating hospitals among women with no indication for requiring a cesarean delivery. Although MPQC’s work is probably not the sole driver, the overall and primary cesarean rate has decreased every year since peaking in 2008 (Massachusetts Births 2014). A Health care level interventions, such as the MPQC’s efforts, with components targeted to women at low risk, could impact the maternal population risk and potentially decrease the burden of maternal morbidity.

Our findings also have implications for individual level risk reduction and secondary prevention of severe maternal morbidity. First, our results support ACOG’s existing recommendation that all birth facilities, including those facilities caring predominantly for

pregnant women at low risk, be capable of stabilizing and transferring patients to tertiary care hospitals (Obstetric Care Consensus 2015). Although our study does not aim to explain why women with no identifiable comorbid risk factors go on to develop severe maternal morbidity, further research is needed to identify new and relevant nonbiomedical and biomedical risk factors that can be used to ensure women deliver in risk-appropriate facilities as outlined by ACOG. This research might require comparisons across different populations of women at low risk, such as those groups residing in different states or nations, to identify ubiquitous risk factors within a these populations that women are exposed to prior to or during pregnancy (Keyes and Galea 2016).

Our study has several strengths. First, severe maternal morbidity is a more frequent occurrence than maternal mortality, allowing sufficient sample size for analytical exploration of adverse delivery outcomes. Severe maternal morbidity also has a definition based in a clearly defined algorithm. Second, we used OCI to convert disparate categorical risk factors for severe maternal morbidity into a single measure of risk and applied it to every delivery hospitalization, a novel population-level approach to maternal health. This approach can be used in the future to investigate maternal risk burden among subpopulations, such as by race/ethnicity and by socioeconomic factors (e.g. neighborhood and income level). Finally, both measures have been previously validated using large, population-based samples, and severe maternal morbidity rates can be compared across states and with national estimates.

Our study also has limitations. First, although PELL is a robust, population-level data system, it includes only delivery hospitalizations in Massachusetts and our results might not be generalizable to other states with differing maternal characteristics. Similarly, PELL does not capture pregnancy terminations or pregnancies that end with miscarriage or stillbirth at ≤ 20 weeks gestation or ≤ 350 g, because fetal death records are not completed for these deliveries. Second, both OCI and the severe maternal morbidity algorithm rely on hospital administrative data. Research has shown that some billing codes in the severe maternal morbidity algorithm have low sensitivity for their respective clinical conditions (Main et al. 2016). Future analysis using the OCI and severe maternal morbidity algorithms will likely be affected be the transition from ICD-9-CM to ICD-10-CM, though it is too early to tell what the affects will be. Third, OCI captures only biomedical comorbid risk factors, and does not take into account environmental risk factors and the social determinants of health. Finally, OCI does not include all known medical risk factors for adverse maternal health outcomes (e.g. obesity).

The population health approach offers a framework for research and interventions to facilitate improvements in maternal health outcomes, and we have taken the first step in applying it to deliveries in Massachusetts. Future analyses using OCI should focus on identification of specific comorbid risk factors that are both amenable to intervention and significant contributors to the population risk burden. Efforts to identify ubiquitous exposures and adapt OCI to nontraditional biomedical risk factors for adverse maternal health outcomes may also be explored. A population health framework can also guide efforts such as state perinatal quality collaboratives in identifying health care processes that are relevant to decreasing the maternal population's overall burden of severe maternal morbidity to complement interventions tailored toward only the highest risk pregnancies. Finally, use

of a tool such as OCI gives public health leaders the ability to track maternal health status, compared with maternal health outcomes in their jurisdictions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Significance

What is already known on this subject? The rate of severe maternal morbidity in the United States has steadily increased. Women with more comorbid risk factors have a higher risk for adverse maternal health outcomes.

What this study adds? Women with few to no comorbid risk factors comprised a substantial proportion of all severe maternal morbidities occurring among delivery hospitalizations in Massachusetts. The mean obstetric comorbidity index score among delivery hospitalizations increased during 1998–2013, suggesting an overall increase in risk factors among pregnant women in Massachusetts.

