

THE CALIFORNIA PREGNANCY-ASSOCIATED MORTALITY REVIEW

Report from 2002 to 2007
Maternal Death Reviews

This project was supported by Federal Title V
Maternal Child Health block grant funds received
from the California Department of Public Health;
Center for Family Health; Maternal, Child and
Adolescent Health Division

Spring 2018



TABLE OF CONTENTS

1. Acknowledgements	4
The California Pregnancy–Associated Mortality Review Committee	5
2. Executive Summary	7
3. Background and Methods	10
Methodology	11
Key Definitions.....	12
4. Findings	13
Pregnancy-Associated Deaths, California Residents; 2002-2007	14
Pregnancy-Related Deaths, California Residents; 2002-2007	16
Causes of Pregnancy-Related Deaths, per CA-PAMR Committee	16
Timing of Pregnancy-Related Deaths.....	22
Demographic and Social Characteristics of Women Who Died	23
Coroner Reports and Autopsies	26
Maternal Characteristics of Pregnancy and Delivery.....	27
Medical Risk Factors of Women Who Died.....	31
Social Risk Factors and Racial/Ethnic Disparities.....	33
5. Preventability of Pregnancy-Related Deaths.....	36
Overall Preventability	37
Contributing Factors	38
Quality Improvement Opportunities.....	43
6. Implications and Recommendations	52
1. Continue Maternal Mortality Case Reviews.....	53
2. Improve Data Collection and Analysis.....	54
3. Anticipate More Women Entering Pregnancy with Chronic Health Conditions.....	55
4. Integrate Assessment of Social Factors Impacting Pregnancy	56
5. Address Provider and Facility Factors through Ongoing Maternity Care Quality Improvement	58
7. Translation Activities	60
California Maternal Quality Care Toolkits Informed by CA-PAMR	61
National Initiatives.....	63
8. The Rise and Fall of Maternal Mortality Rates in California	66
What Caused the Rise in Maternal Mortality?	68
What Is Contributing to the Decline in California Maternal Mortality?.....	71
References	77
Appendix: Technical Notes	80

List of Figures

<i>Figure 1: Case Ascertainment of Pregnancy-Related Deaths, CA-PAMR, 2002-2007</i>	14
<i>Figure 2: Causes of Pregnancy-Associated Deaths, per Death Certificate (n=1,059), 2002-2007</i>	15
<i>Figure 3: Classification of Pregnancy-Related Cardiovascular Deaths, CA-PAMR, 2002-2007</i>	18
<i>Figure 4: Timing of Major Causes of Pregnancy-Related Death, CA-PAMR, 2002-2007</i>	22
<i>Figure 5: Age Group Distribution among CA-PAMR Deaths and California Birth Cohort, 2002-2007</i>	24
<i>Figure 6: Racial/Ethnic Distribution among CA-PAMR Deaths and California Birth Cohort, 2002-2007</i>	25
<i>Figure 7: Maternal BMI among CA-PAMR Deaths and California Women Giving Birth, 2002-2007</i>	27
<i>Figure 8: Maternal BMI among Major Causes of Pregnancy-Related Death, CA-PAMR, 2002-2007</i>	28
<i>Figure 9: Chance to Alter Outcome among Pregnancy-Related Deaths, CA-PAMR, 2002-2007</i>	38
<i>Figure 10: Health Care Provider Factors Contributing to Pregnancy-Related Deaths, CA-PAMR, 2002-2007</i>	40
<i>Figure 11: Facility Factors Contributing to Pregnancy-Related Deaths, CA-PAMR, 2002-2007</i>	40
<i>Figure 12: Patient Factors Contributing to Pregnancy-Related Deaths, CA-PAMR, 2002-2007</i>	41
<i>Figure 13: Maternal Mortality Rates, California Residents and U.S., 1999-2008</i>	67
<i>Figure 14: Disparities in Maternal Mortality Rates by Race/Ethnicity, California Residents, 1999-2008</i>	67
<i>Figure 15: Maternal Mortality Rates, California Residents and U.S., 1999-2013</i>	72
<i>Figure 16: Disparities in Maternal Mortality Rates by Race/Ethnicity, California Residents, 1999-2013</i>	73
<i>Figure 17: Early, Late and Total Maternal Mortality, California Residents, 1999-2013</i>	75

List of Tables

<i>Table 1: Clinical Causes of Pregnancy-Related Deaths, per CA-PAMR Committee, 2002-2007</i>	17
<i>Table 2: Pregnancy-Related Mortality Rates by Race/Ethnicity among All Causes of Pregnancy-Related Death, CA-PAMR, 2002-2007</i>	21
<i>Table 3: Demographic Characteristics of CA-PAMR Pregnancy-Related Deaths and California Birth Cohort, 2002-2007</i>	23
<i>Table 4: Maternal Characteristics of Pregnancy and Delivery among Major Causes of Pregnancy-Related Death, CA-PAMR and California Birth Cohort, 2002-2007</i>	30
<i>Table 5: Risk Level, Mode and Circumstances of Delivery among Major Causes of Pregnancy-Related Death, CA-PAMR, 2002-2007</i>	32
<i>Table 6: Social Risk Factors among Pregnancy-Related Deaths, CA-PAMR, 2002-2007</i>	34
<i>Table 7: Mode of Delivery among Pregnancy-Related Deaths, CA-PAMR, 2002-2007</i>	42
<i>Table 8: Prevalence of Maternal Morbidity among California Hospital Deliveries, 2002-2007</i>	69

©2017 California Department of Public Health. The material in this report may be reproduced and disseminated in any media in its original format, without modification, for information, educational, and non-commercial purposes only.

Suggested citation: *The California Pregnancy-Associated Mortality Review. Report from 2002-2007 Maternal Death Reviews*. Sacramento: California Department of Public Health, Maternal, Child and Adolescent Health Division. 2017

1. Acknowledgements

The California Pregnancy-Associated Mortality Review (CA-PAMR) requires the work and support of many people who deserve acknowledgement. The California Department of Public Health (CDPH), and the Maternal, Child and Adolescent Health (MCAH) Division provided leadership to sound the alarm and act to address rising rates of maternal deaths. We thank the following for their leadership: Shabbir Ahmad, DVM, MS, PhD, Chief of MCAH Epidemiology, Surveillance and Federal Reporting Branch, Leslie Kowalewski, Chief of MCAH Division, Connie Mitchell, MD, MPH, Deputy Director of the Center for Family Health, and Karen L. Smith, MD, MPH, Director of CDPH.

We gratefully acknowledge our colleagues who work with national and state maternal mortality review programs for their support and the generous sharing of expertise and resources. We especially thank Cynthia Berg, William Callaghan, David Goodman, Julie Zaharatos, Andria Cornell, and Michael Lu for their assistance. Gwyneth Lewis from the United Kingdom also has been very helpful to our work.

We extend our gratitude to the many doctors, nurses, midwives and other health professionals who have volunteered considerable time and expertise to the CA-PAMR Committee to review the medical records of women who died. The following page lists the names of the Committee members and their affiliation at time of service. Each has shown remarkable dedication and concern for improving the health and health care of mothers in California.

We sadly acknowledge the women who died during or after their pregnancies, the families who love and miss them, and the clinicians who cared for them. Each maternal death in this report represents a woman whose life ended early. This report seeks to honor the memories of these women by improving the experience of expectant mothers everywhere.

Funding for CA-PAMR is provided through the federal Title V Maternal and Child Health (MCH) Block Grant and relies upon the successful partnership of three organizations and their current and former staff:

California Department of Public Health; Maternal, Child, and Adolescent Health (MCAH)

Elizabeth Lawton, MHS, Amina Foda, MPH, Mike Curtis, PhD

California Maternal Quality Care Collaborative (CMQCC)

Elliott Main, MD, Christine Morton, PhD, Jeffrey Gould, MD, MPH

Public Health Institute (PHI)

Sue Holtby, MPH, Christy McCain, MPH, Ann Kristienne McFarland, CNM, NP, RN, Kathleen Green-Barbour, RN, Karene Matterson, RN, Delphina Alvarez

The California Pregnancy–Associated Mortality Review Committee

Current Members

Affiliations at time of California Pregnancy–Associated Mortality Review Committee service

Elliott Main, MD, Chair

California Pacific Medical Center and California Maternal Quality Care Collaborative (Maternal Fetal Medicine)

Deirdre Anglin, MD, MPH

University of Southern California, Keck School of Medicine (Emergency Medicine)

Conrad Chao, MD

University of California, San Francisco, Fresno Medical Education Program, Community Regional Medical Center (Maternal Fetal Medicine)

Maurice Druzin, MD

Stanford University Medical Center, Lucile Packard Children’s Hospital (Maternal Fetal Medicine)

Michael Fassett, MD

Kaiser Permanente West Los Angeles Medical Center and Kaiser Permanente Bakersfield (Maternal Fetal Medicine)

Edward Riley, MD

Stanford University Medical Center, Lucile Packard Children’s Hospital (Anesthesia)

Marla Seacrist, PhD, RNC

California State University, Stanislaus (Obstetric and Neonatal Nursing)

Elyse Foster, MD

University of California, San Francisco, School of Medicine (Cardiology)

Kristi Gabel, RNC, MN, CNS

Regional Perinatal Programs of California, Region 2 (Sacramento) (Obstetric and Neonatal Nursing)

Dodi Gauthier, MEd, RNC

Association of Women’s Health, Obstetric and Neonatal Nurses and Santa Barbara Cottage Hospital (Obstetric and Neonatal Nursing)

Kimberly Gregory, MD, MPH

University of California, Los Angeles, David Geffen School of Medicine and Cedars Sinai Medical Center (Maternal Fetal Medicine)

Larry Shields, MD

Dignity Health, Marian Regional Medical Center, Santa Maria (Maternal Fetal Medicine)

Afshan Hameed, MD, FACOG, FACC

University of California, Irvine, School of Medicine (Cardiology, Maternal Fetal Medicine)

Thomas Kelly, MD

University of California, San Diego School of Medicine (Maternal Fetal Medicine)

Nathana Lurvey, MD

Southbay Family Healthcare Center and ACOG, District IX (Obstetrics and Gynecology)

Natalie Martina, CNM, MSN

Alta Bates Medical Center (Nurse Midwifery)

Barbara Murphy, MSN, RN

Stanford University School of Medicine, California Perinatal Quality Care Collaborative and California Maternal Quality Care Collaborative (Obstetric and Neonatal Nursing)

Larry Newman, MD, FACOG

Kaiser Permanente, Oakland Medical Center (Maternal Fetal Medicine)

Lucy Van Otterloo, PhD, MSN

Community Perinatal Network, Yorba Linda and California State University, Long Beach (Obstetric and Neonatal Nursing)

*Former Members**Affiliations at time of California Pregnancy–Associated Mortality Review Committee service***Lisa Berry, MSN, RNC**

Association of Women’s Health,
Obstetric and Neonatal Nurses
(Obstetric and Neonatal Nursing)

Debra Bingham, DrPH, RN

Stanford University School of
Medicine and California
Maternal Quality Care
Collaborative (Obstetric and
Neonatal Nursing)

**D. Lisa Bollman, MSN, RNC,
CPHQ**

Regional Perinatal Programs of
California Region 6.7, (Whittier)
(Obstetric and Neonatal Nursing)

Sheila E. Cohen, MB.Ch.B, FRCA

Stanford University School of
Medicine, Lucile Packard
Children’s Hospital (Anesthesia)

Patricia Dailey, MD

Anesthesia Care Associates
Medical Group, Burlingame
(Anesthesia)

Katherine Gregory, MD, MPH

ACOG, District IX (Obstetrics and
Gynecology)

Carolina Reyes, MD

University of Southern California
Keck School of Medicine, and Los
Angeles Best Babies (Obstetrics
and Gynecology)

**Linda V. Walsh, CNM, PhD,
FACNM**

University of San Francisco,
School of Nursing (Nurse
Midwifery)

Jeffrey B. Gould, MD, MPH

Stanford University School of
Medicine, California Perinatal
Quality Care Collaborative and
California Maternal Quality Care
Collaborative (Neonatology)

Margaret “Lynn” Yonekura, MD

California Hospital Medical
Center (Obstetrics and
Gynecology)

2. Executive Summary

Maternal deaths are uncommon, yet as sentinel events, serve as a call to action for public health professionals and maternity care clinicians. California observed its maternal mortality rate rise sharply from 8.0 deaths per 100,000 live births in 1999 to 16.9 deaths per 100,000 live births in 2006. This prompted the California Department of Public Health, Maternal, Child, and Adolescent Health Division to invest Title V Maternal and Child Health (MCH) Block Grant funds in a variety of activities to investigate and improve maternity care and maternal health outcomes.

Over 1,000 women died, from all causes, during childbirth or within one year of a live birth or fetal death from 2002 through 2007.

A cornerstone activity to address maternal mortality was the establishment of the California Pregnancy-Associated Mortality Review (CA-PAMR). CA-PAMR is a statewide examination of maternal deaths using enhanced public health surveillance methodology and in-depth medical record review by an expert, multidisciplinary committee of maternity care and public health professionals. The major goals of the project are to identify pregnancy-related deaths, their causes, associated risks, and prevention opportunities, and then recommend improvements in the quality of maternity care and public health programs and surveillance.

This report presents comprehensive and detailed findings of maternal deaths, with an emphasis on the seven leading causes of pregnancy-related deaths in California. Over 1,000 women died, from all causes, during childbirth or within one year of a live birth or fetal death from 2002 through 2007. Of these, the Committee determined that 333 deaths were pregnancy-related, defined as a death directly related to physiologic changes of pregnancy or from causes aggravated by the pregnancy or its management.

Key findings from the CA-PAMR investigation include:

- Cardiovascular disease was the leading cause of pregnancy-related death. Prior to the CA-PAMR review, and relying on death certificates alone, preeclampsia would have been identified as the leading cause of pregnancy-related death.
- Racial disparities persist. CA-PAMR confirmed that African-American women continue to die at three-to-four times the maternal mortality rate of women of other racial/ethnicities groups, and as high as eight times the rate when deaths from pregnancy-related cardiovascular disease is considered.
- In most cases, multiple patient, facility, and health care provider factors contributed to the pregnancy-related deaths. Common factors included co-morbidities, especially obesity and hypertension, delayed recognition of and response to clinical warning signs, and a lack of institutional readiness for obstetric emergencies.

- Forty-one percent of the pregnancy-related deaths had a good-to-strong chance of preventability.

The major recommendations arising from this in-depth examination are:

- Improvements in public health data collection used in maternal mortality case review will enhance California's ability to monitor maternal mortality and develop evidence-based recommendations to prevent its occurrence.
- Providers of maternity care and reproductive health counseling need to be vigilant about women entering pregnancy with chronic health conditions, including obesity, and in helping them to attain optimal health by the time of pregnancy.
- Social and economic factors need to be taken into account when evaluating effective care and in anticipating the health needs of pregnant and postpartum women.
- Clinicians caring for African-American women need to have a heightened sense of awareness of risk factors among this group, such as potential cardiovascular symptoms or obesity.
- Quality improvement opportunities for both providers and hospital facilities were identified, including implementation of standardized protocols, effective planning and better communication, and appropriate use of obstetric procedures, e.g., labor induction and cesarean sections.
- Better communication and coordination within and across hospital departments where pregnant and postpartum women seek care, especially between emergency and obstetric departments, is necessary.

CA-PAMR was designed to inform and translate findings into strategies to reduce preventable maternal mortality and morbidity. The six years of CA-PAMR case review have informed the development of a series of California Maternity Quality Improvement Toolkits to assist and guide maternity clinicians and birth facilities to improve their readiness, recognition, and response to preventable causes of maternal mortality and morbidity. Four toolkits focusing on obstetric hemorrhage, preeclampsia, cardiovascular disease, and venous thromboembolism have been released and implemented at more than 150 hospitals in California.

After investigating maternal deaths occurring from 2002 through 2007, the rise from 1999 to 2006 was largely attributable to three factors:

- 1) Better documentation of maternal deaths on the death certificate
- 2) Women entering pregnancy at an older age and with a greater incidence of chronic conditions and significant social risk factors
- 3) Significant need for improvement in clinician and facility readiness to respond to certain obstetric complications

Since 2008, California has experienced an impressive decline in maternal mortality to a low of 7.3 deaths per 100,000 live births in 2013 from the high of 16.9 deaths per 100,000 live births in 2006. This is in stark contrast to the nation where maternal mortality rates are triple those of California and appear to be increasing. The decline in maternal mortality in California likely reflects the collective impact of public health investments in maternal health programs and enhanced surveillance coupled with strong engagement and leadership among California maternity care hospitals, providers, insurers, and advocacy organizations to implement quality improvement initiatives.

California is committed to maintaining the momentum toward improved maternal health outcomes for California women and their families, which includes maternal mortality review. The findings can be applied to known areas for improvement, such as preeclampsia, as well as to respond to other areas of need, such as maternal suicides and mental health issues among pregnant and postpartum women. Improvements in the timeliness of mortality reviews are needed so that the prevalence of potential pregnancy-related deaths from specific infectious causes (e.g., Zika) and emerging issues such as the current opioid addiction epidemic, can be monitored and addressed. Finally, while California has seen declines in maternal deaths up to 42 days postpartum, public health needs to better understand and address the concerning rise in maternal deaths occurring later in the late postpartum period (between 43 and 365 days). This may be a national phenomenon deserving of routine monitoring for all states.

I experienced postpartum hemorrhage and emergency hysterectomy after the birth of my second child. In medical terms this is called a near miss... For me, this 'near miss' was an emotional, physical and spiritual ordeal, which tore my life and body apart—symbolically and literally—for months and years afterward. What happened to me is a tragedy.

- A California mom

BACKGROUND AND METHODS

California views maternal deaths as sentinel events, which need to be thoroughly investigated. There are two goals for state reviews of maternal death.

The first is surveillance, to monitor the population's health. The second is to use the results to inform quality improvement.

The critical lessons and recommendations from this review have been applied to improvements in population health, clinical care and health care policy for California's women and their families.

Karen L. Smith, MD, MPH

Director and State Public Health Officer
California Department of Public Health



3. Background and Methods

Aims and Objectives of the California Pregnancy-Associated Mortality Review

The California Pregnancy-Associated Mortality Review started in 2006 to identify possible reasons for the rise in maternal mortality, increase in racial/ethnic disparities, and to develop evidence-informed clinical, policy and programmatic interventions.

