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Natalia Revzina **Date**

Maternal characteristics associated with increased risk of reported maternal death in Georgia, 2010-2013.

BY
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Degree to be awarded: M.P.H.
Executive MPH

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Committee Chair: Roger Rochat, MD

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Maternal characteristics associated with increased risk of reported maternal death in Georgia, 2010-2013.

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Thesis Committee Chair: Roger Rochat, MD

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Abstract

Maternal characteristics associated with increased risk of

reported maternal death in Georgia, 2010-2013.

By

Natalia Revzina, MD

Background/Introduction: Between 1990 and 2015, maternal mortality worldwide dropped by about 44%. In the US the maternal mortality risk was significantly reduced during 20 century, but is rising in the first decade of 21 century. According to the CDC analysis of pregnancy-related mortality in the US 1998-2005 (Berg, Callaghan, Syverson, & Henderson, 2010), the pregnancy-related mortality ratio ranged from 12.0 to 16.8, higher than the ratio in previous decades; subsequent assessment of pregnancy-related mortality in the US 2006-2010(Creanga et al., 2015) revealed further increase. State of Georgia has highest maternal mortality among other states in the US, and it continues to rise. Understanding this trend requires evaluation of both medical and social factors.

Methods: Unmatched case–control analysis using four-year data from GA Department of Public Health was performed to investigate the effects of factors associated with maternal mortality. Multiple strategies were used to identify cases of maternal mortality from Georgia Department of Public Health 2010-2013 data. Check box specifying if a person died while pregnant or within one year of pregnancy on GA death certificate and cause-of-death titles associated with pregnancy, childbirth, and the puerperium were used as indicators of maternal death. Additionally, reproductive age women's certificates of death were linked to birth/fetal death certificates by matching of mothers' longitudinal ID (a unique identifier that is generated to ensure anonymity and to preserve the ability to track a women longitudinally and to link related records). Validation analysis was performed for 2012 maternal mortality cases due to availability of Georgia Maternal Mortality Review Committee (MMRC) review for the year.

Results: Unmatched case–control analysis was based on state data, therefore the cases (maternal deaths) and controls (women who survived for more than one year after giving birth) were from the same source population making the comparison valid. The odds of belonging to black race was 1.8 times higher among women who died compared with women who survived (95% CI 1.8–2.4), and the odds of low education were two times higher among cases compared with controls (95% CI 1.5–3.1). Women who died were also found to have more than two-fold higher odds of smoking tobacco, and about two-fold higher odds of having government insurance, compared with the women who survived. Additionally, the odds of being older were greater among cases compared with controls. Validation analysis revealed high sensitivity of the study algorithm in identifying maternal death cases.

Conclusion: This study contributed to examination of explanatory power of indicators available from the GA Department of Public Health for assessing risk associated with maternal mortality in state of Georgia. It showed that socio-economic factors such as advanced age, black race, low education, government insurance and smoking are associated with increased risk for maternal mortality, and, if not addressed, represent the missed opportunities for preventing maternal deaths and reducing health disparities. Collecting information on the socio-economic in addition to medical factors for every case of maternal death may contribute to maternal mortality review and recommendation process.

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Introduction

Maternal mortality ratio in the US is higher than in other developed countries, and is rising in 21th century (WHO report 2016). State of Georgia has the highest maternal mortality among other states in the US.

Reduction of maternal mortality is a nationwide health improvement priority. Ten percent reduction in maternal mortality is one of the Healthy People 2020 ambitious, yet achievable, objectives for improving the Nation's health (https://www.healthypeople.gov/2020).

At the current stage of evidence-based medicine in the US, maternal deaths can be prevented in about 40% of cases (Berg et al., 2005). A death is considered potentially preventable if it could have been deterred by changes in the healthcare system or by a patient's actions or if the severity of the condition could have been lessened before it progressed to an adverse outcome. The specific medical causes of maternal death with potential preventability are known and include hemorrhage (93% preventable), chronic medical conditions (89% preventable), pregnancy induced hypertension (60% preventable), infection (43% preventable) and cardiovascular conditions (40% preventable) (Berg et al., 2005); furthermore, prevention of unwanted and teen pregnancies are crucial in maternal mortality prevention.

The goal is to identify both medical and non-medical factors that contribute to maternal mortality. As stated in the Healthy People MCH section: "Many factors can affect pregnancy and childbirth, including preconception health status (which is influenced by a variety of environmental and social factors), age, access to appropriate preconception and interconception health care, and poverty." Racial and ethnic disparities in mortality and morbidity for mothers and children, particularly for African Americans, are likely the result of many factors.

Consensus on a set of specific non-medical indicators that capture major aspects of maternal health risk has not been reached. Examination of explanatory power of different indicators for assessing risk associated with maternal mortality is required before the optimal set of indicators is recommended for maternal mortality review and development of preventive strategies.

Background

Between 1990 and 2015, maternal mortality worldwide dropped by about 44%. Globally the risk of pregnancy-related death is lowest in European countries (Kassebaum et al., 2014). In the US the risk was significantly reduced during the 20th century, but is rising in the 21th century.

Country and territory[a]	MMR[b]						% change in MMR between 1990 and 2015[c]	Average annual % change in MMR between 1990 and 2015	Range of uncertainty on annual % change in MMR (80% UI)		Progress towards MDG 5A[d]
	1990	1995	2000	2005	2010	2015			Lower estimate	Upper estimate	
United States of America	12	12	12	13	14	14	−16.7	−0.6	−1.4	0.1	NA

Source: WHO report 2016 (http://www.who.int/reproductivehealth/publications)

According to the CDC analysis of pregnancy-related mortality in the US 1998-2005 (Berg, Callaghan, Syverson, & Henderson, 2010), the pregnancy-related mortality ratio ranged from 12.0 to 16.8 pregnancy-related deaths per 100,000 live births, higher than the ratio in previous decades. Authors concluded that possible reasons for the increase include an increase in the risk of women dying, changed coding in the ICD10, and the addition by states of pregnancy checkboxes to the death certificates. Subsequent assessment of pregnancy-related mortality in the US 2006-2010 (Creanga et al., 2015), revealed continuous increase in mortality ratio and increase of contribution of chronic diseases, suggesting a change in risk profile of pregnant women. Increasing number of maternal hypertension, diabetes, chronic heart disease, and obesity was reported (Kuklina & Callaghan, 2011) (Albrecht et al., 2010).

Recent observational study that analyzed vital statistics maternal mortality data from all US states (MacDorman, Declercq, Cabral, & Morton, 2016) showed that estimated maternal mortality ratio for 48 states and Washington D.C. (excluding California and Texas, analyzed separately) increased by 26.6%, from 18.8 in 2000 to 23.8 in 2014. Analysis of the measurement change also revealed that US maternal mortality ratios in the early 2000s were higher than previously reported, and the 2000–2014 increase was due to improved ascertainment of maternal deaths. Authors concluded that “the maternal mortality ratio for 48 states and Washington D.C. from 2000–2014 was higher than previously reported, is increasing, and places the U.S. far behind other industrialized nations.”

Understanding this trend requires evaluation of both medical and social factors. Social determinants of health include health related knowledge, attitude, beliefs or behaviors. They are shaped by the factors that play causal role and represent the missed opportunities for improving health and reducing health disparities like education, wealth/medical insurance, race, neighborhood living conditions, and childhood environment (Braveman, Egerter, & Williams, 2011), that influence health both directly (pour nutrition, exposure to smoking, pollution and toxins, stress and violence) and indirectly (by modeling life style and health-seeking behavior).

State of Georgia has the highest maternal mortality among other states in the US, and it continues to rise. Historically, a large proportion of Georgia’s population is composed of African Americans (30% according to Census 2015 http://www.census.gov). It is an important characteristic related to maternal mortality, as recent assessment of states-specific pregnancy-related mortality in the US 2005-2014 (Moaddab et al., 2016) documented the most dramatic increase in maternal mortality in non-Hispanic black women, and found a significant correlation between state mortality ranking and the percentage of non-Hispanic black women in delivery population. It is consistent with maternal mortality assessment (Creanga et al., 2012) of trends in pregnancy-related mortality by race, ethnicity and nativity from 1993 to 2006 that confirmed that except for foreign-born white women, all other race, ethnicity and nativity groups were at higher risk of dying from pregnancy-related causes than US-born white women after adjusting for age differences. Additionally, Creanga's multistate analysis of racial and ethnic disparities in severe maternal morbidity for 2008-2010 demonstrated that it disproportionally affects racial/ethnic minority women, especially none-Hispanic black women (Creanga, Bateman, Kuklina, & Callaghan, 2014).