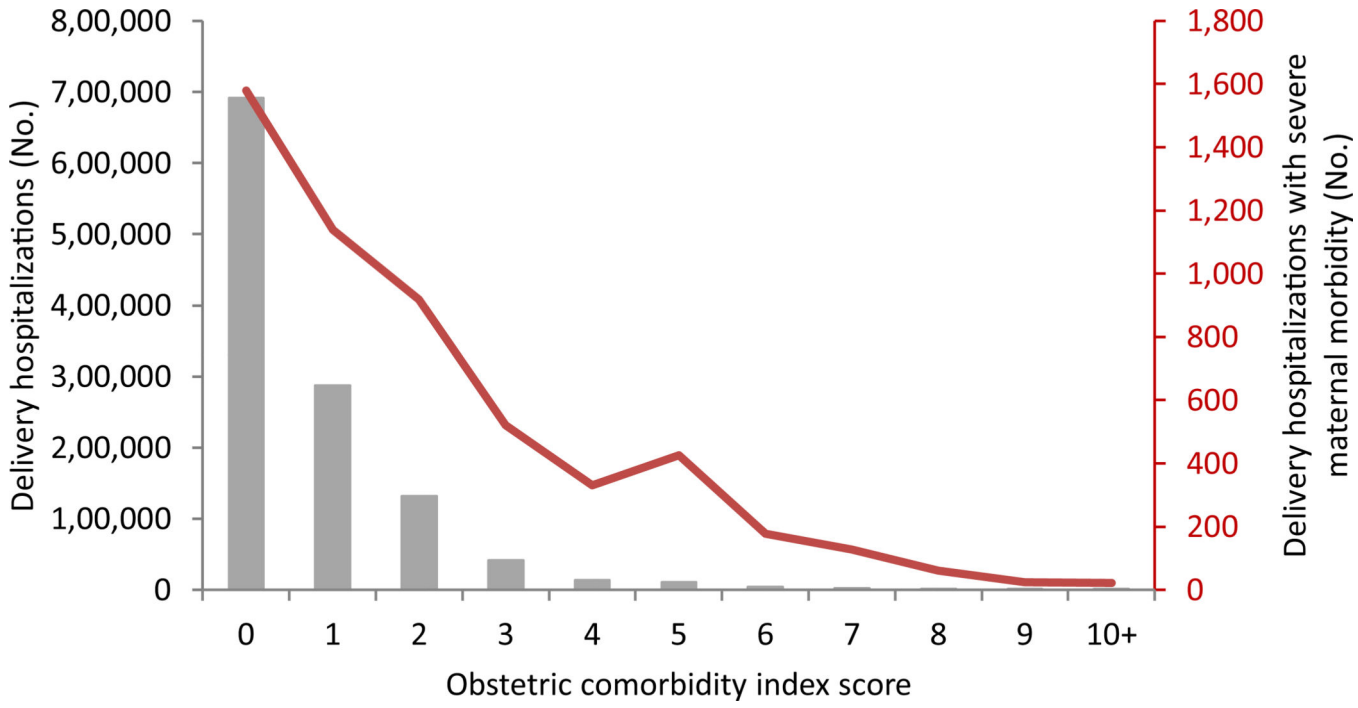

Fig. 1.

Count of all delivery hospitalizations and those with severe maternal morbidity by obstetric comorbidity index score—Massachusetts 1998–2013