Methodology

- Data sources, case ascertainment methodology and confidentiality are described in detail in the Appendix: Technical Notes and in the previous CA-PAMR report (2011).¹
- The CA-PAMR Committee (the Committee) is a multidisciplinary group comprised of experts in nursing, obstetrics, maternal-fetal medicine, midwifery, cardiology, anesthesiology, emergency medicine, public health, and sociology. Committee members reviewed de-identified case summaries with detailed synopses of available hospital and outpatient medical records from the prenatal period up to the death, as well as autopsy and coroner reports.
- For each case, the Committee determined via consensus whether the death was pregnancy-related, causes of death, contributing factors, chance to alter outcome and opportunities for quality improvement.
 - **Causes of death** were categorized into 12 diagnosis groups, one of which was “other.” These categories mirror those used by the Centers for Disease Control and Prevention and the United Kingdom (UK) Confidential Enquiry to allow for external comparisons.^{2,3} In cases with two or more major diagnoses, the Committee selected the diagnosis group based on the underlying disease process that initiated the series of clinical events that initiated the cascade toward death.
 - **Contributing factors** fell into the following three categories: provider, facility, and patient. Healthcare provider factors include actions involving diagnosis, treatment, and communication processes. Facility factors include systems-level processes involving policies, nursing knowledge, or infrastructure. Patient factors include circumstances, risk factors or health behaviors contributing to the cause of death.
 - **Preventability**, or the chance to alter the fatal outcome, was categorized as 1) strong, 2) good, 3) some, or 4) none. A case was considered to have a strong or good chance to alter the outcome when specific and feasible actions, if implemented, might have changed the course of the woman’s disease trajectory and potentially prevented the death.
 - **Quality improvement opportunities**, defined as alternative approaches to recognition, diagnosis, treatment or follow-up, which, if implemented, may have led to better patient care or a better outcome.

KEY DEFINITIONS

Pregnancy-related death

A **pregnancy-related death** is from causes directly related to physiologic changes of pregnancy (direct obstetrical death) or from causes aggravated by the pregnancy or its management (indirect obstetrical death). If a woman dies while pregnant or within one year of termination of a pregnancy from causes unrelated to pregnancy or its management (e.g., injuries or complications of other conditions) then the death is defined as **not-pregnancy-related**. When pregnancy-related deaths and not-pregnancy-related deaths are combined, the whole group is referred to as **pregnancy-associated deaths**.

Note: Deaths of women who were less than 20 weeks pregnant were not included because a fetal death certificate is usually not issued unless the fetal loss occurs after 20 weeks, compromising the ability to perform the birth/death data linkage used to identify cases.

Maternal mortality rate

The **maternal mortality rate** is derived from death and birth certificate data and is defined as the number of women who die from a pregnancy-related cause within 42 days postpartum (numerator) divided by the number of live births in that year (denominator) multiplied by 100,000. See Technical Notes for specific codes included in the numerator.

Note: This measure is sometimes referred to as the *maternal mortality ratio*.

Pregnancy-related mortality rate

The **pregnancy-related mortality rate** is defined as the number of women who die from a pregnancy-related cause up to one year postpartum (numerator) divided by the number of live births in that year (denominator) multiplied by 100,000. Therefore, the difference between maternal mortality and pregnancy-related mortality rates is the time period for inclusion (deaths up to 42 days postpartum versus deaths up to one year postpartum).

Note: The CDC uses the following definition of pregnancy-related mortality: The death of a woman while pregnant or within one year of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by her pregnancy or its management, but not from accidental or incidental causes.

FINDINGS

As we reviewed these tragic cases, we grieved women's deaths, and for the ongoing impact of this loss on their loved ones, their communities and California. We also vowed to act on these findings to improve maternal care for all women, by strengthening clinical practices and public health programs, and sustaining those improvements into the future.

Kristi Gabel, RNC, MN, CNS

Regional Perinatal Programs of California

Region 2, Sacramento

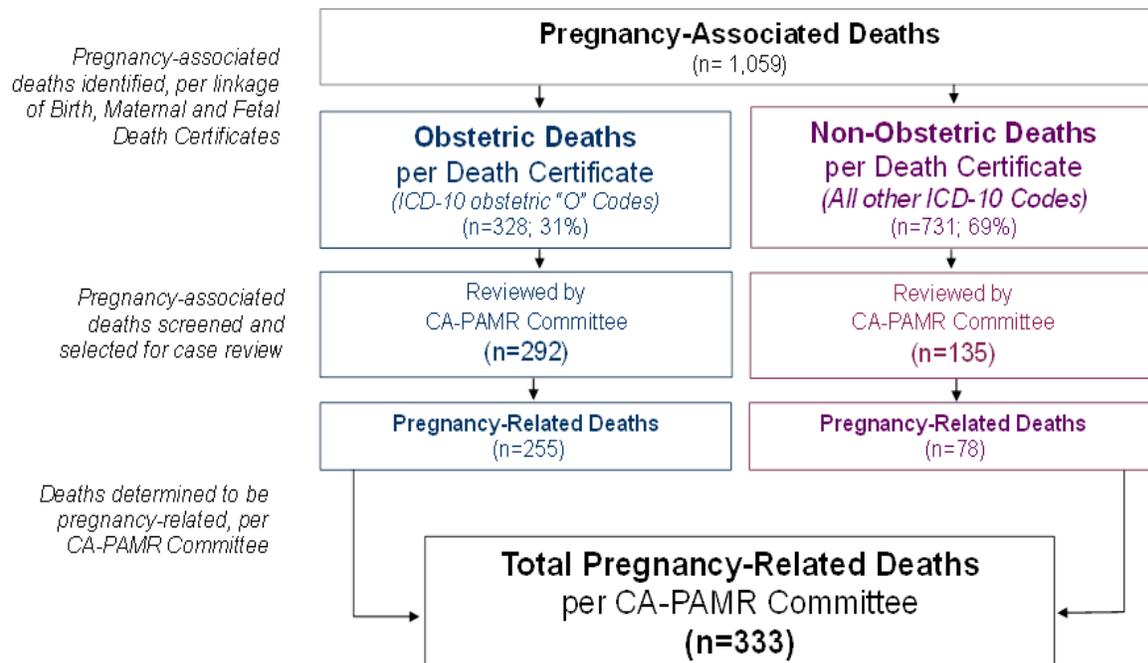


4. Findings

Pregnancy-Associated Deaths, California Residents; 2002-2007

There were 3,310,485 live births in California during this time period (approximately 12% of all U.S. births) and 1,059 of these were identified as pregnancy-associated deaths (i.e., death of a woman while pregnant or within one year of the end of pregnancy, from any cause). All pregnancy-associated deaths were screened using a team-developed algorithm to identify likely pregnancy-related deaths (i.e., either directly related to pregnancy or aggravated by the pregnancy management) that would then be selected for case review. The algorithm scanned for timing of death, the underlying cause of death on the death certificate and additional medical information from text fields on the death certificate (e.g., multiple cause of death, recent surgeries, or notes) or from coroner reports. Of these, 427 received full review by the CA-PAMR Committee to determine if the death was pregnancy-related and to learn about possible preventability or other contributors to the fatal outcome. The Committee determined that 333 (78%) of 427 deaths reviewed were determined to be pregnancy-related (Figure 1).

Figure 1: Case Ascertainment of Pregnancy-Related Deaths, CA-PAMR, 2002-2007



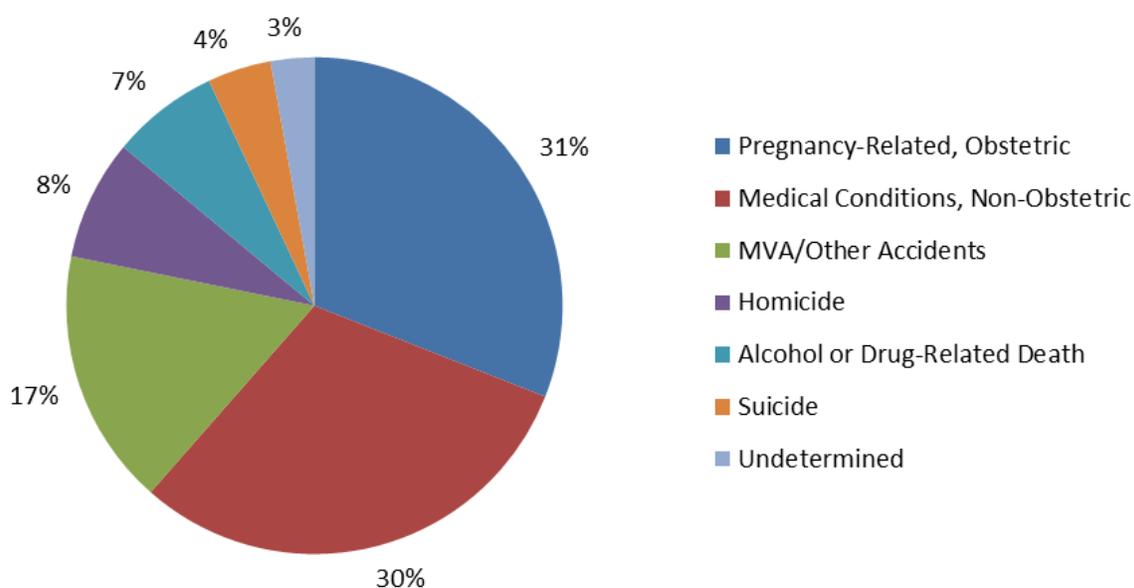
Approximately one-third of the pregnancy-associated deaths using death certificate data (prior to CA-PAMR review) were from obstetric causes, e.g., had an International Classification of Disease, 10th revision (ICD-10) code on the death certificate from the obstetric chapter and which were designated by an 'O' prefix before the specific disease code (referred to as "O codes" hereafter). See the Technical Notes for a listing of specific O codes. Another third were reported on the death certificate as non-

obstetric, medical causes, with the remaining deaths from violent or accidental causes (Figure 2). The ICD-10 codes used to group causes of death are specified in the Technical Notes.

Among the non-obstetric deaths (n=731), the leading causes of death as reported on the death certificate were:

- Other medical conditions (30%)
- Motor vehicle and other non-obstetric accidental deaths (17%)
- Homicide (8%)
- Alcohol and other drug-related causes (7%)
- Suicide (4%)
- Undetermined (3%)

Figure 2: Causes of Pregnancy-Associated Deaths, per Death Certificate (n=1,059), 2002-2007



Among the obstetric-related deaths (n= 328) O-codes, two-thirds (66%) of the causes of death were largely non-specific and were categorized as “other direct obstetric,” “other unspecified obstetric,” “other indirect obstetric,” or “other complications pertaining to the pregnancy and puerperium.” Among the remaining obstetric deaths (n=112), as reported on the death certificate, the leading causes of death were:

- Preeclampsia/eclampsia (12.5%)
- Obstetric hemorrhage (9%)
- Amniotic fluid embolism (6%)
- Cardiovascular disease (5%)

- Sepsis/infection (1.5%)
- Liver-related (0.9%)

Pregnancy-Related Deaths, California Residents; 2002-2007

Of 427 cases reviewed, 333 deaths were determined to be pregnancy-related per CA-PAMR methodology. The next section of this report provides information on maternal and pregnancy characteristics, risk factors, and autopsy results of these pregnancy-related deaths. Key differences are highlighted in Tables 2, 3, and 5, with statistically significant differences noted.

Causes of Pregnancy-Related Deaths, per CA-PAMR Committee

The leading cause of pregnancy-related death among women in California from 2002-2007 was changed after Committee review, from preeclampsia as the leading cause based on death certificate data to cardiovascular disease (CVD) after in-depth review. Table 1 shows that over one quarter (26%) of women died of CVD, with 15% due to cardiomyopathy [diseases of the heart muscle] and 11% due to other cardiovascular causes. Preeclampsia/eclampsia and postpartum obstetric hemorrhage were the second and third leading causes of death in this period, accounting for 16% and 10% of the deaths,

After in-depth Committee review, the leading cause of pregnancy-related death was cardiovascular disease (26%).

respectively. Venous thromboembolism (VTE) [the formation of a blood clot in a deep vein, also referred to as deep vein thrombosis (DVT)] and pulmonary embolism [a blood clot in the lungs (PE)] accounted for 9% of the pregnancy-related deaths. Cerebrovascular accident (CVA) and sepsis accounted 8% each of the pregnancy-related deaths, followed by amniotic fluid embolism (7%). Deaths due to complications from anesthesia, cancer,

drug use complications and acute fatty liver each accounted for less than 2%. Other causes accounted for the remaining 10% of pregnancy-related deaths; these included deaths related to respiratory (pulmonary) disease such as a pneumonia or aspiration (n=9); internal hemorrhage due to splenic or renal artery ruptures (n=7); auto-immune disorder (e.g., systemic lupus erythematosus); iatrogenic causes (n=4); thrombotic disease (thrombocytopenia) (n=4); metabolic diseases such as diabetes or thyroid storm (n=3), and; three other undetermined causes.

Table 1 also demonstrates the benefit of in-depth medical record review by a committee of experts, and the degree to which the sole use of O-codes can misrepresent the number of maternal deaths. Based on death certificate O-codes alone, we would have missed a total of 78 pregnancy-related deaths. Cardiovascular deaths, in particular, were often not coded with an obstetric code (34 of the 87 CVD deaths lacked this coding). These coding issues could have implications in terms of racial/ethnic distributions of pregnancy-related deaths because over a third (35% or 25/71) of the African-American deaths were classified as non-O-codes. Thus, the already disturbingly wide racial/ethnic disparity is most likely even *greater* after including these miscoded deaths. In contrast, 27% percent of the non-O-Code pregnancy-related deaths were among White women and 16% among Hispanics.

Table 1: Clinical Causes of Pregnancy-Related Deaths, per CA-PAMR Committee, 2002-2007

Cause of Death after CA-PAMR Review	Total Pregnancy-Related Deaths N (%)	Original ICD-10 Code on Death Certificate	
		ICD-10 Obstetric “O” Codes N (%)	ICD-10 Non-“O” Codes N (%)
Cardiovascular disease	87 (26%)	53 (21%)	34 (44%)
<i>Cardiomyopathy</i>	51 (15%)	25 (10%)	26 (33%)
<i>Other cardiovascular</i>	36 (11%)	28 (11%)	8 (10%)
Preeclampsia/eclampsia	54 (16%)	48 (19%)	6 (8%)
Obstetric hemorrhage	33 (10%)	33 (13%)	0
Venous thromboembolism	29 (9%)	22 (9%)	7 (9%)
Sepsis	27 (8%)	25 (10%)	2 (3%)
Cerebrovascular accident	26 (8%)	15 (6%)	11 (14%)
Amniotic fluid embolism	24 (7%)	24 (9%)	0
Anesthesia complications	6 (2%)	3 (1%)	3 (4%)
Cancer (diagnosis or treatment de- layed by pregnancy)	5 (1.5%)	4 (2%)	1 (1%)
Drug abuse complications	4 (1%)	1 (.4%)	3 (4%)
Acute fatty liver	4 (1%)	3 (1%)	1 (1%)
All other causes	34 (10%)	24 (9%)	10 (13%)
Total	333	255	78

Note: Suicides were not included in this table even though some may be pregnancy-related.

Miscoding, however, occurred in both directions. Of the O-codes in the pregnancy-associated cohort (n=328), 90 (26%) were not pregnancy-related (55 were excluded from review after screening and 35 were reviewed and deemed not pregnancy-related). The Committee was unable to determine pregnancy-relatedness in two cases.

Cardiovascular Disease

Cardiovascular disease (CVD) in pregnancy accounted for 26% (N=87) of maternal deaths in CA-PAMR from 2002 through 2007, with a rate of 2.6 maternal deaths per 100,000 live births--the highest among all causes of death. Fifty-one women (59%) died from cardiomyopathy (CMP) and the remaining deaths

were from other types of cardiovascular disease. Cardiomyopathies and other cardiovascular conditions were further classified by subtype as shown in Figure 3 using previously published criteria.⁴

Figure 3: Classification of Pregnancy-Related Cardiovascular Deaths, CA-PAMR, 2002-2007

	CVD Classification	Sub-Classifications		
Cardiovascular Pregnancy- Related Deaths N=87	Cardiomyopathy N=51	Dilated Cardiomyopathy N=36	Peripartum CMP (N=16)	
			Non-Peripartum CMP (N=13)	Alcohol or drugs (N=7)
				Myocarditis (N=1)
		Familial (N=1)		
		Unknown etiology (N=4)		
		Subtype could not be determined (N=7)		
		Hypertrophic Heart Disease N=12	Primary (N=2)	
			Secondary (N=6)	Hypertension (N=3)
				Drug use (N=2)
		Etiology could not be determined (N=4)	Valvular disease (N=1)	
	Unable to classify N = 3			
	Other Cardiovascular N=36	Pulmonary Hypertension (N=10)		
		Aortic Dissection (N=7)		
		Coronary Artery Disease (N=5)		
		Unexplained Sudden Death (N=4)		
Non-Valvular, Congenital (N=4)				
Valvular Disease (N=3)				
Other (N=3)				

Preeclampsia/Eclampsia

Preeclampsia/eclampsia (PRE) accounted for 16% (N=54) of all pregnancy-related deaths, and the overall pregnancy-related mortality rate was 1.6 deaths per 100,000 live births. Technically, women do not die of preeclampsia but of its complications, such as intracranial hemorrhage (stroke) or organ failure. Nonetheless, preeclampsia is a major classification in most maternal mortality reviews.

- The majority of preeclampsia/eclampsia deaths were the result of a stroke (31 hemorrhagic, two thrombotic).
- Other root causes of preeclamptic deaths included hepatic failure (n=7), cardiac failure (n=4), multiorgan failure (n=3), pulmonary edema (n=3), eclampsia (n=2), respiratory failure (n=1) and hemorrhage/disseminated intravascular coagulation (n=1).

Hypertension across the pregnancy-related cohort

Even though there were 54 deaths attributed to preeclampsia/eclampsia, almost 40% (N=21) of all of the women who died of any cause had hypertension documented in their medical record at some point during their care. Notably, 41% of the cardiomyopathy deaths, 41% of the “other” causes of

death, 35% of the cerebrovascular deaths, 24% of the venous thromboembolic deaths and 21% of the amniotic fluid embolism deaths had coexisting hypertensive disorders. Overall, the prevalence of hypertension was much higher among the group of maternal deaths compared to the cohort of women who gave birth in California during the same time, where prevalence of any hypertension ranged from 5.85 in 2002 to 6.6% in 2007.⁵

Obstetric Hemorrhage

Obstetric (or postpartum) hemorrhage (HEM) accounted for 10% (N=33) of all pregnancy-related deaths, and the overall pregnancy-related mortality rate was 0.8. Among the 33 hemorrhage deaths, the root causes were uterine atony in 14 cases (including two with retained placenta), placental issues (accreta/percreta) in 11 cases, uterine rupture in 5 cases, and surgical complications in 3 cases.

While the Committee determined that 33 (10%) of all the pregnancy-related deaths from 2002 through 2007 should be classified as obstetric hemorrhage, there were an additional 36 cases in which hemorrhage was a contributing cause of the death, for a total of 69 cases (21% of pregnancy-related deaths) where large amounts of blood products were transfused. For example, among the 24 cases grouped as amniotic fluid embolism, 17 (71%) involved extensive hemorrhage as a co-morbid issue. Severe hemorrhage was an important complication among other causes of death, including acute fatty liver, preeclampsia and sepsis.

Venous Thromboembolism

Venous thromboembolism (VTE) is the formation of a blood clot in a deep vein, also referred to as deep vein thrombosis, and includes a very serious complication, pulmonary embolism. Elevated Body Mass Index (BMI) was a risk factor and 64% of those who experienced a VTE were obese, the highest proportion among all causes of death. Furthermore, 25% of the women who died of VTE had BMIs of over 40. Five of the seven African-American women who died of VTE BMI>40 (mean BMI among African Americans who died of VTE was 48, compared to 35 among Whites and 30 among all Hispanic). Just over one quarter (26%) of the women who delivered and died of VTE had a vaginal birth (n=7), and 74% had a cesarean, primarily scheduled or unplanned during labor, and surgery is a known risk factor for VTE.