A recent study conducted by a subgroup of the GA Maternal Mortality Review Committee revealed that pregnancy-related mortality was significantly higher for black compare to white women living in urban areas in GA. The study also found higher risks of dying from cardiovascular causes in black mothers compared to white mothers in metropolitan Atlanta (Platner, Loucks, Lindsay, & Ellis, 2016).

Another finding related to poor maternal outcomes is a shortage and maldistribution of obstetric services in GA. According to Zertuche et al. (Zertuche, Spelke, Julian, Pinto, & Rochat, 2016), 52% of areas outside of metropolitan Atlanta in state of Georgia has insufficient or complete absence of obstetric care workers and is expected to rise to 72%. Only 24% of ob/gyn residents reported being likely to accept job in rural GA.

Additionally, women in GA have unmet needs in family planning according to 1995 Georgia Women's Health Survey (Rochat et al) and GA DPH Maternal and Women's Health Report 2011 (GA DPH Maternal and Women's Health, Georgia Title V Needs Assessment (2015). About 30% of last pregnancies were mistimed and 17% unwanted with only 2% of respondents used long-acting reversible contraception (LARC) in 1995; the trend continues in 2011 as 54.8% of pregnancies were unintended and 51.4% of women reported using contraception at the time of conception.

The strict regulation policy on reporting pregnancy outcomes of all products of conception in the state of GA may to some extent explain its' higher mortality ratio compare to other states in the US. The state defines a live birth and fetal death as "complete expulsion or extraction from its mother of a product of human conception, irrespective of the duration of pregnancy", and requires a report of fetal death to be filed with the local registrar. It also requires each induced termination of pregnancy that occurs in the state, regardless of the length of gestation or weight, to be reported directly to DPH.

Drivers of success in reducing maternal mortality range from making improvements at the provider and health system level to implementing interventions aimed at reducing social and structural barriers. Local example of a promising intervention program is the Grady Memorial Hospital Interpregnancy Care (IPC) Program in Atlanta, GA where preconception care was targeted at urban African-American women at risk for poor birth outcomes (Biermann, Dunlop, Brady, Dubin, & Brann, 2006); the program has shown to be effective when specific risk factors were identified and interventions were appropriate. Another intervention program in GA, the Georgia Planning for Healthy Babies (P4HB) Program, the Section 1115 Medicaid Demonstration waiver "has the potential to contribute to increased access to family planning and related preventive health services for low income women; the role of the waivers … will remain important in the foreseeable future, especially in states such as GA that are not yet expanding Medicaid." (Dunlop, Adams, Hawley, Blake, & Joski, 2016). Urban Health Initiative (urbanhealthinitiative.emory.edu) is a local example of recognizing the significance of the social determinants of health for impacting wellbeing and working through interdisciplinary and academic-community partnerships to address significant health issues, with maternal health being one of key areas.

Devastatingly high maternal mortality, that continues to rise, and racial disparities in state of Georgia led to creation of a statewide maternal mortality review committee (MMRC). The first year of case reviews was 2012. The mission of MMRC is "to identify pregnancy-associated deaths, review those caused by pregnancy complications and other selected deaths, and identify problems contributing to this deaths and interventions that may reduce these deaths".

The goal is to identify both medical and non-medical issues contributing to a case of maternal death, but consensus on set of specific socio-economic indicators that capture major aspects of maternal health risk for data collection and monitoring is not reached. Examination of explanatory power of variety of indicators for assessing risk associated with maternal mortality is required before the optimal set of indicators is recommended.

I contributed to this examination by analyzing the relationship between a set of indicators available from the Department of Public Health (DPH) of GA and maternal mortality in state of Georgia. Georgia, the state with highest maternal mortality, serves in this study as a laboratory for understanding of factors associated with increased risk of maternal deaths.

The overall goals of this study are:

1. to characterize means of detecting cases of maternal deaths from vital statistical data, as detected by checkbox and record linkage, and describe ICD-10 obstetric codes;
2. for maternal deaths with linked birth or fetal death certificates (with or without O codes), to compare maternal death ratios, by maternal attributes;
3. to compare maternal mortality deaths and maternal characteristics for 2010-1012 with 2013;
4. to compare the maternal characteristics of maternal mortality by race, marital status and presence of father's age on birth certificate. I chose father's age as the most frequently occurring paternal attribute on the birth certificate for 2010-2012;
5. to identify maternal characteristics that are associated with increased risk for maternal mortality by comparing cases (maternal deaths) with controls (women, who delivered in the same time frame and survived for at least one year after delivery for years 2010-2013).

Methods

According to the CDC, a pregnancy-related death is defined as the death of a woman while pregnant or within 1 year of pregnancy termination—regardless of the duration or site of the pregnancy—from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes.

Other deaths occurred while pregnant or within one year of the end of pregnancy are considered pregnancy-associated.

If the woman was pregnant at the time of death, the medical conditions on the death certificate are assigned to one of the categories for conditions related to pregnancy. ICD–10 introduced new details and categories in the cause-of-death titles associated with pregnancy, childbirth, and the puerperium. For example, the causes O96 Death from any obstetric cause occurring more than 42 days but less than one year after delivery and O97 Death from sequelae of direct obstetric causes were added for deaths that occur beyond the maternal death period. Also, the ICD now recommends that countries include separate questions about recent pregnancies on their death certificates.

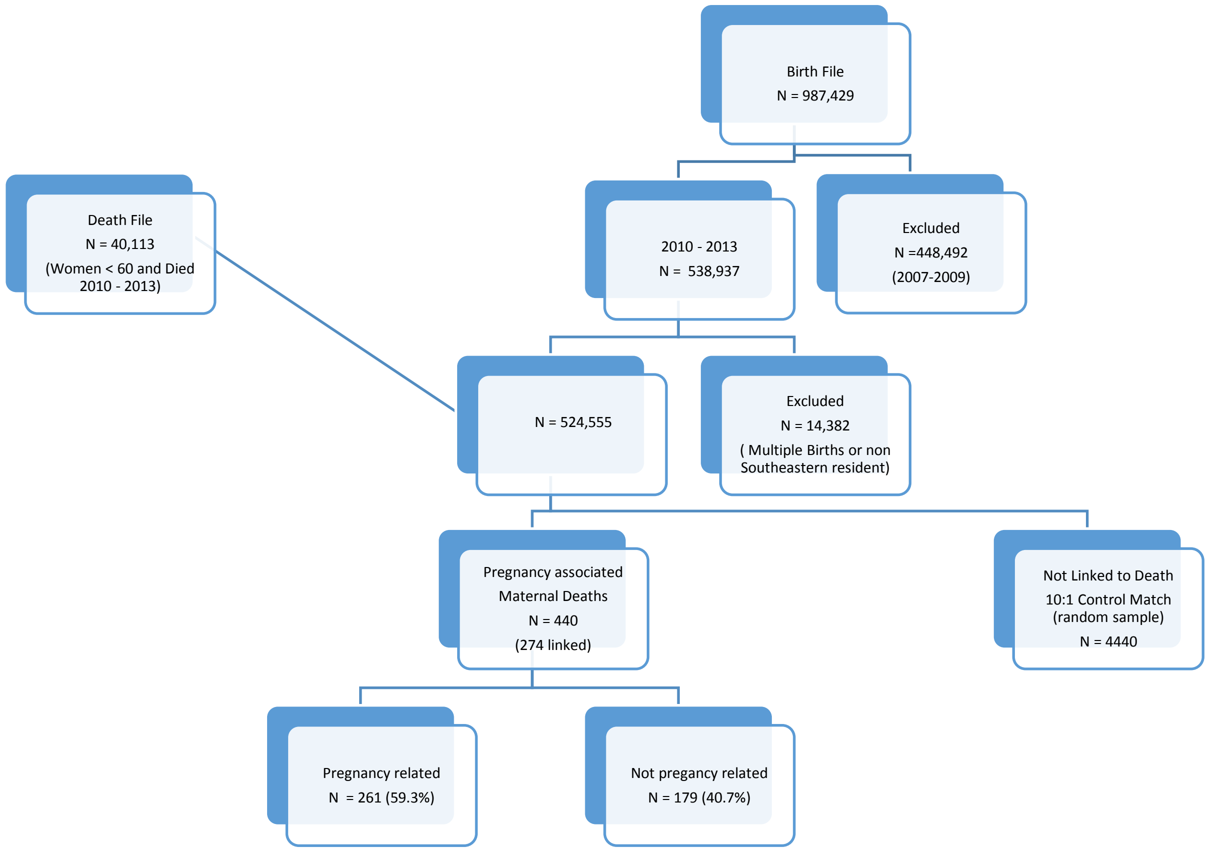
I used 2010-2013 data from Georgia Department of Public Health. Identifying maternal deaths using Georgia Department of Public Health database was a complex issue. Multiple strategies were used to identify cases of maternal mortality.