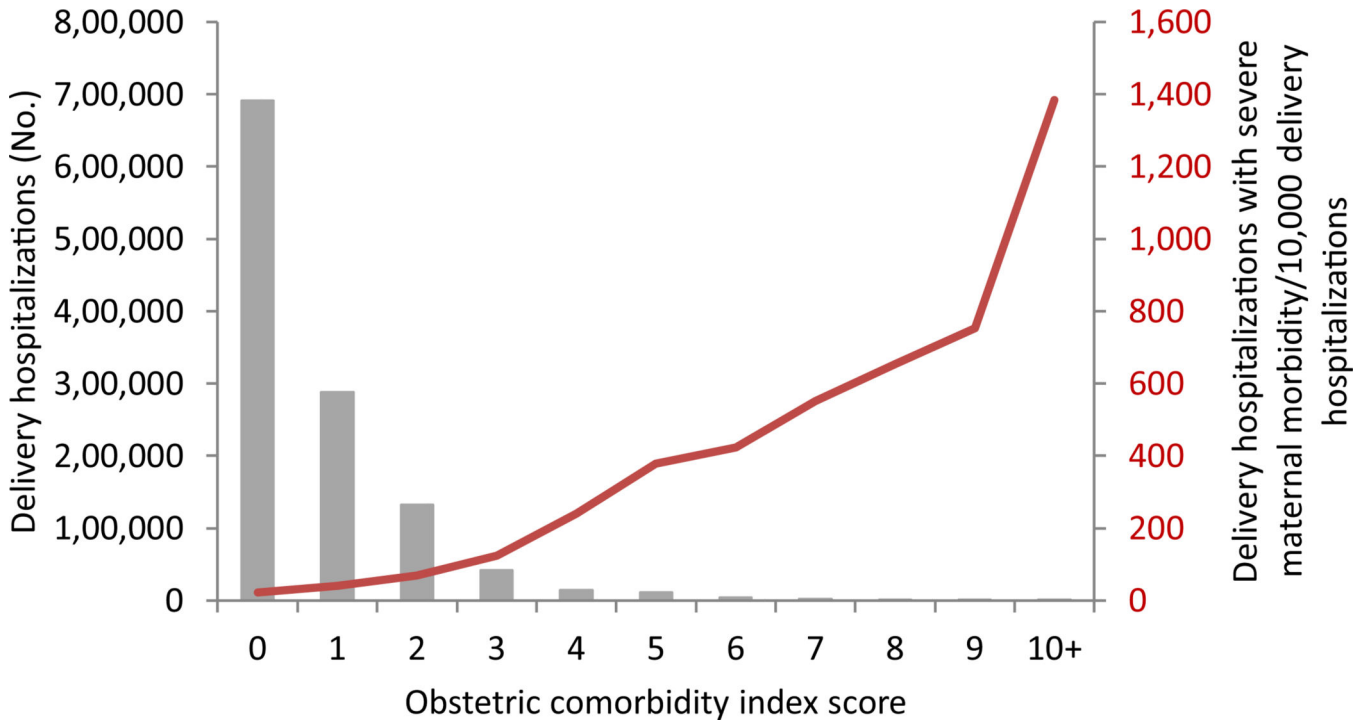

Fig. 2.

Count of all delivery hospitalizations and rate of severe maternal morbidity/10,000 delivery hospitalizations by obstetric comorbidity index score—Massachusetts 1998–2013