Pregnancy-Related Deaths in CA-PAMR from 2002-2007

- **26% of maternal deaths were attributed to cardiovascular disease.**
- **Almost 40% of all women who died of any cause had hypertension noted in their medical record.**
- **64% of women who experienced a venous thromboembolism were obese.**
- **16% were attributed to preeclampsia/eclampsia.**
- **10% were attributed to obstetric hemorrhage.**
- **9% were attributed to sepsis.**
- **8% were attributed to cerebral vascular accidents.**
- **7% were attributed to amniotic fluid embolisms.**

Sepsis

Sepsis (SEP), or systemic infection, accounted for 9% (N=27) of all pregnancy-related deaths, and the overall pregnancy-related mortality rate was 0.8. Root causes of the sepsis deaths were diverse, with endometritis being the most common, accounting for six (22%) of the cases. Other causes included episiotomy (n=5), peritonitis (n=3), and necrosis (necrotizing fasciitis; placental (n=2); colon (n=1)). Infections such as chorioamnionitis, coccidiomycosis, pyelonephritis, accounted for two cases each, and cryptococcal meningitis, Group A Streptococcus; pelvic inflammatory disease and villitis (infection of the chorionic villi) accounted for one case each.

Cerebral Vascular Accidents

Cerebral vascular accidents (CVA) accounted for 8% (N=24) of all pregnancy-related deaths. Among the 24 CVA deaths, 21 were due to intracranial hemorrhage; these were caused by an aneurysm in 13 (50%) of the cases, arteriovenous malformation in two cases, and eclampsia/preeclampsia in three cases, and one each due to medication, a tumor or unable to determine. The remaining five cases were due to thromboses, with one caused by vasculitis, three by venous sinus thrombosis and one undetermined.

Stroke is an adverse outcome seen among multiple causes of death. In addition to the 24 women whose grouped cause of death was cerebrovascular accident, 33 women also experienced some kind of stroke (intracranial hemorrhage, subarachnoid hemorrhage, ischemic stroke): 30 were among preeclampsia/eclampsia deaths and one each were among cardiomyopathy, cancer, and “other” causes. A 2011 study noted that the rate of pregnancy-related hospitalizations with stroke in the United States has been increasing.⁶ The authors hypothesized that the increase could be attributable to the increase of patients with heart disease and hypertensive disorders. CA-PAMR data show that 61% of the women who died of hypertensive disorders also suffered a stroke, whereas only one woman who died of heart disease also had a stroke.

Amniotic Fluid Embolism

Amniotic fluid embolisms (AFE) accounted for 7% (N=23) of all pregnancy-related deaths. Although 71% of the AFE deaths were deemed in part preventable, these were all determined to have some chance to alter the outcome, and none were thought to have a strong-to-good chance. Twenty-nine percent of the AFE deaths were determined to have no chance to be prevented.

Table 2: Pregnancy-Related Mortality Rates by Race/Ethnicity among All Causes of Pregnancy-Related Death, CA-PAMR, 2002-2007

Cause of Death																	
Race / Ethnicity	Cardiovascular Disease		Preeclampsia/Eclampsia		Obstetric Hemorrhage		Venous Thromboembolism		Sepsis		Cerebrovascular accident		Amniotic Fluid Embolism		Other Causes		All Causes of Death
	N	Rate ¹ (95% CI)	N	Rate (95% CI)	N	Rate (95% CI)	N	Rate (95% CI)	N	Rate (95% CI)	N	Rate (95% CI)	N	Rate (95% CI)	N	Rate (95% CI)	Rate (95% CI)
Hispanic	30	1.8 (1.1,2.4)	33	2.0 (1.3,2.6)	20	1.2 (0.7,1.7)	14	0.8 (0.4, 1.3)	13	0.8 (0.4,1.2)	10	0.6 (0.2, 1.0)	7	0.4 (0.1, 0.7)	24	1.4 (0.9,2.0)	8.9 (7.5, 10.4)
Foreign-Born	15	1.4 (0.7,2.1)	24	2.3 (1.4, 3.2)	11	1.0 (0.4, 1.7)	6	0.6 (0.1, 1.1)	5	0.5 (0.1,0.9)	6	0.6 (0.1, 1.0)	6	0.6 (0.1, 1.1)	11	1.0 (0.4,1.7)	8.0 (6.3, 9.7)
U.S.-Born	15	2.4 (1.2,3.5)	9	1.4 (0.5, 2.3)	9	1.4 (0.5, 2.3)	8	1.3 (0.4, 2.1)	8	1.3 (0.4,2.1)	4	--	1	--	13	2.0 (0.9, 3.1)	10.5 (8.0, 13.0)
White	22	2.3 (1.3,3.3)	13	1.4 (0.6, 2.1)	7	0.7 (0.2, 1.3)	7	0.7 (0.2, 1.3)	6	0.6 (0.1,1.1)	4	--	5	0.5 (0.1, 1.0)	17	1.8 (0.9,2.6)	8.5 (6.7, 10.4)
Black	31	17.4* (11.3, 23.6)	6	3.4 (0.7, 6.1)	4	--	7	3.9 (1.0, 6.9)	2	--	4	--	7	3.9** (1.0, 6.9)	10	5.6*** (2.1,9.1)	39.9* (30.6, 49.2)
Other	4	--	2	--	2	--	1	--	6	1.3 (0.2, 2.2)	8	1.6 (0.5, 2.8)	5	1.1 (0.1, 1.9)	2	--	6.1 (3.9, 8.3)
All Pregnancy- Related Deaths	87	2.63 (2.1,3.2)	54	1.6 (1.2,2.1)	33	1.0 (0.7,1.3)	29	0.9 (0.6, 1.2)	27	0.8 (0.5,1.1)	26	0.8 (0.5, 1.1)	24	0.7 (0.4, 1.0)	53	1.6 (1.2,2.0)	10.1 (9.0,11.1)

CI, confidence interval.

Rates for less than five deaths were not calculated because the rates are unreliable, confidence intervals are very wide, and both are easily influenced by a small change in death counts.

¹ Number of pregnancy-related deaths per CA-PAMR Committee (2002-2007) divided by the total number of live births in California per Birth Statistical Master File (2002-2007) multiplied by 100,000. Limited to live births among women with known race/ethnicity (N=3,308,102).

* PRMR significantly higher than all other racial/ethnic groups.

**PRMR significantly higher than Hispanic women.

*** PRMR significantly higher than Hispanic women and women of other race/ethnicity.

Timing of Pregnancy-Related Deaths

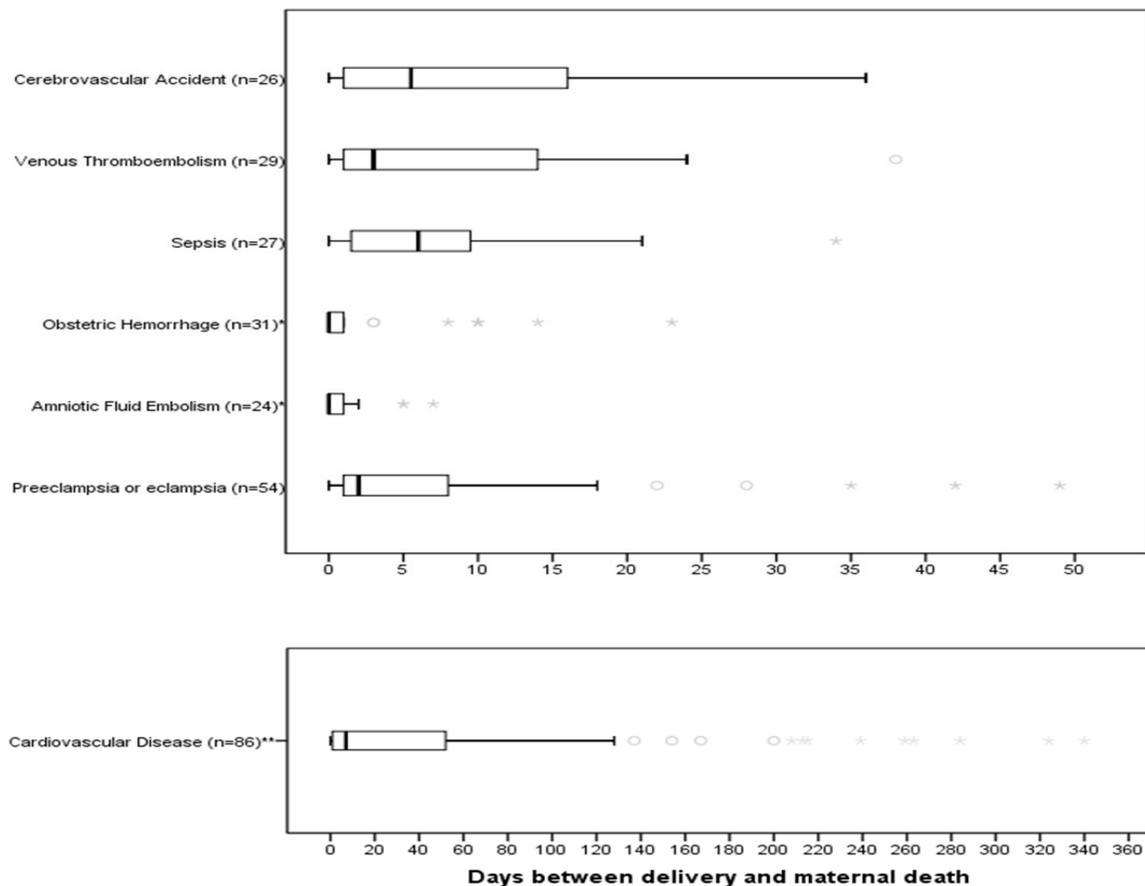
Of the women who died of pregnancy-related causes in California:

- 5% were pregnant at the time of death,
- 83% died between 0 and 42 days from delivery, and
- 12% died between 43 and 365 days postpartum.

The mean timing of death was 21.3 days postpartum.

Figure 4 shows timing of maternal death by major causes. Deaths from AFE (median 0 days; range 0,7) and obstetric hemorrhage (median 0 days; range 0,23) occurred significantly closer to the time of birth than deaths caused by sepsis (median 6 days; range 0,122), CVA (median 5.5 days; range 0,36), VTE (median 3 days; range 0,255), and CVD (median 7 days; range 0,340). Cardiovascular deaths occurred significantly further from delivery than amniotic fluid embolism, hemorrhage and preeclampsia/eclampsia ($p < .01$).

Figure 4: Timing of Major Causes of Pregnancy-Related Death, CA-PAMR, 2002-2007



Demographic and Social Characteristics of Women Who Died

Table 3 shows the distribution of demographic characteristics among the women who died from pregnancy-related causes and women who gave birth in California in 2002-2007.

Table 3: Demographic Characteristics of CA-PAMR Pregnancy-Related Deaths and California Birth Cohort, 2002-2007

	Pregnancy-Related Deaths ¹ , N (%)	California Birth Cohort ² , N (%)
Age (years)		
Younger than 20	16 (5%)*	311,682 (9%)
20-24	56 (17%)*	757,791 (23%)
25-29	69 (21%)*	865,844 (26%)
30-34	87 (26%)	806,364 (24%)
35-39	71 (21%)*	451,918 (14%)
40 and older	34 (10%)*	116,018 (4%)
Missing	~	868 (0%)
Race		
White, non-Hispanic	81 (24%)	948,744 (29%)
Hispanic	151 (45%)*	1,690,129 (51%) ³
U.S.-born Hispanic	67 (20%)	637,350 (19%)
Foreign-born Hispanic	84 (25%)*	1,051,927 (32%)
African American	71 (21%)*	177,796 (5%)
Asian/ Pacific Islander	28 (8%)	390,572 (12%)
Native American	2 (<1%)*	12,371 (0%)
Other/Unknown/Missing	~	90,873 (3%)
Payer Source		
Medi-Cal or other government program	193 (58%)*	1,564,874 (47%)
Private HMO/PPO	124 (37%)	1,622,765 (49%)
Other/Unknown/Uninsured	16 (5%)	122,846 (4%)
Education		
Less than High School	94 (28%)*	345,929 (10%)
High School/up to 12 th grade	106 (32%)*	1,465,010 (44%)
Some Secondary	113 (34%)*	1,407,259 (43%)
Unknown	20 (6%)*	92,287 (3%)
Total	333	3,310,485

¹ Per CA-PAMR Committee

² From California Birth Cohort file; includes live births and fetal deaths

³ Data were missing for 852 Hispanic women, thus the total Hispanic population exceeds the sum of the subcategories.

⁴ Data source Maternal and Infant Health Assessment (MIHA). See Technical Notes for description of MIHA.

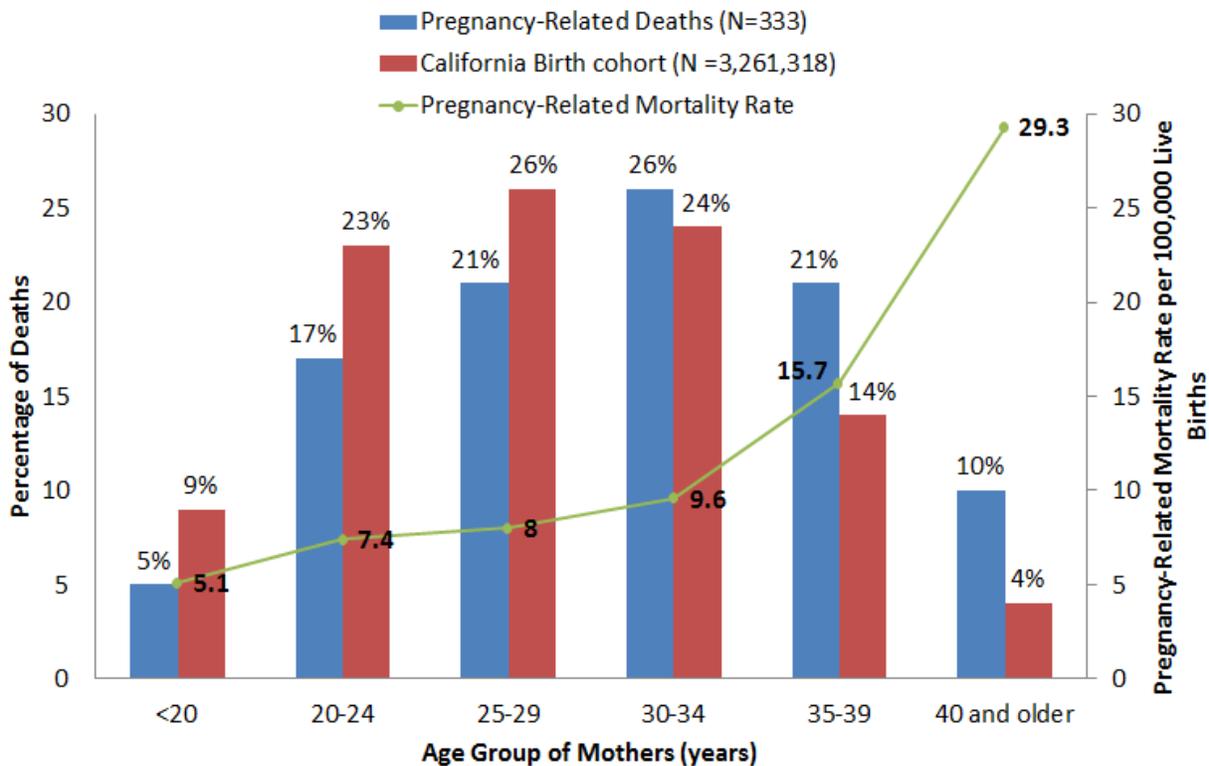
*Proportion differs significantly from California Birth Cohort ($p < .05$) or MIHA.

Age

Women who died from pregnancy-related causes were older than the California birthing population. Women who died were less likely than California women to have been younger than 25 years (22% versus 32%), and more likely to be 35 and older (31% vs. 18% respectively) ($p < .05$), with an overall mean age of 31 years at death. There were no significant age differences among women of different racial/ethnic groups.

Figure 5 shows the proportion of pregnancy-related deaths and births within each age group (red and blue bars) and the green line shows the pregnancy-related mortality rate (the number of deaths divided by the total number of California live births multiplied by 100,000) for each age group. While the rate of pregnancy-related mortality is *higher* among women aged 40 and over (29.3 deaths per 100,000 live births), the greatest *number* of pregnancy-related deaths occurred among women aged 30-34 (26%). There were no significant differences in mean age by major cause of death (Table 4).

Figure 5: Age Group Distribution among CA-PAMR Deaths and California Birth Cohort, 2002-2007

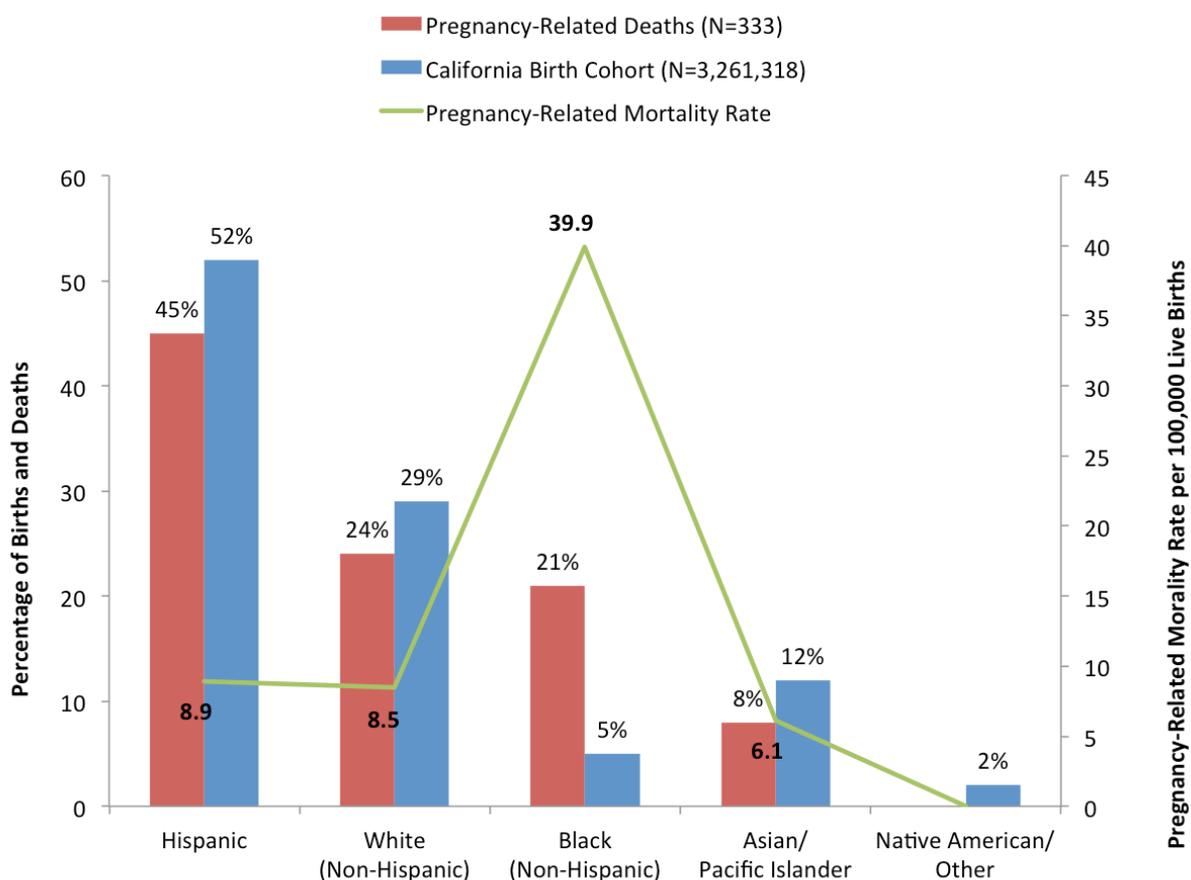


Race/Ethnicity

Figure 6 shows that racial/ethnic disparities persist among pregnancy-related deaths. Only 5% of California births are to African-American women and yet they comprise 21% of the pregnancy-related deaths. Hispanic women, despite representing the largest proportion of deaths overall, had lower proportions of maternal deaths compared to births (45% vs. 52% respectively). One quarter (25%) of

the pregnancy-related deaths were among foreign-born Hispanic women, although this group comprises 32% of births, while among U.S.-born Hispanic women, the proportion of deaths is similar to the proportion of births. The green line in the figure shows the wide disparity in pregnancy-related mortality rates by race/ethnicity, with the pregnancy-related mortality rate among Black women four times as high as that of any other racial/ethnic group ($p < .05$).