Of the 538,937 births identified in GA DPH birth file, 14,382 were excluded based on multiple records (only one birth record per a multifetal pregnancy was included) and not being southeast resident. From 2010-13 GA DPH death file, 40,113 deaths of women less 60 years old were identified.

The Georgia death certificate has a check box indicating if a person died while pregnant or within one year of pregnancy, it was used as one of the identification methods. As a second strategy reproductive age women's certificates of death were linked to 1)birth and 2)fetal death certificates within one year by matching of mothers' longitudinal ID (a unique identifier that is generated to ensure anonymity and to preserve the ability to track a women longitudinally and to link related records, e.g. her baby's birth certificate). All maternal deaths identified by pregnancy check and birth record linkage were accepted. Medical records were reviewed for 2012 maternal death cases by GA Maternal Mortality Review Committee (MMRC); therefore 2012 GA MMRC data served as a gold standard for case identification and as a basis for the study specificity and sensitivity analysis.

The described above algorithm produced 440 cases of maternal deaths. Of the 440 deaths, 297 (67.5%) were identified by pregnancy flag check, 253 (58%) were found by linking women's deaths to birth certificates, and 21 (4.8%) were deaths linked to fetal death certificates. All maternal deaths identified by pregnancy check and birth record linkage were accepted. Of the 440 deaths, 115 occurred during pregnancy, 122 occurred 1-42 days postpartum, and 203 occurred between 43 and 365 days postpartum. Of the 440 deaths, 261 (59.3%) were linked to pregnancy cause of death (O-code), and 179 to other cause of death. For 274 (62.3%) of pregnancies, the outcome of pregnancy was known.

Figure 1. Sample size selection flow chart



This report presents the number of maternal and late maternal deaths as well as maternal mortality ratios. These ratios were computed by dividing the number of deaths by the number of live births registered for the same period and are presented as ratios per 100,000 live births.

Information about women and their pregnancies was obtained from death certificates and, when available, matched birth and fetal death certificates. Race was defined as the race of the mother and categorized as White, Black/African American, Asian, Multiracial, and other. Ethnicity was defined as Hispanic and Non-Hispanic. Marital status was categorized as married, not married and unknown, and partner present, as inferred by reporting of father's age, was examined for maternal deaths linked to birth or fetal death certificate. Maternal prenatal care and obstetric history information are available only on birth and fetal death certificates, and therefore analysis of the variables was limited to deaths occurring after births for which birth or fetal death certificates were available to link. Onset of prenatal care was categorized as first trimester, after first trimester and unknown. Other variables for obstetric history included number of prenatal visits (less than 5 and 5 and more, based on WHO recommendation of a minimum of four antenatal visits); previous pregnancy (yes/no), use of tobacco (yes/no), chronic conditions (diabetes and hypertension), and baby characteristics such as gestational age, prematurity (yes/no), Apgar score and birth attendant.

The controls were sampled randomly and directly from the same population as cases; therefore they are representative of the source population that produced the cases. The cases were identified from the GA DPH death and birth files, and the comparison group was selected at random from the same source population (GA DPH births). The sampling method was chosen to be random to insure that the controls provide an accurate representation of the exposure status of the source population. Given that a consensus on specific socio-economic factors that capture major aspects of maternal health risk has not been reached, I did not match on the factors (e.g., age) to be able to make risk estimates.

The study' power calculations was based on 80% chance of detecting, two-sided confidence level 95%, ratio of controls to cases 10, and approximate percent of controls and cases with exposure (potential risk factors).

Calculations of sensitivity and specificity were performed given the availability of GA MMRC data for 2012. The following formulas were used for the calculations. Sensitivity: probability that a test result will be positive when the disease is present (true positive rate) = a / (a+b). Specificity: probability that a test result will be negative when the disease is not present (true negative rate) = d / (c+d). Positive predictive value: probability that the disease is present when the test is positive. = a / (a+c). Negative predictive value: probability that the disease is not present when the test is negative = d / (b+d).

Results

Goal 1. To characterize means of detecting cases of maternal deaths from vital statistical data, as detected by checkbox and record linkage, and describe ICD-10 obstetric codes;

The multiple strategies of case identification produced 440 cases of maternal deaths. Of the 440 deaths, 297 (67.5%) were identified by pregnancy flag check, 253 (58%) were found by linking women's deaths to birth certificates, and 21 (4.8%) were deaths linked to fetal death certificates. All maternal deaths identified by pregnancy check and birth record linkage were accepted. Of the 440 deaths, 115 occurred during pregnancy, 122 occurred 1-42 days postpartum, and 203 occurred between 43 and 365 days postpartum. Of the 440 deaths, 261 (59.3%) were linked to pregnancy cause of death (O-code), and 179 to other cause of death. For 274 (62.3%) of pregnancies, the outcome of pregnancy was known. Of these, 253 occurred after a live birth and 21 after a stillbirth.

Table 1. Pregnancy-associated maternal death identification method by year, 2010-2013

Event Year	Count of maternal deaths	Number identified by pregnancy flag check	Number of deaths linked to birth certificates	Number of deaths linked to fetal death certificates
2010	92	53 (57.6%)	66 (71.7%)	4 (4.4%)
2011	97	72 (74.2%)	52 (53.6%)	5 (5.2%)
2012	102	60 (58.8%)	56 (55.0 %)	8 (7.8%)
2013	149	112 (75.2%)	79 (53.0%)	4 (2.7%)
TOTAL	**440**	**297 (67.5%)**	**253 (58%)**	**21 (4.8%)**

Figure 2. Identification of 440 pregnancy-associated maternal deaths, by identification method, Georgia, 2010-2013

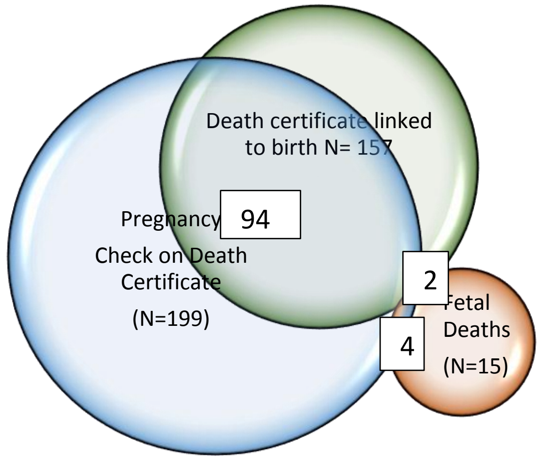


Table 2. Number of Maternal Deaths, detected by all methods, with corresponding O-codes, Georgia, by year

Event Year	Count of maternal deaths	Number with O-code
2010	92	50 (54.4%)
2011	97	68 (70.15)
2012	102	44 (43.1%)
2013	149	99 (66.4%)
TOTAL	**440**	**261 (59.3%)**

Sensitivity and specificity analysis was performed based on available data from GA MMRC

Table 3. Sensitivity and Specificity analysis for the study maternal cases, comparing algorithm-based linked records with maternal death review committee findings, Georgia, 2012

Death records		2012 Deaths from MR Committee		
		Not Related	PR/PA	Total
Study Findings	Missed	15	12	27
	Detected	22	73	95
	Total	37	85	122

The probability that the test result is positive when the maternal death is present - sensitivity - is 86%. The probability that the test result is negative when the maternal death is not present - specificity – is 40.5%. The probability that the maternal death is present when the test is positive -

positive predictive value – is 76.8%. The probability that the maternal death is not present when the test is negative – negative predictive value – is 55.66 %.