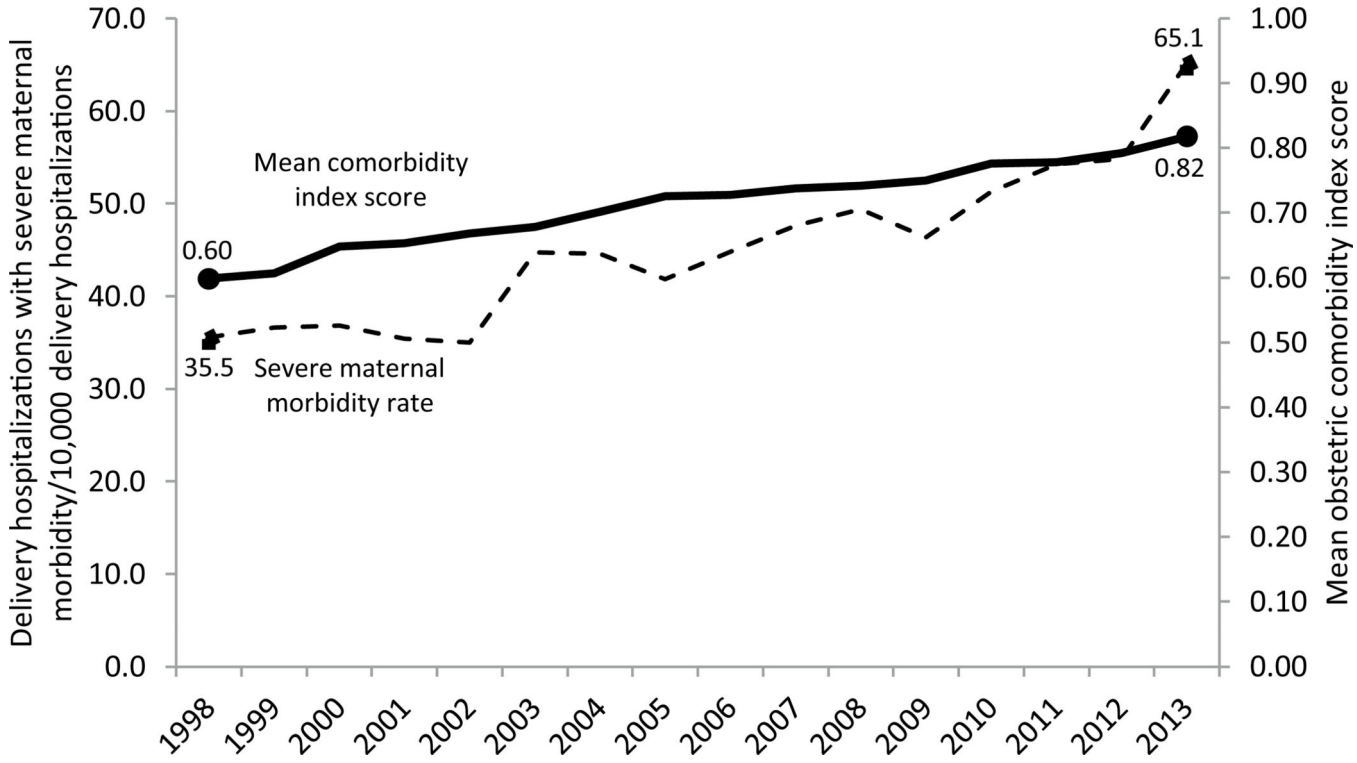

Fig. 3.

Rate of delivery hospitalizations with severe maternal morbidity and mean obstetric comorbidity index score by year—Massachusetts 1998–2013

Table 1

Characteristics of women with live birth delivery hospitalizations—Massachusetts 1998–2013

	Massachusetts delivery hospitalizations		Delivery hospitalizations with severe maternal morbidity	Rate of severe maternal morbidity among delivery hospitalizations Per 10,000
	No.	%	No.	
Age (years)				
< 20	71,795	6.1	271	37.7
20–24	183,292	15.5	606	33.1
25–29	288,534	24.3	1110	38.5
30–34	379,855	32.1	1556	41.0
35–39	213,222	18.0	1299	60.9
40–44	45,840	3.9	434	94.7
> 44	2623	0.2	49	186.8
Missing	21	0	0	0
Race/ethnicity				
non-Hispanic white	812,646	68.6	3068	37.8
non-Hispanic black	98,958	8.3	881	89.0
Hispanic	164,640	13.9	858	52.1
Asian or Pacific islander	84,435	7.1	390	46.2
American Indian or other	21,484	1.8	102	47.5
Missing or unknown	3019	0.3	26	86.1
Delivery payer source				
Private	718,834	60.7	2900	40.3
Public	437,742	36.9	2259	51.6
Self-pay	13,760	1.2	100	72.7
Free care	14,797	1.2	66	44.6
Missing or unknown	49	0	0	0
Method of delivery				
Vaginal	809,249	68.3	1633	20.2
VBAC	31,516	2.7	127	40.3
Primary cesarean	205,570	17.3	2236	108.8
Repeat cesarean	138,112	11.7	1320	95.6

	Massachusetts delivery hospitalizations		Delivery hospitalizations with severe maternal morbidity	Rate of severe maternal morbidity among delivery hospitalizations Per 10,000
	No.	%	No.	
Missing or unknown	725	0.1	9	124.1
Total	1,185,182	-	5325	44.9

VBAC vaginal birth after cesarean

Table 2

Distribution of delivery hospitalizations with and without severe maternal morbidity and rate of severe maternal morbidity by obstetric comorbidity index score—Massachusetts, 1998–2013

Obstetric comorbidity index score	Delivery hospitalizations			Rate of delivery hospitalizations with severe maternal morbidity
	No. without severe morbidity	No. with severe morbidity	Total	Per 10,000
0	689,465	1579	691,044	22.8
1	286,512	1139	287,651	39.6
2	130,842	919	131,761	69.7
3	41,257	520	41,777	124.5
4	13,468	330	13,798	239.2
5	10,799	425	11,224	378.7
6	4023	178	4201	423.7
7	2174	127	2301	551.9
8	873	61	934	653.1
9	307	25	332	753.0
10+	137	22	159	1383.6
Total	1,179,857	5325	1,185,182	44.9