Figure 6: Racial/Ethnic Distribution among CA-PAMR Deaths and California Birth Cohort, 2002-2007



Payer Source

Medi-Cal was the payer source at the time of childbirth for almost half of the women in California (49%) but a greater proportion of the pregnancy-related deaths were among Medi-Cal recipients (58%) ($p < .001$) (Table 3). Using payer source data as a proxy for income status, this disparity indicates that pregnancy-related deaths occurred among women who were, on average, poorer than the average woman giving birth in California. Hispanic and African-American women had higher rates of Medi-Cal utilization compared to Asian/Pacific Islander women (69% and 65% vs. 32%, respectively; $p < .001$), while White women (52%) did not significantly differ from other groups (data not shown).

Education

The proportion of women without a high school diploma was significantly higher among those who died compared to the California birth cohort (28% vs. 10% respectively). Foreign-born Hispanic women represented the largest proportion of all pregnancy-related deaths (25%) and were less likely than any other racial/ethnic group to have completed high school ($p < .05$) (Table 3).

Occupation

Most (62%) of the women who died were employed at the time of death. Fourteen percent worked as managers or in a professional setting (e.g., doctors, business executives, professors, teachers, nurses, pharmacists, lawyers, accountants, etc.), 18% worked in clerical, sales or administrative support jobs (e.g. clerical work, retail sales), 19% worked in service occupations (e.g. restaurant workers, cosmetologists, customer service representatives, child care providers, tourism, etc.), 5% were students, and 5% worked as laborers in either agriculture or construction. There was one soldier in the U.S. Army and two artists.

Fetal and Infant Deaths

Among the 333 pregnancy-related deaths, there were 293 live births (including nine sets of twins) and 49 fetal demises (14.7%). Eighteen women died prior to delivery (i.e., undelivered), resulting in 18 fetal deaths, and an additional 31 women underwent delivery of a stillborn (fetal demise). In addition, there were eight neonatal deaths (0-28 days postpartum) and four post-neonatal deaths (29-365 days postpartum). Previous live births are recorded in medical records, so assuming all these children were still alive, 814 children were left without a mother, including 232 infants who survived the sentinel pregnancy.

Coroner Reports and Autopsies

The majority of pregnancy-related deaths (82%, $n=274$) were reported to the county coroner. Of these, nearly 60% ($n=197$) of the deaths had an autopsy performed. Some causes of death were more likely than others to have had an autopsy performed, including amniotic fluid embolism (88%), VTE (86%), sepsis (74%), and CVD (68%). Without the autopsy reports, case confirmation would have been severely limited. Relying solely on the maternal death certificates was often insufficient to determine the timing of the death in relationship to the pregnancy, especially if they were unlinked to fetal birth or death certificates. The coroner investigative reports were usually very informative and served as invaluable sources of information about both the medical and social context of each woman's life. These reports provided details such as family involvement, substance use, medical history, prenatal provider names, height and weight at the time of death and other key information. The format and comprehensiveness of the both the autopsy and coroner reports varied significantly by county and the lack of an autopsy or key test results hindered the Committee's ability to identify or clarify cause of death in 20 of the cases. For deaths not referred to the county coroner, an autopsy was not done despite family request in four cases.

Maternal Characteristics of Pregnancy and Delivery

Obesity

Figure 7 (Maternal BMI among CA-PAMR Deaths and California Women Giving Birth, 2002-2007) shows the body mass index (BMI) distributions for the pregnancy-related deaths compared to women with live births using the California Maternal Infant Health Assessment (MIHA) data. Among women who died of pregnancy-related causes, 61% were overweight or obese, compared to 41% in the self-reported MIHA data among women who gave birth in California (2002-2007). In particular, women who died were more likely to be in the Obese I, II, and III categories, compared to women who gave birth.

Figure 7: Maternal BMI among CA-PAMR Deaths and California Women Giving Birth, 2002-2007

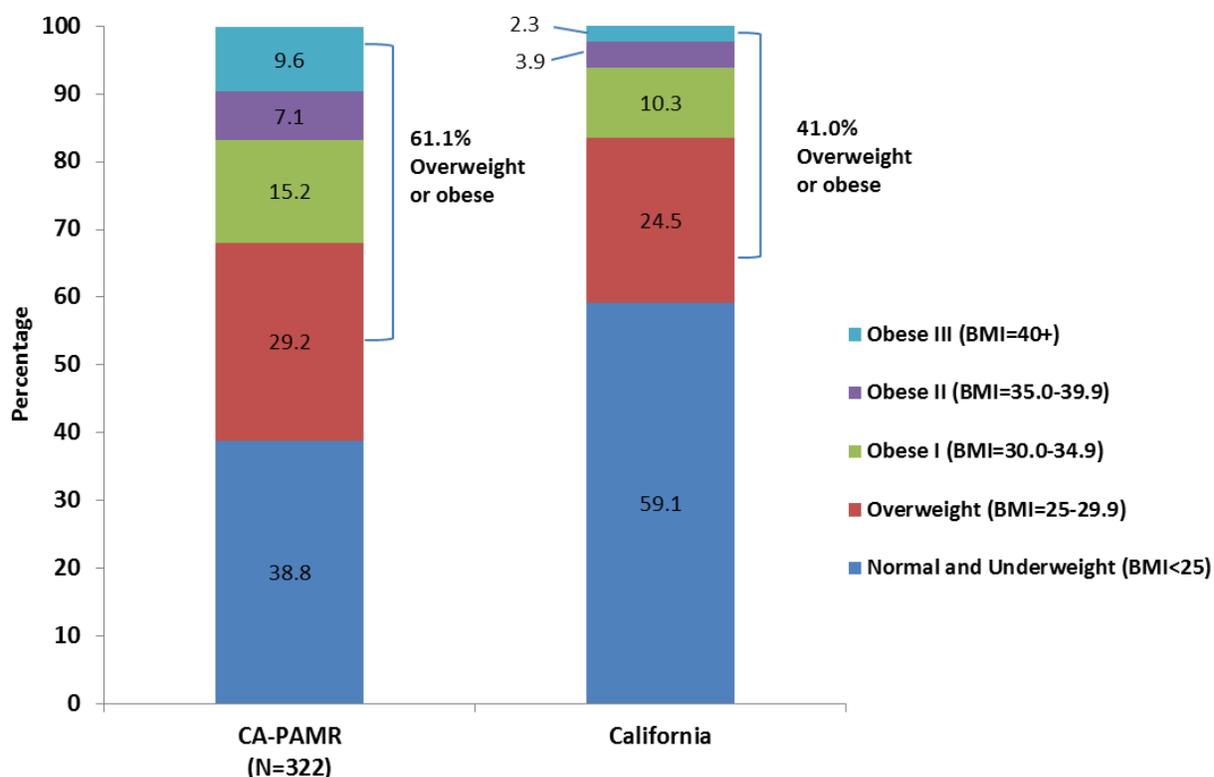
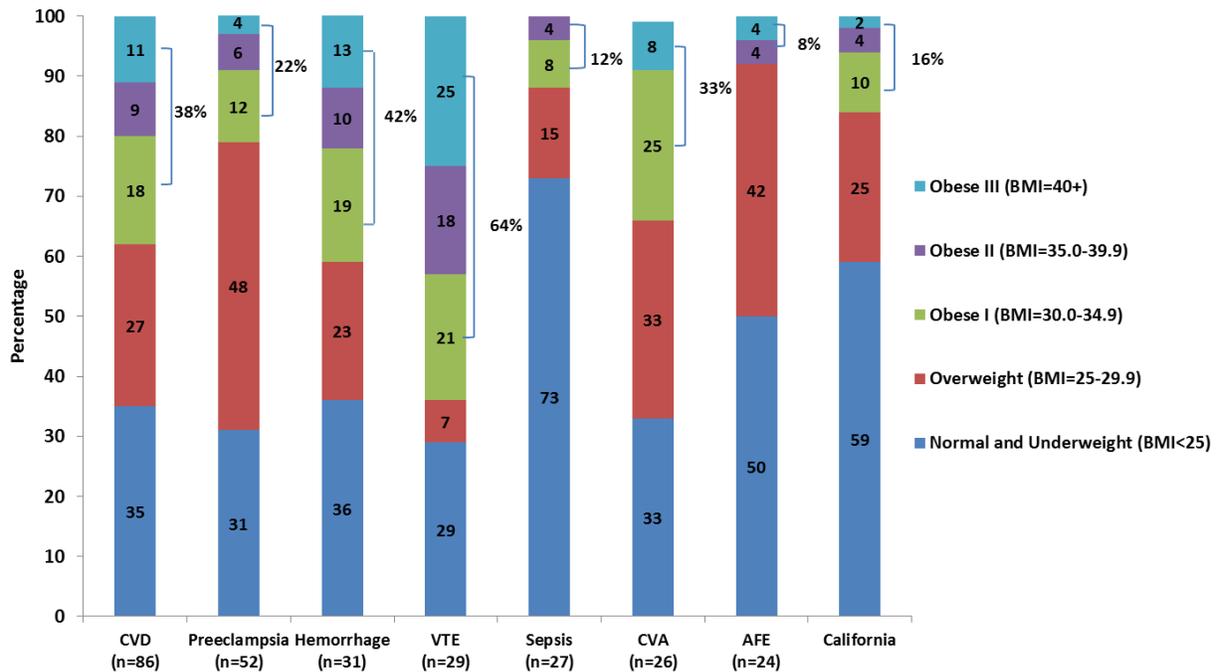


Figure 8 shows pre-pregnancy BMI data for women who died of major causes compared to women who gave birth in California. Women who died of CVD (38%), HEM (42%), VTE (64%) were all more likely to be obese (BMI \geq 30) at the onset of prenatal care than women who gave birth in California (16%) ($p < .05$). Women who died of VTE were more likely to be obese than women who died of preeclampsia, sepsis or AFE (64% vs. 22%, 12% and 8% respectively, $p < .001$).

Figure 8: Maternal BMI among Major Causes of Pregnancy-Related Death, CA-PAMR, 2002-2007

Gestational Weight Gain

Among the 261 cases with available data pertaining to weight gain, 36% (n=120) of the women who died gained an amount of weight exceeding recommended current Institute of Medicine (IOM) guidelines.⁷ Women who were underweight or normal weight were less likely to exceed recommended weight gain than overweight and obese women (BMI 25-29.9, 30.0-34.9 and BMI 40+). Excessive weight gain did not differ by racial/ethnic groups nor by cause of death (all $p > .05$).

Parity

Women who died had similar rates of parity as the California birth cohort when the number of prior births was between one and four births. However, there was an overall higher incidence of grand multiparity among the pregnancy-related deaths, and a strong correlation with particular causes of death. Women who died of hemorrhage (21%), AFE (21%) and cardiovascular disease (11%) were more likely than women in the CA birth cohort (5%) to have had five or more prior births ($p < 0.5$) (Table 4).

Preterm Deliveries and Gestational Age at Delivery

There was a higher amount of preterm delivery (< 36 weeks gestational age) among the pregnancy-related deaths compared to the California birth cohort. Except for AFE, women who died of all causes were more likely to have had a preterm birth ($p < .05$). Infants of women who died of preeclampsia (62% preterm) were born at lower gestational ages than infants of women who died of all other causes ($< .001$) (Table 4).

Prenatal Care

Almost a third (31%) of the women in the CA-PAMR cohort had inadequate prenatal care, as defined by the Kotelchuck Adequacy of Prenatal Care Utilization Index, compared with 22% of the California birth cohort ($p < .001$). Five percent of the pregnancy-related deaths had less than three prenatal care visits (Table 4).



Table 4: Maternal Characteristics of Pregnancy and Delivery among Major Causes of Pregnancy-Related Death, CA-PAMR and California Birth Cohort, 2002-2007

Maternal Characteristics	Major Causes of Pregnancy-Related Death							CA Birth Cohort
	CVD N (%)	PRE N (%)	HEM N (%)	VTE N (%)	SEPSIS N (%)	CVA N (%)	AFE N (%)	
Maternal age (years)								
<30	38 (44%)	21 (39%)	10 (30%)*	15 (52%)	15 (56%)	7 (27%)*	7 (29%)	1,935,317 (59%)
30-39	42 (48%)	25 (46%)	18 (55%)	12 (41%)	8 (30%)	16 (62%)	16 (67%)	1,300,277 (39%)
40+	7 (8%)**	8 (15%)**	5 (15%)**	2 (7%)	4 (15%)**	3 (12%)**	1 (4%)	74,023 (2%)
Parity²								
1	22 (25%)	24 (44%)	6 (18%)	8 (28%)	14 (52%)	5 (19%)	6 (25%)	1,277,780 (39%)
2-4	55 (63%)	25 (6%)	20 (61%)	17 (59%)	10 (37%)	18 (69%)	13 (54%)	1,864,057 (57%)
5+	10 (11%)**	5 (9%)	7 (21%)**	4 (14%)	3 (11%)	3 (12%)	5 (21%)**	164,546 (5%)
Gestational age (weeks) at delivery/demise³								
<32	13 (15%)**	10 (19%)**	7 (21%)**	4 (14%)**	6 (23%)**	8 (30.8%)*	0 (0%)	61,129 (2%)
32-36	18 (21%)**	23 (43%)**	8 (24%)	9 (31%)**	8 (31%)**	5 (19%)	1 (4%)	293,368 (9%)
≥37	56 (64%)*	21 (39%)*	18 (55%)*	16 (55%)*	12 (46%)*	13 (50%)*	23 (96%)	2,781,887 (89%)
Adequacy of Prenatal Care								
Adequate/Adequate Plus	49 (56%)*	41 (76%)	17 (52%)	19 (66%)	17 (63%)	18 (69%)	18 (75%)	2,514,088 (76%)
Inadequate	33 (38%)**	11 (20%)	13 (39%)	8 (28%)	10 (37%)	7 (27%)	5 (21%)	691,562 (21%)
Missing	5 (6%)	2 (4%)	3 (9%)	2 (7%)	0 (0%)	1 (4%)	1 (4%)	104,835 (3%)
Payer Source								
Medi-Cal or other government program	54 (62%)**	32 (59%)	18 (55%)	17 (59%)	17 (63%)	11 (42%)	12 (50%)	1,564,874 (47%)
Private/HMO	28 (32%)*	19 (35%)	11 (33%)	11 (38%)	8 (30%)	15 (58%)	12 (50%)	1,622,765 (49%)
Uninsured/Unknown	5 (6%)	3 (6%)	4 (12%)	1 (3%)	2 (7%)	0 (0%)	0 (0%)	122,846 (4%)
Total (N=280)	87	54	33	29	27	26	24	3,310,485

¹ Limited to women with known age, parity and gestational age within the California Birth Cohort.

² Parity=number of pregnancies ≥20 weeks, regardless of outcome; most recent pregnancy at time of death included.

³ One death did not have gestational age data available.

Some percentages do not equal 100 due to rounding.

* Proportion is significantly lower than CA Birth Cohort (p<.05).

** Proportion is significantly higher than CA Birth Cohort (p<.05).

Medical Risk Factors of Women Who Died

The Committee examined each pregnancy-related death for any patient factors that contributed to the fatal outcome. The Committee also differentiated patient status as “low-risk” or “not-low-risk” at two points during pregnancy: 1) upon entry to prenatal care (up to 10 weeks’ gestation); and 2) at presentation to labor and delivery (intrapartum). Capturing risk status at these two periods allows CA-PAMR to understand whether women are entering pregnancy with preexisting health conditions and/or developing health conditions during pregnancy that increase their risk for complications and poor outcomes. Patients were classified as low-risk if there was absence of potentially complicating medical conditions (e.g., BMI >30, prior cesarean delivery, five or more prior births, currently with multiple gestations, age >40 or <16 years); all others were classified as not-low-risk (Table 5).

Prenatal risk among entire cohort

Nearly three quarters (74%) of the women who died were determined by the Committee to be not-low-risk at entry to prenatal care. Among this group, 42% had BMI \geq 30 26% had a prior cesarean birth, 16% had five or more prior births, 14% were \geq 40 or \leq 16 years of age, and 4% were having multiple gestation. Of all women who were determined to be not-low-risk at entry to prenatal care, 40% were Hispanic, 28% were White, and 26% were African-American. Women who died of preeclampsia were more likely to be low-risk (40%) than women who died from CVD (15%) or hemorrhage (7%) ($p < .001$) (Table 5).

Intrapartum risk among entire cohort

After excluding the 18 women who died prior to delivery and four cases with insufficient data to make a determination, 91% of women were considered not-low-risk by the time of intrapartum care. Of the 75 women who were considered low-risk at entry to prenatal care, 48 moved into not-low-risk status by the intrapartum period, three died prior to delivery, and 27 (36%) remained low-risk.

Among the 27 women who were low-risk at intrapartum care, eight (30%) died of cardiovascular disease, four (15%) died of AFE, four (15%) died of CVA, three (11%) died of sepsis, two (7%) died of VTE and six (22%) died of other causes. Of note, no women who died of hemorrhage or preeclampsia deaths were considered low-risk at intrapartum. There were no racial/ethnic disparities among the 27 low-risk women. In regard to age, 16 (59%) of the low-risk women were between 30 and 39 years, 10 (37%) were ages 20-29 and one was less than 20 years old. By definition, women ages 40 and older were deemed not-low-risk.