Table 4. Live Births and pregnancy-associated (related and unrelated) maternal death ratios, Georgia, 2010-2013 by year

Event Year	Live births	Maternal deaths	Deaths per 100,000 live births	Confidence Interval
2010	134,244	92	68.5	(55.9, 84.0)
2011	132,950	97	73.0	(59.8, 89.0)
2012	129,498	102	78.8	(64.9, 95.6)
2013	127,863	149	116.5	(99.3, 137)
TOTAL	**524,555**	**440**	**83.9**	**(76.4, 92.1)**

The maternal mortality ratio for the 4-year period 2010-2013 was 83.9 maternal deaths per 100,000 live births. The annual mortality ratio ranged from low of 68.5 in 2010 to a high of 116.5 in 2013.

O-codes for maternal deaths causes did not differ between the studied years. When O codes were used for grouping of causes of deaths, an obstetric death of unspecified cause O95 code was most common (75 cases). Other common O codes for maternal death were O96 - death from any obstetric cause 42-365 days after delivery (50 cases), O26.8 - other specified pregnancy-related conditions (45 cases), O99.8 other specified diseases and conditions complicating pregnancy, childbirth and puerperium (20 cases), O99.4 disease of circulatory system complicating pregnancy, childbirth and puerperium (17 cases), and O90.8 other complications of the puerperium (13). Other causes included respiratory conditions, maternal hypertension, amniotic fluid embolism, cardiomyopathy in the puerperium, premature separation of placenta, obstetric blood-clot embolism, mental disorders and pre-existing hypertension.

Table 5. Most Frequent O-Codes

OVERALL		
Code	**Description**	**N**
O95	Obstetric Death of Unspecified Cause	75
O96	Death from any obstetric cause 42 days – 365 days after delivery	50
O26.8	Other specified pregnancy-related conditions	45
O99.8	Other specified diseases and conditions complicating pregnancy, childbirth and the puerperium	20
O99.4	Diseases of the Circulatory system complicating pregnancy, childbirth and the puerperium	17
O90.8	Other complications of the puerperium, not elsewhere classified	13
O99.5	Diseases of the respiratory system complicating pregnancy, childbirth and the puerperium	8
O16	Unspecified maternal hypertension	8
O88.1	Amniotic fluid embolism	6
O90.3	Cardiomyopathy in the puerperium	6
O45.9	Premature separation of placenta, unspecified	6
O88.2	Obstetric blood-clot embolism	5
O99.3	Mental disorders and diseases of the nervous system complicating pregnancy, childbirth and the puerperium	5
O10.0	Pre-existing hypertension complicating pregnancy, childbirth and the puerperium	5

Table 6. Most Frequent 20 O-Codes by Year

2010		2011		2012		2013	
Code	N	Code	N	Code	N	Code	N
O95	10	O95	21	O95	14	O95	30
O96	10	O96	14	O96	11	O26.8	17
O26.8	8	O26.8	9	O26.8	11	O96	15
O99.4	4	O99.4	5	O99.8	3	O99.8	9
O90.8	3	O99.8	5	Others	14	O90.8	8
O99.8	3	Other	28			O99.4	6
O45.9	3					O99.5	5
Other	20					O24.9	3
						O88.1	3
						Other	20
Total	61	Total	82	Total	53	Total	116

Concerning maternal characteristics of cases (maternal deaths) maternal mortality increased with maternal age. African-American women were more likely to have maternal death than were women of other races. Not married women and women who did not report father's information had higher risk of maternal death than married women and women with male partners. Maternal prenatal care and obstetric history analysis was limited to deaths occurring after births for with birth/fetal deaths certificates were available to link. Women who had premature, low birth-weight (<2500 grams) babies were at higher risk for maternal death than women who had full term, normal birth weight babies.

Table 7. Maternal Deaths by demographics, Georgia, 2010-2012 and 2013

Characteristic	**Year Group**		**p-value**
	2010-2012 (N = 291)	**2013 (N = 149)**	
<u>Mother Demographics</u>			
Age (Years)	N = 291	N = 149	
Mean ± SD	30.8 ± 8.9	34.8 ± 11.2	0.0006
Median (IQR)	29.3 (23.9 – 36.6)	32.6 (26.5 – 42.0)	
Age < 18	7 (2.4%)	4 (2.7%)	0.8592
18≤ Age <25	85 (29.2%)	28 (18.8%)	0.0179
25≤ Age <35	113 (38.8%)	55 (36.9%)	0.6950
35≤ Age <45	68 (23.4%)	30 (20.1%)	0.4404
Age ≥45	18 (6.2%)	32 (21.5%)	<.0001
Death during? Pregnancy	82 (28.2%)	29 (19.5%)	0.0383
Death <42 days after pregnancy ended	69 (23.7%)	50 (33.6%)	
Death between 42 days and 1 year after pregnancy ended	140(48.1%)	70 (47.0%)	
Race	N = 291	N = 149	0.0020
White (1)	130 (44.7%)	77 (51.7%)	
Black/African American (2)	150 (51.6%)	55 (36.9%)	
Asian (3)	3 (1.0%)	3 (2.0%)	
Multiracial (6)	6 (2.1%)	14 (9.4%)	
Other	2 (0.7%)	0	
Unknown	0	0	
Ethnicity	290	149	0.3986
Hispanic	9 (3.1%)	7 (4.7%)	
Non-Hispanic	281 (96.9%)	142 (95.3%)	
Unknown	1 (0.3%)		
Marital Status	191	83	
Married	72 (37.7%)	33 (39.8%)	0.0157
Not Married	117 (61.3%)	44 (53.0%)	
Unknown	2 (1.0%)	6 (7.2%)	
Education	181	81	
Advanced Degree (2)	2 (1.10%)	4 (4.9%)	0.1406
Some College or Bachelor's (1)	52 (28.7%)	21 (25.9%)	
High School or Less (0)	111 (61.3%)	46 (56.8%)	
Unknown (-1)	16 (8.8%)	10 (12.4%)	
Insurance	N = 181	N = 81	
Govt Assistance/Self-Pay/Medicaid0	122 (67.4%)	24 (29.6%)	0.7711
Private/Military (1)	31 (17.1%)	7 (8.6%)	
Unknown/Other	28 (15.5%)	50 (61.7%)	
<u>Mother's Prenatal Care / OB History</u>			
Prenatal Visits	N = 191	N = 83	
5 or More (2)	128 (67.0%)	53 (63.9%)	0.7518
1 to 5 (1)	18 (9.4%)	5 (6.0%)	
None (0)	5 (2.6%)	2 (2.4%)	

Unknown	40 (20.9%)	23 (27.7%)	
Mean ± SD	10.3 ± 5.3	9.3 ± 3.9	0.3349
Median (IQR)	10 (8 – 13)	10 (7 – 12)	
Start of Prenatal Care	N = 191	N = 83	
1st Trimester	94 (49.2%)	40 (48.2%)	0.3780
After 1st Trimester	48 (25.1%)	15 (18.1%)	
Unknown	49 (25.7%)	28 (33.7%)	
Tobacco Use	N= 191	N= 83	
Yes	29 (15.2%)	14 (16.9%)	0.4593
No	162 (84.8%)	60 (72.3%)	
Unknown	0	9 (10.8%)	
First Pregnancy	N = 191	N = 83	
Yes	49 (25.7%)	23 (27.7%)	0.6547
No	122 (63.9%)	50 (60.2%)	
Unknown	18 (9.4%)	9 (10.8%)	
N/A	2 (1.1%)	1 (1.2%)	
Mother's Medical History	N = 191	N = 83	
Chronic Diabetes	2 (1.1%)	1 (1.2%)	0.6694
Gestational Diabetes	1 (0.5%)	2 (2.4%)	0.4466
Chronic Hypertension	1 (0.5%)	1 (1.2)	0.9395
Hypertension	2 (1.1%)	0	0.2158
Infant Characteristics	N = 291	N = 149	
Gestational Age (Weeks) Median (IQR)	38 (35 – 39)	37 (34 – 39)	0.4089
Premature (Yes), *N (%)*	57 (29.8%)	35 (42.2%)	0.0381
Birth Weight (grams) Median (IQR)	3005 (2182 – 3430)	2749 (2069 – 3118)	0.0260
< 1500 grams, N (%)	22 (11.5%)	10 (12.1%)	0.8852
< 2500 grams, N (%)	38 (19.9%)	29 (34.9%)	0.0066
APGAR Score at 5 min	N = 179	N = 81	
Median (IQR)	9.0 (8.0 – 9.0)	-1 (-1 – 9.0)	<.0001
< 3, N (%) (0)	5 (2.8%)	1 (1.2%)	0.7951
< 5, N (%) (1)	2 (1.1%)	0	
≥ 5, N (%) (2)	169 (96.0%)	38 (97.4%)	
Birth Attendant	N = 181	N = 81	
MD	110 (60.8%)	31 (38.3%)	0.1251
Other	19 (10.5%)	7 (8.6%)	
Unknown	52 (28.7%)	43 (53.1%)	

Goal 3-4 for maternal deaths with linked birth or fetal death certificates (with or without O codes), to compare maternal death ratios, by maternal attributes; compare maternal mortality deaths and maternal characteristics for 2010-1012 with 2013;

Table 8. Maternal Deaths by demographics restricted to linked birth-maternal death data, Georgia, 2010-2012 and 2013

Demographic	**Overall N = 274**			**2010 – 2012 N = 191**			**2013 N = 83**	
	Births	**Deaths**	**Death Ratio/100,000**	**Births**	**Deaths**	**Death Ratio/100,000**	**Births**	**Deaths**
Race								
White	261,187	125	47.9	196,921	87	44.2	64,266	38
Black/African American	173,633	133	76.6	130,780	99	75.7	42,853	34
Asian	18,301	4	21.9	13,723	2	14.6	4,578	2
American Indian/Alaska Native	583	0	0.0	438	0	0.0	145	0
Native Hawaiian/ Pacific Islander	619	0	0.0	494	0	0.0	125	0
Multiracial	16,513	12	72.7	12,581	3	23.8	3,932	9
Unknown	53,719	0	0.0	41,755	0	0.0	11,964	0
Age								
Age < 18	14,908	6	40.2	11,993	3	25.0	2,915	3
18≤ Age <25	171,984	99	57.6	131,456	65	49.4	40,528	23
25 Age <35	266,342	126	47.3	199,864	82	41.0	66,478	44
35≤ Age <45	70,364	54	76.7	52,661	41	77.9	17,703	13
Age ≥45	957	0	0.0	718	0	0.0	239	0
Marital Status								
Married	285,384	105	36.8	216,235	72	33.3	69,149	33
Father Yes	-	-	32.3	210,826	57	27.0	-	-

Demographic	Overall N = 274			2010 – 2012 N = 191			2013 N = 83	
	Births	**Deaths**	**Death Ratio/100,000**	**Births**	**Deaths**	**Death Ratio/100,000**	**Births**	**Deaths**
Father No	-	-	49.6	5,409	15	277.3	-	-
Not Married	236,034	161	68.2	178,542	117	65.5	57,492	44
Father Yes	-	-	64.4	125,723	62	49.3	-	-
Father NO	-	-	72.5	52,819	55	104.1	-	25
Unknown	3,137	8	255.0	1,915	2	104.4	1,222	6
Father Yes	-	-	-	125	2	1,600		-
Father NO	-	-	-	1,790	0	0		-
Education					N=181			N = 81
Advanced Degree (2)	32,126	6	18.7	21,311	2	9.4	10,815	4
Some College or Bachelor's (1)	227,278	73	32.1	171,721	52	30.3	55,557	21
High School or Less (0)	243,065	157	64.6	186,031	111	59.7	57,034	46
Unknown (-1)	22,086	26	117.7	17,629	16	90.8	4,457	10

Goal 4.To compare the maternal characteristics of maternal mortality by race, marital status and presence of father's age on birth certificate.

Table 9. Maternal Deaths by marital status/father reporting, by black and non-black race, restricted to linked birth-maternal death data, Georgia, 2010-2012

	Black			Non-Black			Overall		
Marital status/father	Maternal deaths	Births	MM ratio	Maternal deaths	Births	MM Ratio	Overall		
							Deaths	Births	Ratio
Married – father reported	23	35071	65.6	34	175755	19.3	57	210826	27.0
Married - father not reported	5	1444	346.3	10	3965	252.2	15	5409	277.3
Married	28	36515	76.7	44	179720	24.5	72	216235	33.3
Not married – father reported	35	60372	58	27	65476	41.2	62	125848	49.3

Not married - father not reported	35	33893	103.3	20	20716	96.5	55	54609	100.7
Not married	70	94265	74.3	47	86192	54.5	117	180457	64.8
Overall father reported	58	95443	60.8	61	241231	25.3	119	336674	35.3
Overall no father reported	40	35337	113.2	30	24681	121.6	70	60018	116.6
All	98	130780	74.9	91	265912	34.2	189	396692	47.6
Crude odds ratios	Crude OR compared with married, non-Black MMR	Black births	MM ratio	Not Black	Not Black	MM			
			O.R.			O.R.			
Married – father reported	23	35071	3.4	34	175755	1.0			**1.0**
Married - father not reported	5	1444	17.9	10	3965	13.1			**10.3**
Not married – father reported	35	60372	3.0	27	65476	2.1			1.8
Not married - father not reported	35	33893	5.4	20	20716	5.0			3.7

Overall, Black MMR about 2.2 times higher than Non-Black MMR (74.9 vs 34.2). Maternal mortality among unmarried is 1.9 times higher than among married (64.8 vs. 33.3) and maternal mortality among those who reported no father is 3.3 times higher than among those who reported a father (116.6 vs. 35.3). Married women not reporting a father have 10.3 odds of maternal death compared with those who report a father (277.3 vs. 27.0). Unmarried women not reporting a father's name have a 2.0 odds of maternal death compared with those who report a father's name (100.7 vs. 49.3).

Overall, married Black women who report a father have same odds of maternal death as unmarried Black women who report a father (65.6 vs. 58). Married non-Black women who report a father have 0.5 odds of maternal death as unmarried non-Black women who report a father (19.3 vs. 41.2).

Table 10. Summary of Health Districts with Unknown Racial Categorizations (N = 53719)

Hospital	Frequency	Percent	Percent Births in Health District
East Metro Health District (Lawrenceville)	9621	17.91	17.6
DeKalb Health District	7590	14.13	17.6
Fulton Health District	5779	10.76	11.6
Cobb/Douglas Health District	5402	10.06	12.4
North Georgia Health District (Dalton)	5133	9.56	23.6
Clayton County Health District (Jonesboro)	3019	5.62	18.1
Northwest Health District (Rome)	2496	4.65	8.0
LaGrange Health District	2244	4.18	6.1
Northeast Health District (Athens)	1938	3.61	8.6
North Health District (Gainesville)	1672	3.11	5.7
Coastal Health District (Savannah)	1578	2.94	4.6
Southwest Health District (Albany)	1503	2.8	7.7
Southeast Health District (Waycross)	1382	2.57	7.3
West Central Health District (Columbus)	1319	2.46	6.4
East Central Health District (Augusta)	903	1.68	3.6
South Health District (Valdosta)	872	1.62	6.2
North Central Health District (Macon)	670	1.25	2.5
Non-Georgia District	396	0.74	4.4
South Central Health District (Dublin)	202	0.38	3.0

Goal 5 to identify maternal characteristics that are associated with increased risk for maternal mortality by comparing cases (maternal deaths) with controls (women, who delivered in the same time frame and survived for at least one year after delivery) for years 2010-2013

I conducted an initial descriptive analysis of cases and controls to identify potential associated factors (Table 5). I found that mothers who died were significantly older (median age of 30.4 vs. 27.6 in control group, p<0.0001), 47% of them were Black/African American compared to 37% in control group (p<0.0001), almost 60% were unmarried compared to 45% among surviving mothers (p<0.0001), majority (60%) had low education compared to less than half (47%) among controls (p<0.0001), commonly used government insurance 56% vs. 37% controls (p<0.0001), and 16% smoked tobacco vs. only 6% in surviving mothers(p<0.0001).