Risk Status during Pregnancy

- **Nearly 74% of the women who died were found to be not-low-risk at entry to prenatal care.**
- **91% of women were considered not-low-risk by the time of labor and delivery (intrapartum care).**

Table 5: Risk Level, Mode and Circumstances of Delivery among Major Causes of Pregnancy-Related Death, CA-PAMR, 2002-2007

Major Causes of Pregnancy-Related Death								
	CVD N (%)	PRE N (%)	HEM N (%)	VTE N (%)	SEPSIS N (%)	CVA N (%)	AFE N (%)	Total among Major Causes
Risk level at entry to prenatal care ^{1,2}								
Low	12 (15%)	21 (40%)	1 (4%)	3 (11%)	9 (36%)	8 (35%)	9 (39%)	63 (24%)
Not Low	71 (86%)	32 (60%)*	26 (96%)	24 (89%)	16 (64%)	15 (65%)	14 (61%)	197 (76%)
Risk level Intrapartum ^{1,2}								
Low	8 (10%)	~	~	2 (7%)	3 (12%)	4 (17%)	4 (17%)	21 (8%)
Not Low	76 (91%)	53 (100%)	27 (100%)	25 (93%)	23 (89%)	20 (83%)	19 (83%)	243 (92%)
Mode of delivery ²								
Vaginal	34 (40%)	12 (23%)	12 (40%)	7 (26%)	18 (67%)	8 (33%)	7 (30%)	98
Cesarean (total)	50 (60%)	41 (77%)**	18 (60%)	20 (74%)	9 (33%)	16 (67%)	16 (70%)	170
Total # of deliveries²	84	53	30	27	27	24	23	268
Circumstances of cesarean (% of total deliveries within each cause of death)								
Planned/Scheduled	10 (12%)	2 (4%)	3 (10%)	5 (19%)	1 (4%)	2 (8%)	1 (4%)	24
Unplanned/Labor	21 (25%)	7 (13%)	5 (17%)	10 (37%)	6 (22%)	6 (25%)	4 (17%)	59
Crash/Emergent	7 (8%)	27 (51%***)	8 (27%)	2 (7%)	1 (4%)	5 (21%)	7 (30%)	57
Perimortem/CPR	12 (14%)	5 (9%)	2 (7%)	3 (11%)	1 (4%)	3 (13%)	4 (17%)	30

¹ The Committee was unable to determine prenatal risk level in eight cases and intrapartum risk level in four cases; these deaths are excluded from the respective analysis.

² 18 women died prior to delivery and were excluded from the total number of deliveries reported in this table, thus the numbers of each cause of death may not match those reported in Table 1.

* Women who died of preeclampsia/eclampsia were less likely to be “not-low-risk” than women who died from CVD or HEM (but not VTE) ($p < .01$).

** Women who died of preeclampsia/eclampsia were more likely than those who died of CVD or SEP (but not hemorrhage) to have had a cesarean ($p < .05$).

*** Women who died of preeclampsia/eclampsia were more likely than those who died of CVD or VTE to have had a crash/emergent cesarean ($p < .05$).

Mode of Birth

The majority of the women who died had cesareans (compared to approximately a third of all California births⁸). The cesareans were predominantly performed in response to maternal or fetal distress as a life-saving attempt, with only 14% previously scheduled. The distribution of causes of death and circumstance of the cesarean are presented in Table 5.

Social Risk Factors and Racial/Ethnic Disparities

Social risk factors are important to examine in the context of pregnancy and can create co-morbid health conditions or exacerbate existing health problems and lead to poorer health outcomes for the woman and her infant. Table 6 includes social risk factors identified from the medical records and varied across women's records, depending on the availability and quality of documentation. Other social risk factors not presented here could have also contributed to health outcomes of pregnancy such as housing conditions, access to safe and easy transport to medical care, occupational conditions, access to healthy foods, and experiences of racism. In future analysis, the address of the deceased could be linked to measures of disparity in the neighborhoods where these women lived.

From available medical records data, more than two-thirds (68%, N=225) of the women who died had at least one documented social risk factor which may have contributed to their demise. Some factors, considered more severe than others (e.g., lack of prenatal care, illicit drug use (e.g., methamphetamine, cocaine, opiates, barbiturate), severe mental illness, homelessness, incarceration and exposure to violence; bolded items in Table 6), were apparent in nearly one-fourth (25%, N=82) of the deaths. We contrasted the prevalence of social risk factors among the deceased with population-based estimates for pregnant women or women of childbearing age, where available. Slightly different years or criteria may be available for the population data sources when compared to what was found in the medical record data for the pregnancy-related deaths. For example, MIHA data on perinatal mental health are available for 2013-2014 and include self-reported prenatal and postpartum depressive symptoms, whereas the CA-PAMR data had access to any mental health disorder noted. Though not completely comparable, such comparisons may be a useful starting place to understand the degree to which social risk factors were present or over-represented among the pregnancy-related deaths.

The percent of uninsured (4%) was similar to that of the population but also represents increased risk for a woman during pregnancy, since it indicates a lack of access to medical care.

Women who died were more likely to have had less than 12 years of education and foreign-born Hispanic women were more likely than all other groups to have had less than a high school degree ($p < .001$) (Table 6).

From available medical records data, more than two-thirds (68%, N=225) of the women who died had at least one documented social risk factor which may have contributed to their demise.

Table 6: Social Risk Factors among Pregnancy-Related Deaths, CA-PAMR, 2002-2007

Social Risk Factor ¹	CA-PAMR N (%) ²	CA Birth Cohort (2002-2007) or MIHA (2010) ³ (%)
Uninsured during prenatal care	13 (4%)	3%
No prenatal care (<3 visits)	29 (9%)	NSD
Less than 12 years of education	94 (28%)***	10%
Single/no domestic partner	133 (40%)***	15%
No father of baby involvement	67 (23%)	NSD
Methamphetamine, cocaine, opiate or barbiturate use during pregnancy or postpartum*	35 (11%)	NSD
Cannabis use during pregnancy or postpartum**	14 (4%)	NSD
Alcohol use during pregnancy (1 st and 3 rd trimester)**	21 (7%)	12%*** ³
Tobacco use during pregnancy (1 st and 3 rd trimester)**	51 (17%)***	6% ³
Any mental health condition (including depression)	40 (15%)	13-14% ³
Severe mental health condition: bipolar, psychosis, panic	13 (5%)	NSD
Prior suicide attempt	5 (2%)	NSD
Homeless/unstable living situation	26 (12%)	NSD
Exposure to violence (intimate partner violence (IPV) or other)	20 (10%)	7% ^{3,4}
Father of baby incarcerated	6 (2%)	NSD
Decedent incarcerated	2 (1%)	NSD
Child Protective Services (CPS) Involvement	8 (2%)	NSD
None of the above factors	108 (32%)	NA

NSD=No source data / No comparison group

¹ Factors were not mutually exclusive – women may have had more than one risk factor.

² Percentages are calculated based on available data, missing data were excluded from the denominators.

³ MIHA mental health data include self-reported prenatal and postpartum depressive symptoms only. MIHA violence data includes only intimate partner violence during pregnancy. Please refer to the Technical Notes for a description of Maternal and Infant Health Assessment (MIHA) Survey.⁹

⁴ Includes IPV only.

*Includes methamphetamine, cocaine, heroin, barbiturate use based on positive toxicology screen during pregnancy, postpartum or on autopsy or self-report. Does not include cannabis.

**Based on self-report or positive toxicology screen.

***Significantly more likely p<.01

Substance Use

Substance use is a stigmatized health issue that can impact not only disclosure of use, but also inquiry of use by providers. Toxicology screens are more reliable indications of substance use than self-report data, but may not reflect all use or all substances. The below rates of use combines data from both sources to provide the fullest measure of substance use available through medical records.

Eleven percent of the women who died had a positive toxicology screen or self-report for illicit drugs (methamphetamine, cocaine, heroin, other opiates or barbiturates) during pregnancy (Table 6). White women were more likely than Hispanic women to have used illicit drugs (21% vs. 7%, respectively; $p < .05$). Fourteen women (4%) either self-reported or had positive toxicology screens for marijuana use (no comparison data available). Compared to MIHA respondents, CA-PAMR women were less likely to consume alcohol during pregnancy (7% vs. 12% respectively, $p < .01$). White women were more likely than Hispanic women to have consumed alcohol during pregnancy (14% vs. 4%, respectively; $p < .05$) (Data not shown). Seventeen percent of the women who died smoked tobacco during pregnancy compared to only 6% who reported smoking in the MIHA survey ($p < .001$). White and African-American women who died were more likely than Hispanic women to smoke tobacco during pregnancy (35% and 21% vs. 6%, respectively; $p < .001$).

Mental Health, Housing, and Violence Issues

Mental health conditions, including prenatal and postpartum depression, occurred in the same proportion among women who died and the MIHA respondents (Table 6). Five percent of the CA-PAMR cohort suffered from severe mental illness, defined here as bipolar disorder, schizophrenia, psychosis, anorexia or panic attacks. Five women who died (2%) had a prior suicide attempt (not mutually exclusive from other mental health conditions). There were no racial/ethnic differences in the proportion of documented mental health issues among women who died. Twelve percent of the women who died were noted to have been homeless or living in an unstable environment. Approximately 10% of the women who died had a documented history of violence exposure, which included intimate partner violence (IPV), sexual assault and childhood abuse, compared to 7% of the MIHA population (which only asked about IPV). There were no racial/ethnic differences in the proportions of women who died, or in the MIHA population, with documented exposure to violence.

Incarceration

Among the women who died, two were incarcerated while pregnant. One of these women died while at the detention facility; the other woman was under criminal justice supervision 16 days postpartum when she experienced sudden cardiac arrest (Table 6).

Child Protective Service (CPS) Involvement

Among the women who died, eight women had mention of CPS involvement and did not have custody of their children (Table 6).

PREVENTABILITY OF PREGNANCY-RELATED DEATHS

Witnessing a maternal death first hand, I cannot begin to describe the horror and pain such an event causes all involved, including the patient, family and care providers. Even when an occurrence is not preventable, it is heart rendering. However, in reviewing cases there were many instances when the death could have been prevented or potentially ameliorated.

Tom Kelly, MD
Perinatologist
University of California,
San Diego Medical Center



5. Preventability of Pregnancy-Related Deaths

In this section, we compare the major causes of pregnancy-related death in terms of preventability, key maternal characteristics, contributing factors related to health care provider, facility and patient dimensions and quality improvement opportunities.

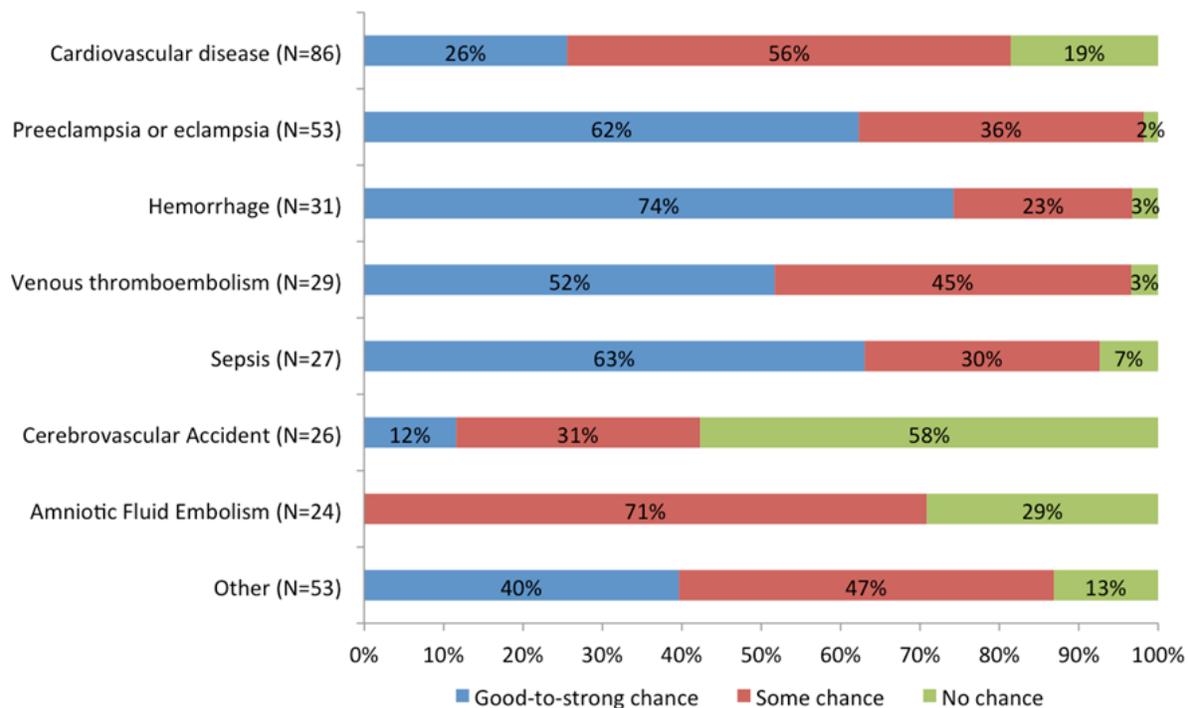
Overall Preventability

Overall, 41% of all pregnancy-related deaths had a good-to-strong chance of preventability, similar to what was published in the last California PAMR report.¹ The Committee assessed preventability as the chance to alter the fatal outcome, categorized as 1) strong; 2) good; 3) some; or 4) none. The case was considered preventable when the Committee agreed that specific and feasible actions, if implemented, might have changed the course of the woman's trajectory and resulted in a non-fatal outcome. Examples of cases where there was a good-to-strong chance to alter the outcome included women with:

- Untreated severe hypertension who died from intracranial hemorrhage
- Postpartum hemorrhage with delayed recognition who suffered massive blood loss and coagulopathy
- Major risk factors for venous thrombosis who did not receive any form of perioperative VTE prophylaxis who then developed fatal pulmonary emboli

As shown in Figure 9, deaths from hemorrhage, preeclampsia or eclampsia, sepsis were all significantly more likely than cardiovascular disease, amniotic fluid embolism or cerebral vascular accidents (all $p < .05$) to have had a good-to-strong chance to alter the outcome. Deaths from VTE were significantly more likely than AFE or CVA deaths to be preventable ($p < .05$). Nearly three-quarters of the hemorrhage deaths were preventable (74%). Deaths due to amniotic fluid embolism were significantly less likely to be preventable than all other causes, with none having a good-to-strong chance. The CA-PAMR committee was unable to determine the chance to alter the outcome, because of insufficient information, in two hemorrhage deaths, and one cardiovascular and preeclampsia/eclampsia death each.

The Committee determined that 45 deaths (14%) may have been prevented if different actions had been taken prior to pregnancy.

Figure 9: Chance to Alter Outcome among Pregnancy-Related Deaths, CA-PAMR, 2002-2007

Preconception Care

Preconception care and reproductive life planning are recognized as a critical component of health care for women of reproductive age. The Committee was asked to assess each case for actions that could have been undertaken before conception that may have reduced or prevented subsequent complications. The Committee determined that 45 of the deaths (14%) could have been prevented if different actions had been taken in the preconception period. The most common recommendations for preconception care focused on behavioral and chronic conditions affecting women's health prior to pregnancy, including obesity, substance use and high-risk medical conditions such as rheumatoid arthritis, thyroid issues and severe primary pulmonary hypertension.

Contributing Factors

A contributing factor is any behavior or systems issue, or the deficiency thereof, which increases the severity of morbidity or the likelihood of mortality. These factors do not necessarily cause the fatal outcome, but may be one of a number of factors occurring in the chain of events leading to the maternal death. Contributing factors can thus be analyzed to help guide development of quality improvement efforts. For this analysis, factors contributing to pregnancy-related deaths were identified and categorized into those relating to 1) the patient; 2) the healthcare facility and 3) the healthcare professional. When a contributing factor was identified, the CA-PAMR Committee was asked to weight whether the contributing factor definitely or probably contributed to the death.

Healthcare provider factors were the most common type of contributor to the maternal death identified by the Committee, present among 269 cases (81%) with an average of 2.5 factors per case. Healthcare provider factors were particularly common for preeclampsia/eclampsia and hemorrhage, consistent with their higher degree of preventability. The most common provider factor was delayed response to clinical warning signs, followed by ineffective care (Figure 10).

The Committee found that healthcare provider factors were the most common contributor to maternal death.

Facility-related contributing factors were less frequent than provider- or patient-related factors, identified in 145 of the deaths (44%) with an average of 0.8 factors per case. Preeclampsia and hemorrhage were associated with the most facility factors, with inadequate staff knowledge systems issues (i.e., lack of massive transfusion or hypertension protocols) and coordination of care (i.e., delays in treatment of hypertension or blood product administration) identified for each cause of death, respectively (Figure 11).

Patient-related factors, particularly underlying medical conditions and obesity, were identified in 75% of the deaths (N=249), with an average of 1.9 patient-related factors per woman. These factors were most commonly identified among CVD and VTE cases (Figure 12). The leading patient factors among preeclampsia/eclampsia deaths were delays in seeking care (41%), underlying medical conditions (35%) and presumed lack of knowledge regarding the severity of a symptom or condition (35%). Frequent patient factors among hemorrhage deaths were delays in seeking care (33%) and patient refusal of blood products for religious reasons (18%).