Table 11. Univariate Analysis of Risk Factors for Maternal Death, Georgia, 2010-2012

Characteristic	Maternal Group		p-value
	Alive (0) (N = 4440)	**Died (1) (N = 440)**	
Mother Demographics			
Mother's Age (Years)	N = 4306	N = 440	
Mean ± SD	27.9 ± 6.1	32.2 ± 9.9	<0.0001
Median (IQR)	27.6 (23.1 – 32.3)	30.4 (24.3 – 38.4)	
Race	N = 3932	N = 440	
White	2194 (55.8%)	207 (47.1%)	<.0001
Black/African American	1444 (36.7%)	205 (46.6%)	
Asian	161 (4.1%)	6 (1.4%)	
Multiracial	121 (3.1%)	20 (4.6%)	
Other	12 (0.3%)	2 (0.5%)	
Ethnicity	N = 4274	N = 439	
Hispanic	595 (13.9%)	16 (3.6%)	<.0001
Non-Hispanic	3679 (86.1%)	423 (96.4%)	
Marital Status	N = 4400	N = 274	
Married	2402 (54.6%)	105 (38.3%)	<0.0001
Not Married	1966 (44.7%)	161 (58.8%)	
Unknown	32 (0.7%)	8 (2.9%)	
Education	N = 4306	N = 262	
Advanced Degree (2)	257 (6.0%)	6 (2.3%)	<.0001
Some College or Bachelor's (1)	1821 (42.3%)	73 (27.9%)	
High School or Less (0)	2008 (46.6%)	157 (59.9%)	
Unknown (-1)	220 (5.1%)	26 (9.9%)	
Insurance	N = 4306	N = 262	
Govt Assistance/Self-Pay/Medicaid0	1599 (37.1%)	146 (55.7%)	<.0001
Private/Military (1)	1156 (26.9%)	38 (14.5%)	
Unknown/Other	1551 (36.0%)	78 (29.8%)	
Mother's Prenatal Care / OB History			
Prenatal Visits	N = 4400	N = 274	
5 or More (2)	3281 (74.6%)	181 (66.1%)	0.0043
1 to 5 (1)	200 (4.6%)	23 (8.4%)	
None (0)	93 (2.1%)	7 (2.6%)	
Unknown	826 (18.8%)	63 (23.0%)	
Mean ± SD	11.0 ± 4.5	10.0 ± 5.0	0.0005
Median (IQR)	11 (9 – 13)	10 (7 – 12)	
Start of Prenatal Care	N = 4399	N = 274	

Characteristic	Maternal Group		p-value
	Alive (0) (N = 4440)	**Died (1) (N = 440)**	
1st Trimester	2464 (56.0%)	134 (48.9%)	0.0412
After 1st Trimester	954 (21.7%)	63 (23.0%)	
Unknown	981 (22.3%)	77 (28.1%)	
Tobacco Use	N = 4400	N = 274	
Yes	257 (5.8%)	43 (15.7%)	<.0001
No	3922 (89.1%)	222 (81.0%)	
Unknown	221 (5.0%)	9 (3.3%)	
First Pregnancy	N = 4400	N = 274	
Yes (1)	1335 (30.3%)	72 (26.3%)	0.0104
No (0)	2799 (63.6%)	172 (62.8%)	
Unknown (-1)	238 (5.4%)	27 (9.9%)	
N/A (-2)	28 (0.6%)	3 (1.1%)	
Mother's Medical History	4440	274	
Chronic Diabetes	7 (0.2%)	3 (1.1%)	0.0041
Gestational Diabetes	34 (0.8%)	3 (1.0%)	0.7535
Chronic Hypertension	9 (0.2%)	2 (0.7%)	0.1211
Hypertension	3 (0.07%)	2 (0.73%)	0.0048
Infant Characteristics	N = 4400	N = 274	
Gestational Age (Weeks) Median (IQR)	39 (38 – 40)	38 (34 – 39)	<.0001
Premature (Yes), *N (%)*	658 (15.0%)	92 (33.6%)	<.0001
Birth Weight (grams) Median (IQR)	3255 (2869 – 3572)	2891 (2182 – 3384)	<.0001
< 1500 grams, N (%)	105 (2.4%)	32 (11.7%)	<.0001
< 2500 grams, N (%)	353 (8.0%)	67 (24.5%)	<.0001
APGAR Score at 5 min Median (IQR)	N = 4306	N = 260	
< 3, N (%) (0)	30 (0.7%)	6 (1.4%)	0.0009
< 5, N (%) (1)	20 (0.5%)	2 (0.8%)	
Birth Attendant	N = 4306	N = 262	
MD	1742 (40.5%)	141 (53.8%)	<.0001
Other	410 (9.7%)	26 (9.9%)	

A logistic regression model was built including five variables that were identified from initial analysis and from previous literature to be associated with maternal death.
The five factors were independently associated with maternal death after controlling for other variables (Table 12). The analysis was repeated excluding motor accidents and assaults (Table13).

Table 12. Reduced logistic regression model with pregnancy associated maternal death as outcome *(including motor accidents and assaults), Georgia, 2010-2013*

Independent Variables	Odds Ratio	95% CI	P-Value
Age (per year)	1.06	(1.03, 1.08)	<.0001
Race (black vs. non-black)	1.82	(1.37, 2.42)	<.0001
High school education (less or equal vs. more)	2.39	(1.74, 3.27)	<.0001
Tobacco use (yes vs. no)	2.55	(1.71, 3.82)	<.0001
Insurance (government vs. private)	2.00	(1.32, 3.06)	0.0012

N (Alive) = 3476; N (Death) = 225

Tables 13. Reduced logistic regression model with pregnancy associated maternal death as outcome *(excluding motor accidents and assaults), Georgia 2010-2013*

Independent Variables	Odds Ratio	95% CI	P-Value
Age (per year)	1.08	(1.06, 1.11)	<.0001
Race (black vs. non-black)	1.75	(1.27, 2.42)	0.0002
High school education (less or equal vs. more)	2.16	(1.52, 3.09)	<.0001
Tobacco use (yes vs. no)	2.38	(1.51, 3.76)	0.0002
Insurance (government vs. private)	1.90	(1.20, 3.02)	0.0063

N (Alive) = 3476; N (Death) = 178

Motor accidents and assaults cases were not included in the second model as I wished to investigate if the association of the five factors with maternal deaths would change. The odds of belonging to black race were 1.8 times higher among women who died compared with women who survived (95% CI 1.8–2.4), and the odds of low education were two times higher among cases compared with controls (95% CI 1.5–3.1). Women who died were found to have more than two-fold higher odds of smoking tobacco, and about two-fold higher odds of having government insurance, compared with the women who survived. Furthermore, the odds of being older were greater among cases compared with controls.

Discussion

The low incidence of maternal mortality in the US and incompleteness of data makes studies on the risk of maternal deaths difficult; however, I was able to perform an unmatched case–control analysis using four-years data from GA Department of Public Health to investigate the effects of the factors associated with maternal mortality. As the analysis was based on state data, the cases (maternal deaths) and controls (women who survived for more than one year after giving birth) were from the same source population, thereby making the comparison valid.

Validation of the case identification algorithm was performed for 2012 maternal mortality cases because of availability of Georgia Maternal Mortality Committee (MMRC) review for the year. It showed high probability (86%) that the study test is positive (maternal death) when the maternal death is present; high probability that the maternal death was present when the study analysis identified it as positive (PPV 76.8%); and acceptable (in the absence of other methods) probability that the maternal death was not present when the study analysis identified it as negative (NPV 55.66 %). The indicators may suffice to apply the algorithm to identify maternal death cases and perform maternal mortality analysis to years lacking maternal death investigations by MMRC using maternal medical charts. The MMRC data, which is used in this study as a gold standard for the maternal deaths identification, is itself prone to errors given that it is not first-hand collected data. Primary source for the cases identification for the Maternal Mortality Committee review was GA DPH data (same as used for this study), and the cases validation analysis was performed using medical charts review as a second step. Therefore, maternal cases potentially missed in the first step, would not be included in the second step of MMRC review.

I found five factors to be associated with increased risk of maternal deaths in the state of GA including older age, African American race, low education, government insurance and tobacco use. Absence of a partner, identified using reported father's age, is an important factor potentially associated with increased risk of higher maternal mortality; it was not included in the final model due to missing data on paternity for 2013 case file.