Figure 10: Health Care Provider Factors Contributing to Pregnancy-Related Deaths, CA-PAMR, 2002-2007

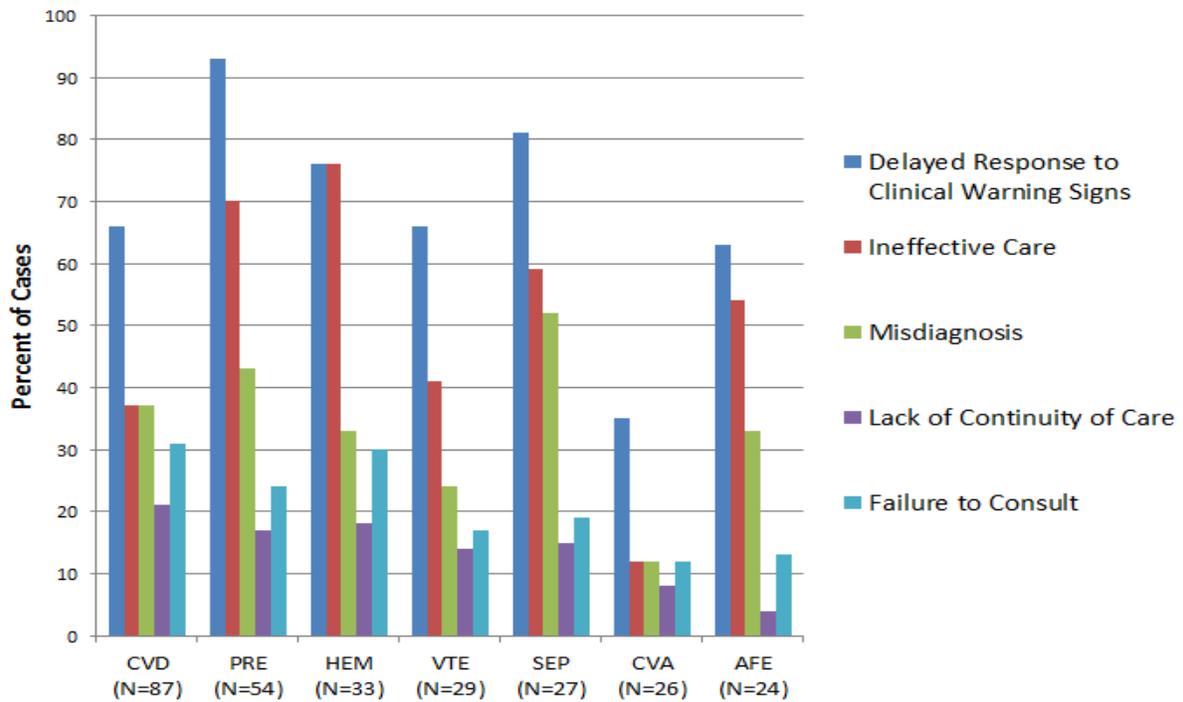


Figure 11: Facility Factors Contributing to Pregnancy-Related Deaths, CA-PAMR, 2002-2007

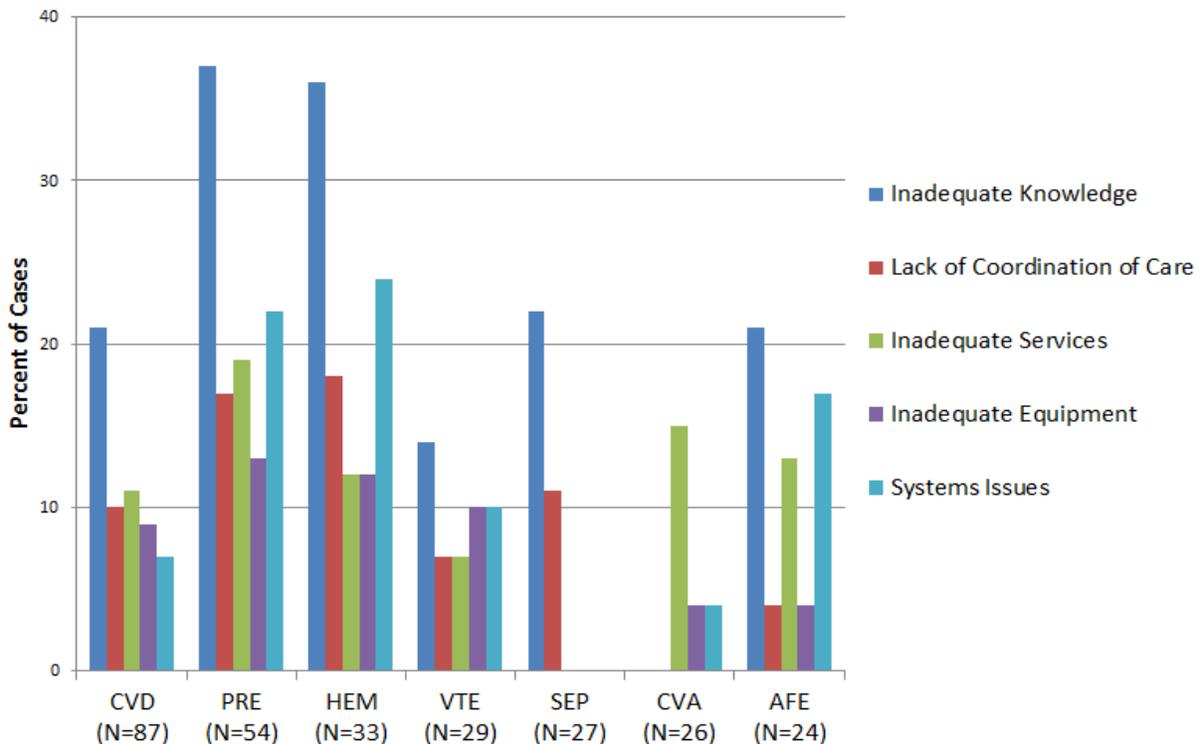
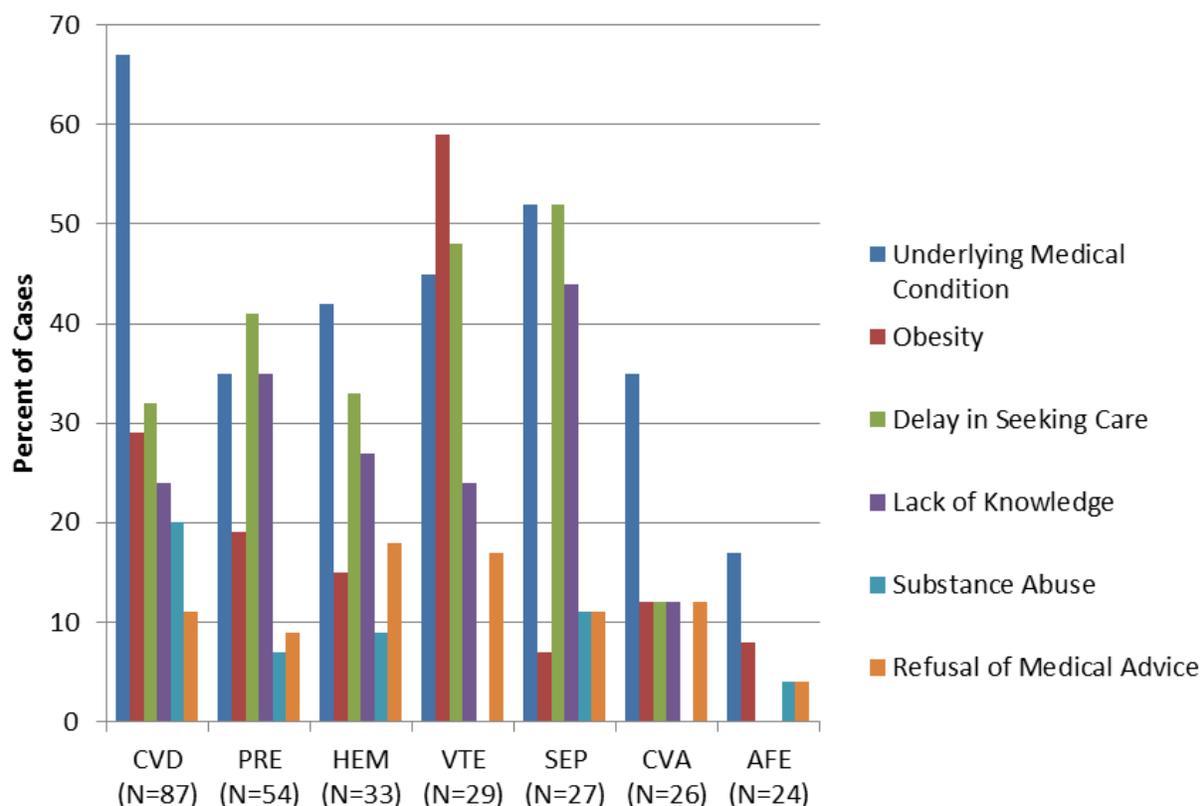


Figure 12: Patient Factors Contributing to Pregnancy-Related Deaths, CA-PAMR, 2002-2007

Cesarean Delivery as a Contributing Factor

Cesareans can be a life-saving procedure for a woman or her baby. However, regardless of the indication, a cesarean introduces risks to the woman via surgical complications (e.g., infection, blood loss, injury to other organs and venous thromboembolism), anesthesia-related complications and potential complications for subsequent pregnancy due to permanent scarring of the uterus (e.g., placenta previa, placenta accreta and uterine rupture).^{10,11,12,13,14,15} Since women who are very ill or in critical condition will likely have an emergency cesarean, maternal mortality directly attributable to cesarean surgery itself is hard to calculate. Recent investigations in low-risk populations have given estimates of direct cesarean-related mortality that range from 5.6 to 28 per 100,000 procedures.^{16,17} In this cohort of maternal deaths, an urgent, emergent or perimortem cesarean delivery was often indicated in order to address the deteriorating status of the woman or her fetus.

Overall, 204 (61%) of the women who died gave birth by cesarean, 111 (33%) had a vaginal birth and 18 (5%) died before delivery. During case review, the Committee assessed whether immediate or subsequent complications of the cesarean in the current or a prior pregnancy or anesthesia-related complications during cesareans were contributing factors in the maternal death. The medical necessity of the procedure was not evaluated.

Table 7: Mode of Delivery among Pregnancy-Related Deaths, CA-PAMR, 2002-2007

Deaths Before Delivery					18
Total Delivered					315
Cesarean Type	Unplanned in Labor	Planned or Scheduled	Crash or Emergent	Perimortem or Undergoing CPR	
Primary	51	5	46	30	132
Repeat	20	24	22	6	72
Total	71	29	68	36	204
Vaginal Type	Spontaneous	Assisted (w/ forceps or vacuum)	Vaginal Birth after Cesarean (VBAC)		
Total	93	15	3		111

The Committee determined that the current cesarean contributed to the death in 29 (14%) of the 204 women who delivered by this method. Over half of these were repeat cesareans (55%). Complications that occurred at labor and delivery included hemorrhage (41%), placental complications (accrete/percreta or previa) (28%), preterm delivery (31%), and cardiorespiratory collapse (31%). These 29 women died of obstetric hemorrhage (35%), post-operative VTE (24%), post-operative infection (sepsis) (14%), CVD (14%), preeclampsia (10%) and one woman died of anesthesia complications (3%).

The Committee determined that a prior cesarean directly contributed to the death in six percent of the women who had cesareans, the majority of which (84%) were repeat cesareans in the fatal pregnancy. Complications that occurred at labor and delivery among the 19 women included 81% hemorrhage; 75% placenta previa or accreta/percreta; 31% preterm delivery, and 19% had a uterine rupture (complications not mutually exclusive). In terms of the grouped cause of death, these 19 women died most frequently of hemorrhage (63%) and VTE (21%) followed by CVD (11%) and sepsis (5%).

In addition to the 29 surgery-related deaths, there were eight additional cases where spinal anesthesia for the cesarean contributed to severe hypotension and subsequent cardiac arrest.

Induction and Augmentation as a Contributing Factor

Induction of labor, whether via mechanical or medical means, can be medically necessary due to maternal or fetal conditions, such as preeclampsia or fetal growth restriction. The timing of delivery in such cases must balance the maternal and newborn risks of late-preterm and early-term delivery with the risks of further continuation of pregnancy.¹⁸ Among the women who died, 18 died prior to delivery. Of the remaining 315 women who gave birth, 125 (40%) had a cesarean without labor, 75 (24%) had their labor induced and 34 (11%) had their labor augmented with Pitocin or another artificial drug used to stimulate and strengthen contractions. Among the 109 women who were induced or had augmented labor, 39% had a cesarean.

The Committee reviewed induction and augmentation as a potential contributing factor only for the 2005-2007 deaths (n=175). Induction or augmentation was deemed a contributing factor in nine (5%) of these deaths. Three of these deaths were from AFE, two each from hemorrhage and VTE, and one each of CVD and sepsis.

Quality Improvement Opportunities

Background

In the past, maternal mortality reviews have often identified what went wrong in patient care without outlining clear strategies and priorities for improving care and maximizing patient safety. One of the key goals of the CA-PAMR is to specify generalizable opportunities for maternity care improvement or lessons learned that would help others avoid similar maternal deaths in the future. For each case reviewed, the Committee identified one or more quality improvement opportunities (QIO) that could be addressed to improve maternity care and services in California.

The QIO data was derived from Committee members' open-ended responses to the question, "In this particular case, what alternative approaches to recognition, diagnosis, treatment or follow up, at the system, provider, and/or patient levels, may have led to better patient care and/or a better outcome?" When looking at opportunities to improve care, it is most helpful to review them by cause of death or by location of care delivery.

Cardiovascular Disease (n=87)

Only a small fraction of these women had a known diagnosis of cardiovascular disease prior to death, even though most (84%) of the women who died had presented with symptoms either during pregnancy or postpartum. Data from CA-PAMR suggest that one-fourth of these deaths may have been prevented if heart disease had been diagnosed earlier; this was especially true for the cardiomyopathy deaths. Seven critical symptoms commonly presented among pregnant or postpartum women who died from pregnancy-related CVD, including out-of-range heart rate, systolic blood pressure, respiration rate, oxygen saturation, and cough and wheezing. The presence of these symptoms, in conjunction with apparent patient risk factors such as obesity and family history, should have been evaluated as possible cardiac situations.

Data from CA-PAMR suggest that one-fourth of deaths due to cardiovascular disease may have been prevented if diagnosed earlier.

Quality improvement opportunities regarding cardiovascular disease in the health care provider domain include:

- *Physician care issues* could be improved with better recognition and response to women who presented with potential clues (i.e., clinical warning signs) suggestive of a cardiac etiology. These warning signs include shortness of breath, fatigue, tachycardia, blood pressure change, or low oxygen saturation, which presents as altered mental status that is often interpreted as

‘anxiety’. Failure to recognize these clues as indicative of a significant underlying problem resulted in delay in or lack of appropriate workup to establish the diagnosis in an expeditious manner. For example, in multiple cases, women’s symptoms of shortness of breath were misdiagnosed as either asthma or anxiety, despite many visits during which a diagnosis could have been made. In these

cases, low oxygen saturation levels should have been followed up with echocardiogram or further evaluation. Since similar complaints can be normal in late pregnancy, clinicians need to carefully assess shortness of breath in the presence of other co-occurring symptoms, such as chest pain, tachycardia, edema, especially among those women with BMI >35 and rule out cardiac causes. Delays in, or failure to identify and/or respond to clinical warning signs are highly associated with delays in or failure to diagnose and treat cardiovascular disease.

By failing to recognize and respond to clinical warning signs, clinicians missed opportunities to diagnose and effectively treat preeclampsia and its corollary disease pathways.

- Many opportunities to improve treatment were associated with *systems level issues*, such as coordination of care between nurses and physicians in triage, determining which unit is best suited to patient acuity (Labor and Delivery versus Intensive Care), obtaining relevant consultation with specialists or arranging timely transport to higher-level facility. Opportunities related to facility factors included improving staff knowledge and practices around closer monitoring in the postpartum unit by nursing staff, more effective nursing communication with physicians about patient status, and better coordination between nursing and medical triage in the emergency department. Inadequate or unavailable services or consultations within facilities contributed to the death in 10% of all cardiovascular cases. The Committee identified:
 - Gaps in policies and protocols around the need for providers and systems to have a Care plan within a regional care policy for high-risk patients,
 - Better case management of women with co-morbid conditions (such as obesity and substance use), and
 - Protocols for appropriate imaging in pregnancy, treatment for hypertension and consulting among specialists and better coordination across hospital units.
- *Patient factors* identified among the CVD deaths include underlying medical conditions such as hypertension and obesity. In many cases, women lacked knowledge regarding the importance of a sign or symptom, which contributed to the deaths. Examples include the importance of continuing to take cardiac medications postpartum; one woman discontinued medications for unclear reasons and this omission was thought to contribute to her demise.
- In a few cases, it was clear that women experienced symptoms, such as shortness of breath, or fatigue and did not seek care. The reviews suggested that insurance coverage possibly affected

women's ability to seek care; ten of the women who died of CVD had to change insurance coverage at some point in their pregnancy or early postpartum and another seven women had a gap in care or were uninsured. A large proportion of women who died of CVD had presented in the postpartum period and access to medical care may have been limited by public insurance coverage through the conventional postpartum period only. Other women's failure to seek follow up care may have been due to thinking these symptoms were normal for the postpartum period.^{19,20} The QIOs illustrate information/knowledge gaps and can contribute to patient education in this area.

Cardiomyopathy Case Vignette* A Hispanic woman in her early 30s pregnant with her third child had moderately elevated blood pressure in the early third trimester. She also reported having one-to-three anxiety attacks per week. A week later she presented to the labor and delivery (L&D) unit of her hospital to rule out labor and to evaluate her shortness of breath. She was discharged with a diagnosis of "anxiety attack". She returned the following week to the same hospital in early labor with signs of preeclampsia. She had a rapid labor and delivery but two days postpartum she complained of shortness of breath and was noted to have mild hypertension. She was seen by a psychiatric nurse, given anti-anxiety medications and discharged home the next day. Five days later, she went to the emergency department of a different hospital complaining of anxiety, shortness of breath, non-productive cough and leg swelling. She was admitted and treated for presumed pneumonia. On hospital day 3, she had several cardiac arrests, and despite resuscitation efforts, died 12 days postpartum. The Committee determined strong chance to alter outcome because of the constellation of risk factors, persistent symptoms and classic signs of heart failure.

*Not a real case but an example based on actual cases reviewed.

Preeclampsia/Eclampsia (n=54)

- A major theme in the QIOs is that despite clinical warning signs indicating a serious deterioration in the patient's condition, *healthcare clinicians* failed to recognize and respond in a timely manner to signs and symptoms consistent with preeclampsia/eclampsia. By failing to recognize and respond to clinical warning signs, clinicians missed opportunities to diagnose and effectively treat preeclampsia and its corollary disease pathways in 35 (65%) of the women who died from preeclampsia. The particular warning related to blood pressure levels illustrates a major theme. The QIOs specify blood pressure levels observed in the medical record that should have alerted clinical action. Failure to respond to elevated blood pressure increases the risk of stroke.
- Other clinical warning signs were identified as opportunities to recognize and respond to severe hypertensive disease (proteinuria, headaches, epigastric pain, and mental status changes) were not recognized as serious. Patient complaints of headaches, epigastric, chest and abdominal pain were either ignored or misinterpreted, as were behaviors among women described as combative or who had altered or deteriorating mental status due to decreased oxygen saturation levels. These opportunities to improve outcomes were present in the prenatal period, during the childbirth hospitalization, and when women presented to the Emergency Department.
- In addition, the presence of various comorbid conditions (pulmonary edema, hypotension, liver hematoma) as well as signs of fetal compromise and/or impaired growth was not

considered in the context of the overall clinical picture. These cases demonstrated a lack of critical thinking or “putting the pieces of the puzzle” together to form a diagnosis. The lack of clinical reasoning or judgment in these cases, combined with the lack of recognition of the deteriorating status of the patient, led to delays in diagnosis and treatment.

- As an alternative approach, the Committee identified the need for standardized treatment protocol in 26 (48%) of the cases. Eight of these were specific to measurement and/or treatment of hypertension; another eight were related to the need for a plan for high-risk patients. Protocols were recommended in four cases for management of severe hemorrhage and three cases for code management.

*Preeclampsia Case Vignette** A 20-year-old White woman pregnant with her second child presented to the hospital in late pregnancy complaining of a severe headache. Her blood pressure (BP) was mildly elevated, and labs showed signs of preeclampsia with protein in the urine and low platelets, anti-seizure medications were started and had a successful labor induction and delivery. Despite multiple severely elevated BPs (>170 systolic and >120 diastolic) during labor, she did not receive anti-hypertensive treatment. After giving birth, she had persistent severe high BP and was treated with oral medications without effect. She complained of severe headache, dizziness, and blurred vision but there was no further evaluation by an OB. She was found unresponsive three hours later and died of a subarachnoid hemorrhage later that day. The Committee determined there was a strong chance of preventing her death as there was a clear diagnosis and multiple missed opportunities for aggressive BP control, especially after the birth.

*Not a real case but an example based on actual cases reviewed.

Obstetric Hemorrhage (n=33)

The quality improvement opportunities (QIOs) identified among the hemorrhage deaths in regards to *health care providers* included lack of recognition and response to clinical warning signs of severe bleeding, including not quantitatively assessing cumulative blood loss, missing the significance of low oxygen saturation levels and other abnormal vital signs. Several QIOs addressed issues around level of care and the need for smaller hospitals to either transfer patients requiring higher level of care or have a lower threshold for calling a rapid response team to address an emergent situation.

A key opportunity to improve outcomes involved communication issues among nurses and physicians, especially in situations where the obstetrician is not in the facility. Nursing staff need to understand when to notify the physician of a woman’s deteriorating status and be empowered to utilize the chain of command in their facility in the absence of timely response.

Six women who died of hemorrhage-related causes were Jehovah’s Witnesses who refused blood products that might have saved their lives. The Committee identified several quality improvement opportunities for these patients, including assessment for risk of hemorrhage, monitor prenatal levels of anemia and ensure adequate iron stores before birth, plan for delivery at a facility with the resources and skilled personnel to manage a severe hemorrhage and consider the use of cell saver or autologous blood donation prior to the delivery.²¹

The most common alternative approach among the QIOs in the hemorrhage deaths was the need for standardized protocols to address severe hemorrhage. Delays in administration of life-saving blood products resulted from systems issues around communication between labor and delivery units and the blood bank. Patients with known risk for hemorrhage require a plan for delivery at a hospital with capacity to address their needs, and all obstetric physicians and nurses need training and education on how to manage postpartum hemorrhage using standardized protocols.

Venous Thromboembolism (n=29)

Overall, the Committee identified the need for a hospital VTE protocol in 15 (52%) of the cases. The Committee noted that at the time of the death, postpartum thromboprophylaxis was not standard, but was more common at the time of the review (a six-to-seven year time lag). Several of the cases involved a severely obese woman having a prolonged induction with limited mobility for 48 hours or more. Another theme emerging from the QIOs among the VTE cases was the need for early mobility post cesarean. Given that the majority of women who died of VTE were NOT low-risk, another theme was the need for home visitation and case management for high-risk patients in the prenatal and postpartum periods.

The most common quality improvement opportunity related to patient factors was around the need for patient education of the signs and symptoms that require immediate clinical care.

The Committee determined that the prior or current cesarean probably or definitely contributed to the deaths of ten women whose primary cause of death was VTE. Among the 11 women for whom prior or current cesarean contributed to their deaths, six had BMI 30+ (two unknown BMI and three normal BMI). Two deaths from VTE involved women with fetal demise and long inductions.

All but two women with cesarean who died of VTE had no prophylaxis. The two women who did receive prophylactic treatment were diagnosed with deep vein thrombosis; however, one woman stopped taking the medications postpartum and subsequently died, while the other woman was prescribed medication at too low a dosage. Among the QIOs related to patient factors, the most common alternative approach identified was around the need for patient education of the signs and symptoms that require immediate clinical care. Another issue was women missing prenatal care appointments and/or poor compliance with recommended medical treatment.

Sepsis (n=27)

Quality improvement opportunities among women who died of sepsis showed that:

- Physicians did not perform adequate work-up and laboratory evaluation for women who complained of severe abdominal or vulvar pain.
- Although the agent of infection differed among the cases, a clear theme emerged regarding the need to administer antibiotic therapy earlier and more aggressively. In several cases, the type of medication was inappropriate for the specific infection.

- Patient education was a key QIO, with Committee recommendations for better discharge education for women regarding worrisome signs and symptoms of possible infection.
- QIOs were identified in the Emergency Department especially around coordination of care and identification of high-risk status for women who had frequent visits within a short period of time to the same ED.

Cerebral Vascular Accidents (n=26)

Quality improvement opportunities among the CVA deaths included:

- Healthcare provider failure to recognize clinical warning signs of low oxygen saturation leading to hypoxia in women with changes in mental status, i.e., agitation or uncooperative behavior.
- Other warning signs such as severe blood pressure levels, blurred vision and chest pain were not adequately assessed.
- Several QIOs pointed to inadequate evaluation of warning signs and thus failure to respond with timely treatment and appropriate imaging tests.

Amniotic Fluid Embolism (n=24)

Overall, AFE accounted for 7% of all pregnancy-related deaths. Although 71% of the deaths were deemed in part preventable, these were all determined to have some chance to alter the outcome, and none were thought to have a strong-to-good chance. Twenty-nine percent were determined to have no chance to be prevented.

- Few patient factors were contributory among AFE deaths, with 33% of the cases having at least one patient factor. Patient factors included underlying medical condition (17%) and refusal of medical advice in 4% of the cases. Despite having only some or no chances to alter the outcome, just one case had no QIOs.
- The majority of the QIOs related to issues of failing to identify patient symptoms that could be indicative of AFE, especially low oxygen saturations (six cases). Once patients experienced critical symptoms, the Committee found that there were issues with resuscitation and delivery in seven cases – with delayed delivery and/or ineffective attempts to resuscitate a pregnant woman. An alternative approach to consider is that in a critical scenario, the treating team should not move a patient to the operating room to perform an emergent cesarean as an important means of saving critical time.
- In ten cases, the QIOs focused on the lack of a massive transfusion protocol to address disseminated intravascular coagulation (DIC) in the situation of AFE.
- Nine of the 23 cases were found to have issues around inappropriate use or dosages of induction/augmentation medications such as Pitocin and misoprostol.

Quality Improvement Opportunities in Selected Areas

Anesthesia and Resuscitation

Since 1980, there has been a remarkable reduction of anesthesia–related deaths (to rates of ~1% of all maternal death) in both the U.S. and in the UK.^{22,23,24} Among all 333 pregnancy-related deaths in California, the Committee determined that six (1.8%) were directly related to anesthesia. However, anesthesia complications were a contributing factor in the deaths in an additional eight cases, and more broadly, there were quality improvement opportunities (QIOs) related to anesthesia complications in 53 (16%) of cases. The most frequent areas for improvement involved intubation and extubation, the majority involved avoidable delays (e.g., prolonged hypoxia with delays in intubation and oxygenation immediately prior to cardiovascular collapse) or cases where the patient was extubated before she was clinically stable. Nine cases were identified as having issues related to the intubation technique, which may suggest the need for more frequent drills around emergent procedures. In 12 cases, improvement opportunities were concerning medication orders by the anesthesia provider, and some of these overlapped with intubation issues. Coordination of care between anesthesiologists, obstetricians and intensivists was an area for improvement in five cases, and showed the need for better communication and handoffs among clinicians caring for very ill pregnant or postpartum women in key hospital areas, e.g., Emergency Department, Intensive Care Unit, postpartum floor, as well as Labor and Delivery.

An additional 15% of all maternal deaths had quality improvement opportunities related to the role of resuscitation practices. These were not the main driver for the cause of death but represented cases where the team could have improved their response to a maternal cardiovascular collapse. While resuscitation codes may be optimally conducted under the supervision of an anesthesiologist, all clinicians should be able to start resuscitations. In the findings, half of the QIOs related to resuscitation pointed to delays in clinician responses to acute maternal condition, for example, a six-minute delay in calling for a rapid response team. In a third of cases, the resuscitation issue was the delay or failure to deliver the baby emergently. The delays also highlight the important role for Maternal Early Warning Criteria, as an alternative approach, to rapidly escalate the level of intervention for ill mothers.²⁵ One study recently reported impressive reduction in severe maternal morbidity in a large California hospital system using such criteria.²⁶

Delays in clinician response highlight the important role for establishing Maternal Early Warning Criteria to rapidly escalate the level of intervention for ill mothers.

Resuscitation of a pregnant woman is complicated by the presence of a large pregnant uterus obstructing blood return to the heart. Therefore, a critical step for restoring cardiovascular function is prompt delivery of the fetus, generally within four-five minutes, now incorporated in national guidelines.²⁷ An important education point is that the resuscitation and emergent delivery needs to occur wherever the woman collapses (i.e., ‘codes’). Delays were common related to moving the

patient to the Operating Suite rather than rapidly addressing the issue where she was (for example, the Emergency Department). Every facility should review their policies for cardiovascular collapse to ensure appropriate information on pregnant women and the role of cesarean in the resuscitation.

Other improvement opportunities involving resuscitation efforts were identified in 11 of the deaths, with four related to the lack of a massive transfusion protocol; several related to techniques for resuscitating obese pregnant women or using left uterine displacement during resuscitation; and three cases where equipment issues were a problem.

Emergency Department

Among the pregnancy-related deaths, two-thirds of women received care in the Emergency Medicine Department (ED) at some time in the prenatal or postpartum period, with nearly 40% having more than two visits to the ED. The Committee identified quality improvement opportunities among nearly one-third of women who received care in the ED. In terms of timing of care, opportunities for quality improvement in the ED setting occurred most frequently among women presenting in the postpartum period (n=30), underscoring the need for clinicians to routinely assess whether a woman has been recently pregnant, just as they routinely ask about last menstrual period to assess for possible pregnancy. In particular, clinical warning signs of pain and shortness of breath in postpartum women were not associated with possible post-pregnancy complications in the ED. QIOs were identified in 17 cases during the prenatal period and 12 intrapartum.

In the Emergency Medicine Department setting, opportunities for quality improvement occurred most frequently among women presenting in the postpartum period, underscoring the need for clinicians to routinely assess whether a woman has been recently pregnant.

Our findings point to the need for better coordination of care, as well as improved consultation between ED clinicians and their obstetric colleagues. Key education points for ED clinicians identified in the QIOs included awareness of risk of cardiac condition among postpartum women presenting with severe chest pain or other symptoms; and best practices for managing resuscitation of pregnant women, particularly around optimal delivery in the context of a code. Increased awareness has emerged among ED providers of the need for training to care for pregnant women who experience cardiac arrest and timeframes for performing emergency or perimortem cesarean deliveries.²⁸

Maternal Levels of Care

Among the deaths, 51 (15%) involved issues related to facility readiness for the severity of the woman's health condition either because of health conditions prior to delivery or conditions that developed at the time of delivery. Not all hospitals have the same capacity for all levels of maternity care. Over one fourth (n=14) of the 51 women with QIOs related to maternal levels of care had

conditions identified in the prenatal period or early in their hospitalization that should have resulted in a plan of care with the appropriate specialists and at a facility prepared to manage their condition. For example, a woman with two prior cesareans and a placenta previa was not referred to a higher-level facility during prenatal care. When presenting in labor, there were delays in examining her and she was not transported, despite the likelihood of placenta accreta. Finally, during the surgical procedure, when the extent of the placenta accreta was recognized, the patient was not stabilized and transported. The woman's high-risk status was well established prior to the birth and there could have been a plan for care that included a high-risk pregnancy specialist and a facility that had adequate resources to manage her care. A total of 15 women who died experienced delays in transfer to a higher level of care, whether because the hospital where they were receiving care did not recognize the need for transfer, or encountered difficulty in locating a provider or specialist at a facility that could accept the transfer. One key translation activity from this finding is to create preexisting agreements regarding transfer of care between hospitals with differing capacity or maternal level of care.

Of the 51 deaths with issues related to maternal levels of care, about half (n=26) had a good-to-strong chance to alter the outcome, while the other half (n=25) had some chance. Other issues identified among this group of quality improvement opportunities include Emergency Medical Services (EMS) responding to critical calls and transporting severely ill pregnant women to the nearest hospital, which, in three cases, did not have obstetric services, or if it did, had a very low volume of births, and thus did not have access to specialist care. In two cases, patients went to hospitals that were not adequate to address their condition.

Regionalization of perinatal care is a conceptual and policy framework that classifies health care facilities according to their resources and expertise for high risk or specialized care. In practice, most hospitals are categorized by their level of neonatal intensive care, but few hospitals have designated maternal levels of care. In response to the increasing rates of women who enter pregnancy with high risk conditions, or who develop severe complications in pregnancy, and the rising U.S. maternal mortality rate, the American College of Obstetricians and Gynecologists and the Society for Maternal Fetal Medicine recently issued a joint "call for an integrated, regionalized framework to identify when transfer of care may be necessary to provide risk-appropriate maternal care for women with health conditions that warrant designation as high risk."²⁹

IMPLICATIONS AND RECOMMENDATIONS

What this maternal mortality review has revealed is the absolute need for all of us to work together to provide safe, timely and effective care to pregnant women and their families.

Elliott Main, MD

California Pacific Medical Center
California Maternal Quality Care Collaborative



6. Implications and Recommendations

The following conclusions and recommendations are based on the CA-PAMR Committee's systematic review of over 400 maternal deaths and the detailed case ascertainment described in the Appendix: Technical Notes. While the recommendations are aimed at further reducing mortality rates in the state, the clinically oriented recommendations may also help with the prevention, recognition, and response to severe maternal morbidity. Severe maternal morbidity is estimated to be 50 to 100 times more common than maternal mortality,^{30,31} thus the impact of actions taken based on in-depth review of roughly 80 deaths a year potentially extends to many more women.

CA-PAMR findings suggest five key recommendations:

- 1. Continue maternal mortality case reviews**
- 2. Improve data collection and analysis**
- 3. Anticipate more women entering pregnancy with chronic health conditions**
- 4. Integrate assessment of social factors impacting pregnancy**
- 5. Address provider and facility factors through ongoing maternity care quality improvement**

1. Continue Maternal Mortality Case Reviews

One of the most valuable aspects of initiating maternal mortality reviews is the ability to assess preventability and identify ways to reduce avoidable morbidity and mortality. Mortality reviews can improve understanding of what constitutes a pregnancy-related death through clinical case review, rather than relying on death certificate data alone. In the course of reviewing 427 cases in 33 daylong meetings over eight years, the CA-PAMR project created another powerful asset – the Review Committee. The expert Committee members who volunteered their time have become an incredible resource on maternal mortality for the state and nation. They accomplished this in several ways: contributing expertise from their professional experience and respective fields, serving as leaders on task forces for related toolkit development and implementation, promoting quality improvements within their healthcare institutions, and relaying key opportunities to the professional organizations they represent. The collective impact of these contributions by CA-PAMR Committee members has likely contributed to declining maternal mortality rates in California.

Although the focus of this report is obstetric deaths, CDPH is currently examining maternal mental health and deaths from suicide from 2002-2012. Building on lessons learned, the second Committee comprised of perinatal mental health specialists utilizes a more streamlined

methodology. The project goals are similar, however: to increase the capacity and actions of the perinatal mental health workforce within the state, with the aim of reducing preventable maternal mental health morbidity and mortality from suicide. Additionally, the linked datasets combined with the coroner, autopsy, and toxicology reports (i.e., core enhanced surveillance) enables monitoring and high-level description of trends for all causes. Findings from these reviews will be presented in a forthcoming report in the near future.

Valid and timely vital statistics data are fundamental for effective mortality surveillance and reviews.

2. Improve Data Collection and Analysis

A key action for California is to continue to develop its capacity to examine the numerous dimensions contributing to maternal mortality. Efforts are under way to examine trends in obstetric deaths using methodology that goes beyond monitoring maternal mortality rates, but does not require the resources needed to conduct data-intensive, in-depth case reviews. Since California initiated its maternal mortality review, the CDC, among other organizations, has developed new tools and methodology that can help streamline CA-PAMR processes going forward. As well, use of tools developed by the CDC would allow California and other states to more fully participate in national initiatives to improve surveillance of maternal mortality and inform ongoing quality initiatives to reduce maternal morbidity and mortality.

Improve Case Identification, Access to Timely Data, and Linkage Process

Public health surveillance systems are the framework typically used to monitor and report trends in maternal mortality, and through linkages of various datasets, to identify the cohort of women who die from any cause while pregnant or within one year postpartum. Thus, valid and timely vital statistics data are fundamental for effective mortality reviews.

Adopt the U.S. standard death certificate format for the pregnancy check box. A key recommendation to improve the quality of vital statistics data is for California to amend its death certificate to include the same format of the pregnancy check box as the U.S. standard death certificate. Currently, the California death certificate pregnancy check box asks whether the decedent was pregnant in the year prior to the death. A change to include whether the woman was pregnant at time of death, or if the death occurred within 42, or 43-365 days of the birth, will better define the timing of the death in relationship to the pregnancy or birth, and improve the accuracy of codes used to calculate maternal mortality rates. This change has been recommended for the upcoming updates to CDPH vital statistics forms and is likely to take effect in 2018.

Ensure timely review of maternal deaths. Another key step to improving California's surveillance of maternal mortality is developing the capacity to obtain and analyze more recent vital statistics data, even if on a provisional basis. As vital statistics information systems are modernized, CDPH

MCAH is developing data agreements with its vital statistics partners to acquire more timely data and thus avoid delays as annual datasets are finalized. These data agreements and the acquisition of quarterly provisional data will support a more timely review.

Refine and develop linkage processes. California developed a linkage methodology that combined hospital discharge data with vital records (birth, fetal and maternal death records) and these files serve to identify pregnancy-related deaths, deaths from violent causes, or other emerging issues. Over the past decade, the parameters of the linkage methodology were adjusted to reduce false positive cases and to verify evidence of pregnancy among women with “loose matches” meaning obstetric deaths reported on the death certificate that were not linked to a live birth or fetal death. Although this is a foundational step in setting up a mortality review and enhanced surveillance of maternal deaths, little guidance exists on how to accomplish this crucial step. States could benefit from documentation and standardization of core linkage considerations in order to help create consistency in the calculation of pregnancy-related mortality rates by establishing consistent denominators across states.

Communicate the Value of Autopsy and Coroner Reports

Autopsy reports and coroner investigations provide valuable information on maternal deaths in addition to the information obtained from medical records, and have proven to be particularly critical in determining certain causes of death, such as those from amniotic fluid embolism, cardiovascular disease and venous thromboembolism. The coroner and toxicology reports have been essential in the ongoing review of maternal suicides for determining whether deaths involving fatal drug overdoses may have been intentional or accidental. Autopsy findings can also contribute to more accurate death certificate completion and better systemic identification of obstetric deaths. Although standard guidelines exist for determining when a death is referred to the coroner, the CA-PAMR project found wide variation in the availability and comprehensiveness of reports across California. A key next step for maternal mortality reviews is to share this report with the forensic community and highlight the need and value of these reports, and consider inclusion of a Medical Examiner or board-certified forensic pathologist on review committees.

3. Anticipate More Women Entering Pregnancy with Chronic Health Conditions

The findings from the 2002-2007 case reviews demonstrate women had high rates of preexisting risk and chronic health conditions, intrapartum complications, and advanced maternal age. Most of these factors were higher than the average population of childbearing women, as described in Chapter 4. Accordingly, the following actions are warranted:

Improve Care for Women with Known Health Risk Factors

Clinicians (before, during and after pregnancy) and birthing facilities need to fully evaluate women who have known risk factors, including obesity, and other underlying medical conditions, and

establish a support plan that includes a full scope of care and services. In addition, clinicians and facilities need a well-defined plan to minimize risks for delivery and postpartum for women with underlying conditions, such as cardiovascular and autoimmune disorders, or beliefs that proscribe or prohibit certain types of care (e.g., blood transfusions among Jehovah's Witnesses).

Understand the Critical Importance of Care Transitions

CA-PAMR findings revealed that for some women, especially those with complex or severe medical and mental health issues, having better care transitions from clinic outpatient care to hospital inpatient care to home would have prevented their deaths. Improved hospital discharge planning and increased use of postpartum check-ups are both warranted, particularly for changing health status. California mandates coverage of maternity care by insurers. However, some women lose pregnancy Medi-Cal coverage 60 days post-delivery and even with improved insurance coverage due to California's implementation of the Affordable Care Act (ACA), these women can be lost to follow-up postpartum care.