<u>Advanced Maternal Age</u>
Notable result from this study is the high maternal mortality ratios for women aged 35 years and older. Almost 30% of all women in GA who died of pregnancy complications were aged 35 or older, which is comparable with finding (Creanga, Bateman, Kuklina, & Callaghan, 2014) of 27.4% in the US. Health care providers and the general population need to be aware of an increase in maternal complications and deaths when pregnancy is delayed to advanced maternal age. Biologically, fertility decreases and risk of adverse pregnancy outcomes increases after the age of 35 years. Availability of assisted reproductive technologies increase a chance for conceiving a

pregnancy especially with implantation of multiple embryos, though the risk of adverse outcome rises due to chronic diseases related to advanced age and due to multifetal pregnancy. Analysis (MacKay, Berg, King, Duran, & Chang, 2006) of 4992 pregnancy-related deaths in the US showed that risk of pregnancy death among women with twin and higher order pregnancies was 3.6 times that of women with singleton pregnancy (20.8 compared with 5.8). Recent evaluation (Nove, Matthews, Neal, & Camacho, 2014) revealed that highest risk for maternal mortality is in women older than 40 years. The data showed that preventing 100 000 pregnancies until 20–24 years would prevent 70 maternal deaths, while preventing 100 000 pregnancies in women aged 40 years or older leads to prevention of more than 1000 deaths.

Common reasons to postpone pregnancy include but not limited to the availability of effective contraception and advanced fertility treatments; desire to achieve higher education and reach financial independence, changes in expectations of women in terms of career development, and presence of supportive partner. In the study (Tough, Vekved, & Newburn-Cook, 2012) secure relationship (97%), feeling in control of one's life (82%) and feeling prepared to parent (77%) had greatest influence on childbearing. Most recent developments in the field of modern long-acting reversible contraceptives (e.g, Skyla, Mirena) have great profile on safety and effectiveness for both nulliparous and parous women and minimum side effects; and some, such as subdermal implants and intrauterine devices, offer additional benefit of being not user dependent.

Women should be supported in their reproductive health choices. However, they need to be provided with comprehensive information before the choices are made. Age-, education- and culturally-appropriate adaptations of family planning counselling that address medical and socio-economic factors related to childbirth throughout a woman's life should be implemented in reproductive practice to improve informed decision-making process and reduce adverse maternal outcomes.

Advance maternal age is an evolving public health concern. Burden associated with increased use of assisted reproductive technologies and prolonged specialized care to compensate for increased morbidity in advanced-age mothers and their babies should be expected. Therefore, further research of this trend is warranted to develop appropriate strategies for adverse pregnancy outcomes prevention.

African-American Race

The finding in this study that African American race is significantly associated with increased risk for maternal mortality is in agreement with the recent assessment of states-specific pregnancy-related mortality in the US 2005-2014 (Moaddab et al., 2016). The authors documented that the most dramatic increase in maternal mortality is in non-Hispanic black women and found a significant correlation between state mortality ranking and the percentage of non-Hispanic black women in delivery population. It is consistent with multistate analysis (Creanga, Bateman, Kuklina, et al., 2014) of racial and ethnic disparities in severe maternal morbidity for 2008-2010 revealing that it disproportionally affects racial/ethnic minority women, especially non-Hispanic black women. Looking at differences inside the state of Georgia, pregnancy-related mortality ratio outside of rural areas were found to be significantly higher for black compared with white women in 2010 to 2012 (Platner et al., 2016). Evaluation of cumulative neighborhood deprivation index (NDI) in Georgia-resident women 1994-2007(Kramer, Dunlop, & Hogue, 2014) revealed that higher cumulative NDI was associated with adverse pregnancy outcomes for black but not white women as they age. Population-based case-control study of stillbirth regarding the relationship of stress estimated by number of significant life events (SLE) to the racial disparity for African Americans (Hogue et al., 2013) has shown that the proportion of women with multiple SLE factors were higher among black women and the number of SLEs was independently associated with stillbirth.

Moreover, maternal stress was identified as a potential explanatory factor for excess preterm delivery among black women because of their exposure to racism-associated stress (Hogue & Bremner, 2005; Wadhwa et al., 2001). Additionally, Black women were twice as likely as white women to experience physical abuse during pregnancy (4.1% vs 2.1% accordingly) based on PRAMS 2009-2011 data for state of GA. Results from previous decade (Creanga et al., 2012) at the national level indicated that racial minorities contributed 40.7% of all live births in US and 61.8% of pregnancy-related deaths during 1993-2006.

The recommendations of addressing racial disparities in health care availability, access and utilization to decrease maternal mortality sound extremely valid in light of recent evaluation of performance of racial and ethnic minority-serving hospitals (Creanga, Bateman, Mhyre, et al., 2014). Considerable differences in delivery-related indicators by hospital type and patients' race and ethnicity were revealed, with black-serving hospitals performing worst on 12 of 15 indicators. More research of the cumulative impact of racism in terms of repeated exposures of African Americans mothers to psychosocial, physical, occupational and healthcare stressors is needed to help inform policy makers. Integration of mental and psychosocial services into primary and prenatal care is an opportunity to make it available and affordable for African Americans women. Additionally, supplementation with food rich in probiotics and micronutrients may help address racial disparity in nutrient deficiencies and microbiome composition (Dunlop, Kramer, Hogue, Menon, & Ramakrishan, 2011). Recent randomized clinical trial (Joseph et al., 2009) on the efficacy of clinic-based intervention targeting behavioral and psychosocial risk factors (e.g., smoking, depression, partner violence) among 1044 pregnant African American women found that it significantly reduced the psychosocial and behavioral risks and very preterm birth (El-Mohandes, Kiely, Gantz, & El-Khorazaty, 2011). Further studies are needed to examine extent to which the risk reduction among African American women might avert adverse pregnancy outcomes, including severe maternal morbidity and mortality.

Low maternal education

Low maternal education was found in this study to be associated with increased maternal risk of dying; odds of low education were two times higher among cases compared with controls. Maternal education has been identified as one of the strongest predictors of use of contraception and timing of child-bearing in the study by Johnson et al. Higher level of education is linked with advanced health-seeking behavior. Study (Ross & Wu, 1996) found positive association between education and health, as well-educated people are more likely to find full-time high-paid job; have greater sense of control over their life and health, and higher levels of emotional support. New evaluation (Mirowsky & Ross, 2015) indicated that all the factors are linked to health-promoting behavior and earlier adaptation of health-related recommendations.

GA data also showed positive association between education and reduction of unintended pregnancies, early start of prenatal care, less mental distress and less physical abuse during pregnancy (GA DPH Maternal and Women's Health, Georgia Title V Needs Assessment (2015). In relation to the Medicaid population, low education negatively affects patients' ability to navigate through numerous bureaucratic procedures to start care on Medicaid (Stuber & Bradley, 2005). Further collection and evaluation of education data in reproductive health research will enable monitoring of education patterns in maternal health indicators. It will contribute to deeper understanding of relationship between education and reproductive outcomes and development of strategies to address it.

Government Insurance

Mothers who died were found to have about two-fold higher odds of having government insurance, compared with the women who survived. Getting access to prenatal care on Medicaid may require significant efforts according to recent study on barriers to Medicaid enrollment among community health centers patients in ten states and the District of Columbia (Stuber & Bradley, 2005). The prevalence of perceived enrollment barriers was high: 40% agreed that the Medicaid application was long and complicated, 41% found it hard to find translator, 34% agreed that it was difficult to obtain transportation to apply for Medicaid or to get the documents needed to apply (30%), 27% agreed that the hours were inconvenient, and 30% agreed with at least 3 of these items. Respondents who reported having a physical health problem in the past 4 weeks and who were non-Hispanic Black were more likely to be misinformed about Medicaid. Respondents who reported having a mental health problem in the last 4 weeks, education less than ninth grade and women were more likely to perceive enrollment barriers. Therefore African American and low educated women, and women with chronic physical and mental health problems should be targeted for outreach interventions, as overcoming bureaucratic barriers may delay start of prenatal care and therefore impact pregnancy outcome. After pregnancy completion, Medicaid coverage ends at 6 weeks postpartum visit. The Department of Community Health in state of GA reported following rates of postpartum visits for the three Medicaid CMOs: 60.78%, 61.81% and 63.24% in 2013 (GA DPH Maternal and Women's Health, Georgia Title V Needs Assessment (2015) http://dph.georgia.gov/sites/dph.georgia.gov/files/MCH/TitleV/Maternal_Womens_Health.pdf). Thus about 40% of Medicaid postpartum population are left vulnerable to unwanted or mistimed pregnancy and therefore poor pregnancy outcomes. Furthermore, lack of primary care coverage outside of pregnancy may contribute to the cycle of adverse maternal outcomes. More research is needed on different aspects (e.g., barriers to enrollment and finding health care providers, quality and continuity of care) related to federal and state programs for pre-conception, prenatal and inter-pregnancy periods, and creative strategies to be devised to assist most vulnerable groups.

Smoking tobacco

Women who died were found to have more than two-fold higher odds of smoking tobacco. Potential underreporting of smoking by mothers and inconsistent collection/extraction of smoking information by hospital staff /public health officials may impact completeness of birth certificates data and therefore result of this analysis. Three recent studies compared smoking data from birth certificates and other sources. Comparison of estimates from Pregnancy Risk Assessment Monitoring System (PRAMS) and birth certificates (Tong, Dietz, Farr, D'Angelo, & England, 2013) in eight states revealed that PRAMS captures more mothers who smoked during pregnancy for all sociodemographic groups. An evaluation in Washington (Searles Nielsen, Dills, Glass, & Mueller, 2014)of maternal smoking from birth certificates and newborn blood cotinine levels revealed that for every 100 non-smoking (according to birth certificate) mothers 2 newborns tested positively for maternal smoking. A study in New York City and Vermont (Howland et al., 2015) that compared smoking data on birth certificates and medical records showed 25% difference (higher on medical records). Improving quality of smoking status data on birth certificates may require education of hospital staff and public health officials about importance of the data and specialized training on data quality improvement/quality assurance process.

Although current strict smoking policies that prohibit smoking inside most public places (Georgia Smoke free Air Act, O.C.G.A. §§ 31-12A-1 through 31-12A-13 (2005)) have a potential to influence a decrease in smoking intensity and smoking cessation,   development and implementation of programs that target women during reproductive age and especially during pregnancy are vital. Most recent assessment of average annual smoking-attributable mortality ratios revealed increase among women in Georgia compared with 1996—1999 ("State-specific smoking-attributable mortality and years of potential life lost--United States, 2000-2004," 2009). National Vital Statistics Report on smoking prevalence during pregnancy in 46-state and District of Columbia area that represent 95% of all births in the US concluded that women of certain socio-economic characteristics (young, non-Hispanic Native American, low educated, unmarried, with Medicaid insurance) have highest smoking rates. Moreover, mothers who initiated prenatal care in the third trimester or had no care had smoking rates twice that of women with early prenatal care, and had lowest quitting rates. Women with unintended pregnancies usually become aware of pregnancy later in gestational age (Naimi, Lipscomb, Brewer, & Gilbert, 2003) and might be less motivated to start prenatal care and change harmful habits. As indicated in the National Birth Defects Prevention Study 1997-2002 (Dott, Rasmussen, Hogue, & Reefhuis, 2010), women with unintended pregnancies were more likely than those with intended pregnancies to initiate or continue cigarette smoking even after they learned about pregnancy, signifying prevention of unintended pregnancies as a priority (54.8% of unintended pregnancies in 2011 in GA).

During pregnancy, pregnancy intention and smoking status must be obtained as a part of pregnancy risk assessment. Delivery of health education about consequences of smoking for mother (e.g., placental complications) and baby (e.g., stillbirth, low birth weight) and provision of interventions, developed based on understanding of factors that play role in continuation of harmful behaviors, should be considered every time women in the high risk group come in contact with the healthcare system. The American College of Obstetricians and Gynecologists outlined pregnancy tailored smoking cessation techniques 5 A’s ("Committee opinion no. 471: Smoking cessation during pregnancy," 2010) addressing both physiologic and psychologic aspects of addiction to smoking, including counselling, behavior and cognitive therapy, hypnosis, acupuncture, and pharmacologic therapy. The National Vital Statistics Report (Curtin & Matthews, 2016) identified differences in maternal smoking behavior among geographic areas potentially due to variations in tobacco control programs targeting pregnant women. Smoking-cessation programs contribute to up to 50% increase in smoking cessation in pregnant women (Dolan-Mullen, Ramirez, & Groff, 1994). Recent randomized clinical trial that tested the efficacy of clinic-based intervention targeting pregnant African American’s smoking among other behavioral and psychosocial risks found that it significantly reduced the risks (Joseph et al., 2009). Programs targeting preconception, prenatal and inter-pregnancy smoking are important for preventing adverse pregnancy outcomes and saving associated healthcare cost. The total smoking during pregnancy attributable costs were an estimated $1.4 billion – 11% of costs of complicated births - in 1995 dollars ("Medical-care expenditures attributable to cigarette smoking during pregnancy -- United States, 1995," 1997); by 2010 more than 60% of the smoking attributable spending was paid by public programs, including Medicaid (Xu, Bishop, Kennedy, Simpson, & Pechacek, 2015). Given that smoking is a modifiable risk factor associated with poor pregnancy outcomes and high healthcare cost, ongoing public health efforts are essential to reach the Healthy People 2020 goal of 98.6% prenatal smoking abstinence and reduction of postpartum relapse of smoking among women who quit smoking during pregnancy.

<u>Limitations</u>

The study has important limitations. Reporting bias arising from the recently discovered underreporting of fetal deaths in state of Georgia cannot be rule out, especially for fetuses in early gestational age. No maternal deaths from abortions and ectopic pregnancies were identified possibly due to bias in coding of causes of death and/or accuracy of pregnancy check. Maternal mortality from abortion is a rare event - about 1 maternal death per 100,000 abortions. Georgia has about 30,000-35,000 abortions per year, so in 4 years it is expected to have about 1 maternal death from abortion. In recent study (Creanga et al., 2011) on trends in ectopic pregnancy mortality revealed

that ectopic pregnancy mortality ratio was 6.8 times higher for African Americans than whites and 3.5 times higher for women older than 35 years old than those younger than 25 years during 2003-2007. I was not able to investigate effect of pre-existing and pregnancy-related medical conditions, which were identified in previous literature to be associated with maternal deaths, due to missing data. Marital status is a weak indicator of a partner presence, as roughly half of unmarried women will report a father on birth certificate. Based on past studies of infant mortality, those reporting a father will have no increased risk of maternal death while those not reporting a father will have a markedly increased risk. Reported father's information serves as an indicator of male partner's presence in a woman's life. Unfortunately, fathers' data was missing in 2013, therefore it was not used for modeling.
Thus, further studies are encouraged to examine these factors.

Strength
This study contributed to examination of explanatory power of indicators available from the Department of Public Health for assessing risk associated with maternal mortality in state of Georgia. It showed that socio-economic factors such as advanced age, black race, low education, smoking and government insurance and absence of paternity information are associated with increased risk for maternal mortality, and, if not addressed, represent the missed opportunities for preventing maternal deaths and reducing health disparities. Collecting information on the socio-economic in addition to medical factors for every case of maternal death may contribute to Maternal Mortality review and recommendation process in state of Georgia.

Conclusion:
Achieving Healthy People 2020 target of reducing maternal mortality ratio by 10% requires understanding of factors associated with increased risk of maternal deaths, identification of preventable factors and development of strategies to address them. Women's health should be considered as a starting point for improving reproductive outcomes.
In many cases pregnancy is too late to avert poor maternal and feto-infant outcomes, although comprehensive high quality prenatal care is essential. The socio-economic factors such as age, race, education, smoking and insurance status are known before pregnancy. Comprehensive evaluation of a woman's reproductive plan, physical and psychosocial risks, and provision of targeted interventions (e.g., family planning counselling and provision, mental health care, smoking cessation 5A's) should be incorporated in primary care settings to make it available and affordable to all socio-economic groups. Evidence-based interventions exist today to reduce risky behaviors, stress and chronic conditions.
Establishment of a statewide maternal mortality review committee is an important accomplishment by state of GA. In addition to review of medical factors, evaluation of data on socio-economic factors and psychosocial interventions that were or were not implemented (and reason for it) for every case of maternal death can provide valuable insight into social determinants of poor maternal outcomes and development of comprehensive strategies to address them. Further studies are needed to examine extend to which the psychosocial risk reduction avert adverse pregnancy outcomes, including maternal mortality.
The findings in this study can be used by clinicians, public health professionals, Maternal Mortality Review Committee, policy makers and other stakeholders.

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