Promote Prenatal Education and Self-Advocacy for Pregnant and Postpartum Women

Three-quarters of the women who died had at least one patient contributing factor, most commonly an underlying medical condition, or suffered from a lack of provider recognition of the seriousness of symptoms leading to delays in seeking care. Efforts are warranted to improve women's understanding of their individual risk factors and overall health, as well as the specific signs and symptoms indicating serious medical problems and need for follow-up. Likewise, primary care providers need to be aware of their role in helping women optimize their health prior to pregnancy. This information can help providers, in partnership with their patients, plan a course of care during pregnancy and postpartum, and prepare women to recognize the signs and symptoms of worsening health status and to seek care. Planning a course of care for the pre- and inter-conception periods, including attaining a healthy weight or receiving family planning services where appropriate, can help women optimize their health for subsequent pregnancies. Ideally, such plans will help increase the likelihood of pregnant women becoming better informed patients, so they are better able to self-advocate in complex and fragmented healthcare systems.

4. Integrate Assessment of Social Factors Impacting Pregnancy

In addition to medical care, health is shaped by social factors including income, education, neighborhood and working conditions, as well as early childhood experiences. Income and wealth affect access to health-promoting options, education helps shape healthy behaviors, and stressful conditions and experiences can contribute to unhealthy behaviors. Case reviews based primarily on medical records do not provide the full context and impact of social determinants of health on pregnancy-related

CA-PAMR confirmed the increased risk of mortality among African-American women and women with lower social and economic resources.

deaths. However, mortality review committee members can speak to issues of social factors in caring for pregnant and postpartum women based on their years of practice, and in turn, contribute those insights in the case review discussions, in teaching and mentoring clinicians, and in better risk assessment of patients.

Better Understand and Address Racial and Economic Disparities

CA-PAMR case reviews confirmed the increased risk of mortality for African-American women and women with lower social and economic resources. African-American women comprise nearly five and half percent of California mothers with a live birth but accounted for 21% of pregnancy-related deaths and 36% of pregnancy-related cardiovascular deaths. The persistent disparity in mortality may be greater than the three-to-fourfold higher risk in published statistics since nearly half of the cardiovascular deaths were not captured in the mortality statistics (i.e., not coded as an obstetric death on the death certificate). In addition, African-American women had higher cause-specific mortality rates for four of the leading seven causes of death identified in CA-PAMR (preeclampsia, venous thromboembolism, amniotic fluid embolism, and cardiovascular disease) compared to other race/ethnicities. On a more optimistic note, CA-PAMR observed no disparity for African-American women, compared to the rest of the women whose deaths were reviewed, in terms of the adequacy of prenatal care, overall preventability of the deaths, and the frequency or types of quality improvement opportunities.

Findings also confirm that women with lower socioeconomic means were disproportionately represented in maternal deaths. These deaths occurred among women who had delivery services paid for by California's public insurance program (Medi-Cal), which included pregnancy-eligible recipients in addition to women with ongoing eligibility. Such coverage is crucial for reducing disparities in access to health care and may be contributing to the decline in maternal mortality in California. However significant improvements can be realized with expanded eligibility through ACA, and improvements in continuity of care, especially in the postpartum period.

Improve Prenatal Screening and Treatment for Mental Health, Intimate Partner Violence, and Drug and Alcohol Use

Some women need expanded mental health and other specialized support during pregnancy or in the year following their pregnancy. Comprehensive prenatal and postpartum care should include screening and intervention for mental health conditions and behavioral health issues, such as intimate partner violence and drug and alcohol abuse. The majority of pregnant women in California receive prenatal care, and these interactions with providers present an opportunity to assess for high-risk situations, to probe further if the woman is in psychological or emotional distress, or in a potential homicidal environment (e.g., address whether there is access to firearms or intimate partner violence) and to make appropriate referrals and interventions. Screening for substance abuse in general, and in particular for opioid addiction, has also emerged as a general need. While California has an overall lower prevalence of opioid abuse than the U.S., there are regional pockets of abuse within the state which need increased attention and response. Screening for intimate partner violence is already required in hospitalized patients and highly encouraged for

clinicians based on guidelines from the U.S. Preventive Services Task Force and recommendations of the American Congress of Obstetricians and Gynecologists.

5. Address Provider and Facility Factors through Ongoing Maternity Care Quality Improvement

Support Large-Scale Maternal Quality Improvement Initiatives

The findings from CA-PAMR show the value of reviewing maternal deaths through several lenses, including patient, provider and health facility contributing factors and quality improvement opportunities. The lessons learned can be applied to large-scale and institution-specific quality improvement implementation projects to improve readiness, recognition, and response to preventable causes of maternal morbidity and mortality. The following insights and recommendations for common causes of pregnancy-related deaths have arisen after reviewing maternal deaths in California:

- **Maternal Hemorrhage**—The primary recommendation for hospitals is to adopt a standard plan for assessing risk of hemorrhage, adoption of treatment protocols, and training for all clinicians to include practice drills and debriefs in order to be prepared to rapidly respond to the rare event of a massive hemorrhage emergency.
- **Hypertensive Disorders of Pregnancy**—All maternity clinicians and birthing facilities need a standardized plan for early recognition and aggressive management of severe hypertension in pregnant and postpartum women. The maternal deaths described in this report were largely due to stroke as a result of uncontrolled severe blood pressure.
- **Venous Thromboembolism** —This very preventable cause of morbidity and mortality is best addressed with standardized use of prophylaxis for blood clots among women with significant risk factors.
- **Cardiovascular Disease**—The findings from maternal deaths led to the development of a triage tool to identify women, African-American women in particular, for cardiac evaluation during pregnancy and postpartum. In the setting of symptoms and risk factors, clinicians need to consider cardiac diagnosis when encountering complaints common to late pregnancy/early postpartum and cardiovascular disease such as shortness of breath, fatigue, swelling of lower extremities, and anxiety.
- **Clinical warning signs**—Small changes in vital signs such as blood pressure, heart rate, oxygen saturation and temperature, can be big clinical warnings. Because most pregnant women are healthy, clinicians may overlook such small changes. PAMR cases revealed that many signs of worsening clinical status were not perceived as an early warning sign, resulting in delayed diagnosis and treatment.

- **Improved communications**—In addition to implementing standardized protocols for preventable causes of maternal morbidity and mortality, hospitals and clinicians need to prioritize effective communications between nursing staff, obstetric physicians and other medical specialists for timely, responsive treatment, and for transfer of care when needed.

Address Issues of Overuse

Hospitals and clinicians need to address issues of potential overuse of labor induction and cesareans. These procedures are generally safe, but should be restricted to cases with clear medical indications, because of the short- and long-term morbidities associated with both labor induction and cesareans. In particular, cesarean or surgical deliveries appear to drive the need for blood transfusions, especially among obese women, who were more likely than non-obese women to have given birth via cesarean. Because prior cesareans can put women at risk, primary cesareans should be limited to only those that are medically indicated. Almost a quarter of the women who died had a Pitocin-induced labor and over a third of those resulted in cesareans. Additionally, over half (56%) of the amniotic fluid embolism deaths had induced labors, more than any other cause.

Underscore the Emergency Medicine Department as Site of Care

The Committee identified quality improvement opportunities among nearly one-third of cases in which women visited the Emergency Medicine Department (ED). Among the CA-PAMR maternal deaths, two-thirds of women received care in the ED during or after pregnancy, with nearly 40% having more than two visits to the ED. Key education points identified for ED clinicians include:

- Awareness of risk of a potential cardiac condition among postpartum women presenting with severe chest pain or other symptoms
- Protocols around appropriate imaging (CAT scans, MRIs, X-rays) during pregnancy, when indicated by patient symptoms.
- Best practices for managing resuscitation of pregnant women, particularly around optimal delivery timing in the context of cardiopulmonary resuscitation

ED clinicians need to assess women of reproductive age, not just for current pregnancy status but for pregnancy in the past few months, in order to formulate a more accurate plan for diagnosis and care. The CA-PAMR findings also point to the need for better coordination of care, as well as improved consultation between ED clinicians and their obstetric colleagues.

TRANSLATION ACTIVITIES

These case reviews shine a glaring light on racial disparities in maternal death and major pregnancy complications. The care we provide must be accessible, culturally sensitive and equitable for African-American women and other marginalized communities.

Kimberly Gregory, MD, MPH

University of California, Los Angeles,
David Geffen School of Medicine and
Cedars Sinai Medical Center



7. Translation Activities

California Maternal Quality Care Toolkits Informed by CA-PAMR

From its inception, a key rationale for the CA-PAMR was to translate the findings into quality improvement activities with the goal of improving maternal outcomes. The California Department of Public Health contracted with the California Maternal Quality Care Collaborative (CMQCC) at Stanford University to develop four maternal quality care toolkits that have been informed by CA-PAMR findings, including preventability, contributing factors and quality improvement opportunities for each cause of death. For each toolkit, a Task Force was convened, comprised of multidisciplinary experts from diverse institutional settings across California, who contributed to the substantive content and also served as reviewers for the entire toolkit. Each Task Force also included representatives who provided important perspectives on the patient and family experience of a severe maternal event. All toolkits are freely available to download at www.cdph.ca.gov and www.cmqcc.org. The rationale for each toolkit and implementation activities are briefly described below.

CA-PAMR has informed the development of a series of Toolkits to assist and guide maternity clinicians and birth facilities to improve their readiness, recognition, and response to preventable causes of maternal morbidity and mortality.

Obstetric Hemorrhage

Obstetric hemorrhage was the first topic to emerge as a critical focus for maternity improvement from CA-PAMR findings. This cause of death had the highest rates of preventability and many opportunities for improvement were identified. Rapid recognition and treatment are necessary to prevent progression of hemorrhage as women can lose large volumes of blood very quickly due to the physiologic changes of pregnancy. Obstetric hemorrhage is a low-volume, high-risk event for any given birth facility: without advance planning, the probability of mounting a rapid, coordinated response is low.

The *Improving Healthcare Response to Obstetric Hemorrhage Toolkit*²¹ was first released in 2010 followed by an updated version in March 2015. The primary aim of the toolkit is to guide and support obstetrical providers, clinical staff, hospitals and healthcare organizations to develop methods within their facilities for timely recognition and an organized, swift response to hemorrhage. The latest version features a modified format to improve usability, as well as updated best practices around risk assessment, active management of third stage labor, and prevention and treatment recommendations.

CMQCC conducted two consecutive OB Hemorrhage Quality Improvement Learning Collaboratives. Beginning in January 2010, 30 hospitals enrolled in the first collaborative, which ended in December

2010. In January 2011, a second collaborative began and ended December 2011. Nine new facilities joined the second collaborative and 15 continued from the first collaborative. All CMQCC collaborative cohorts represented approximately 120,000 California births.

Preeclampsia

Hypertensive disorders of pregnancy, including gestational hypertension, preeclampsia and eclampsia are a leading cause of maternal mortality occurring in 12-22% of pregnancies.³² These disorders are responsible for approximately 17% of maternal mortality in the U.S.³³ CA-PAMR found a similar incidence of maternal mortality related to preeclampsia and associated syndromes, with an overall mortality rate among the pregnancy-related deaths of 1.6/100,000 from 2002 to 2007. All of these deaths were determined to have at least some chance to alter the outcome, with half having a strong-to-good chance to alter the outcome.

The *Improving Healthcare Response to Preeclampsia Toolkit*³⁴ was released in January 2014. The goal of the toolkit is to guide and support obstetrical providers, clinical staff, hospitals and healthcare

Cardiovascular disease has emerged as the leading cause of maternal mortality in the U.S. and California and encompasses a range of cardiac conditions including cardiomyopathy.

organizations to develop methods within their facilities for timely recognition and organized, swift response to preeclampsia and to implement successful quality improvement programs for preeclampsia that will decrease short- and long-term preeclampsia-related morbidity in women who give birth in California. The toolkit provides a series of

articles on best practices for hypertensive disorders that range in topics from diagnostic challenges to appropriate implementation of accepted medical therapy and recognition of institutional limitations in providing care for complex maternal patients. Of particular interest, the toolkit addresses the management of severe preeclampsia < 34 weeks gestational age, the importance of recognition and treatment of delayed postpartum preeclampsia/eclampsia in the Emergency Department, and early postpartum follow-up upon discharge. In addition, the toolkit provides care guideline summaries in checklist, flowchart and table chart formats.

CMQCC convened a Preeclampsia Quality Improvement Learning Collaborative from January 2013 through August 2014. The collaborative involved 26 hospitals of all levels of care that were evenly distributed throughout California. These hospitals represented approximately 154,368 births over a 24-month period.

Cardiovascular Disease in Pregnancy and Postpartum

Cardiovascular disease (CVD) has emerged as the leading cause of maternal mortality in the U.S. and California and encompasses a range of cardiac conditions including cardiomyopathy.^{4,33} There is a significant overlap between signs and symptoms of cardiac disease and those of normal pregnancy, specifically shortness of breath, fatigue and swelling. In-depth review of California deaths indicated that only a small fraction of the women had a known diagnosis of CVD prior to death despite having

presented with symptoms either during pregnancy or shortly after childbirth.⁴ Therefore, healthcare providers must familiarize themselves with risk factors, warning signs and physical findings that suggest an underlying cardiac problem and necessitate further work-up. One fourth of the deaths were judged preventable if heart disease had been included in the differential diagnosis and timely diagnosis and treatment were received.

The *Improving Healthcare Response to Cardiovascular Disease in Pregnancy and Postpartum Toolkit* was released in 2017. The toolkit will serve as a resource for obstetrics, primary care, and Emergency Medicine providers who interact with women during prenatal, intrapartum and postpartum periods. The key elements include an algorithm for clinicians to apply to symptomatic or high-risk pregnant or postpartum women to guide stratification and initial work-up. The toolkit contains brief sections for clinicians on necessary resources for caring for women with congenital or other cardiovascular disease, sections on contraception counseling, and cardiovascular medications appropriate during pregnancy and while breastfeeding. The toolkit also features information and infographics geared directly for women diagnosed with or at risk of CVD. These include signs and symptoms of CVD, future CVD risk and long-term health issues, and patient education on contraceptive options and planning a pregnancy with known CVD.

Venous Thromboembolism

Pregnancy related venous thromboembolism (VTE), which includes both deep vein thrombosis (DVT) and pulmonary embolism (PE), is one of the leading causes of maternal morbidity and mortality. Findings from the 2002-2007 CA-PAMR show that VTE accounted for 9% (n=29) of all maternal deaths, with an overall pregnancy-related mortality risk of 0.9 maternal deaths per 100,000 live births. Nearly all of these deaths (97%) had at least some chance of preventability and more than half of them (52%) had a good-to-strong chance.

The *Improving Healthcare Response to Venous Thromboembolism Toolkit* was released in Winter 2018. The overall goal of the toolkit will focus on developing recommendations for risk stratification to identify patients at risk for VTE, targeted thromboprophylaxis, use of sequential compression devices, anesthesia and special consideration strategies for cesarean deliveries, and the obese population. The toolkit will align with and support the National Partnership for Maternal Safety VTE Bundle by providing every California hospital with evidence-based recommendations for practice and care processes. The VTE bundle is organized into four domains: readiness, recognition and prevention, response, and reporting of system learning. Each facility/unit will be able to individualize the specific components of the VTE toolkit to fit their particular culture and available resources.

National Initiatives

National Partnership for Maternal Safety

Formed in 2012 as a project of the [Council on Patient Safety in Women's Health Care](#), the purpose of the initiative is to address the rising rates of severe maternal morbidity and mortality in the U.S. through the creation of Maternal Safety Bundles. Bundles are small, straightforward sets of evidence-

based practices that, when performed collectively and reliably, have been proven to improve patient outcomes. The goal of the National Partnership for Maternal Safety is for every birthing facility in the U.S. to have three core Maternal Safety Bundles implemented within their facility within three years. Maternal Safety Bundles have been developed to address the following topics:

- Maternal Mental Health: Depression and Anxiety
- Maternal Venous Thromboembolism
- Obstetric Hemorrhage
- Reduction of Peripartum Racial/Ethnic Disparities
- Safe Reduction of Primary Cesarean Birth
- Severe Hypertension in Pregnancy
- Support after a Severe Maternal Event

CMQCC, with funding from Merck for Mothers, is helping to implement three of the safety bundles in California through the California Partnership for Maternal Safety Project.

Alliance for Improvement of Maternity Care – AIM

<http://www.safehealthcareforeverywoman.org/aim.html>

Launched in 2014, AIM is a national partnership of organizations convened with the goal of reducing severe maternal morbidity by 100,000 events and maternal mortality by 1,000 deaths by 2018. The AIM program is funded through a cooperative agreement with the Maternal and Child Health Bureau of the Health Resources and Services Administration. The AIM goals are to align national, state, and hospital level efforts to improve maternal health and safety and to promote maternal safety bundle implementation to ensure consistent maternity care. Currently in ten states, AIM facilitates multidisciplinary and interagency collaboration between states and hospitals, supports harmonized data-driven continuous quality improvement processes, and provides evidence-based implementation resources to streamline bundle implementation.

Building U.S. Capacity to Review and Prevent Maternal Deaths

<http://www.cdcfoundation.org/building-us-capacity-review-and-prevent-maternal-deaths>

<http://reviewtoaction.org/>

Building U.S. Capacity to Review and Prevent Maternal Deaths promotes maternal mortality review as the best way to understand rising rates of maternal mortality and prioritize interventions that effectively reduce pregnancy-related death. It supports essential review functions to enable data to be combined across jurisdictions for national learning that was previously not possible. The project is a partnership between the Centers for Disease Control and Prevention, the Association of Maternal and Child Health Programs, and the CDC Foundation with funding from Merck, through an award agreement with its *Merck for Mothers* program. The Maternal Mortality Review Information Application (MMRIA) supports and standardizes record abstraction; case summary development;

documentation of committee decisions; and routine analysis – critical steps of the maternal mortality review process. The companion Review to Action website connects jurisdictions with a maternal mortality review committee (MMRC) or those interested in establishing one to best practices, resources, and support and raises awareness of the potential of committees to effect change and eliminate preventable maternal deaths.



THE RISE AND FALL OF MATERNAL MORTALITY RATES IN CALIFORNIA

Public health surveillance alerts us to shifts in the population's health and in regards to maternal mortality, California has learned and responded but we must remain ever vigilant.

Connie Mitchell, MD, MPH

Deputy Director

Center for Family Health

California Department of Public Health



8. The Rise and Fall of Maternal Mortality Rates in California

California's maternal mortality rate increased from 7.7 deaths per 100,000 live births in 1999 to 16.9 deaths per 100,000 live births in 2006, consistent with a rise in U.S. rates (Figure 13). In California, the average maternal mortality rate was 14.0 deaths per 100,000 live births for the three-year period of 2006 to 2008. African-American women had three-to-four times higher rates of maternal death over the same time period. In 2006-2008 the rates of maternal mortality were 46.1 per 100,000 live births for African-American women, and respectively, 12.8, 12.4, and 9.3 deaths per 100,000 live births for Hispanic, White, and Asian/Pacific Islander women (Figure 14).

Figure 13: Maternal Mortality Rates, California Residents and U.S., 1999-2008

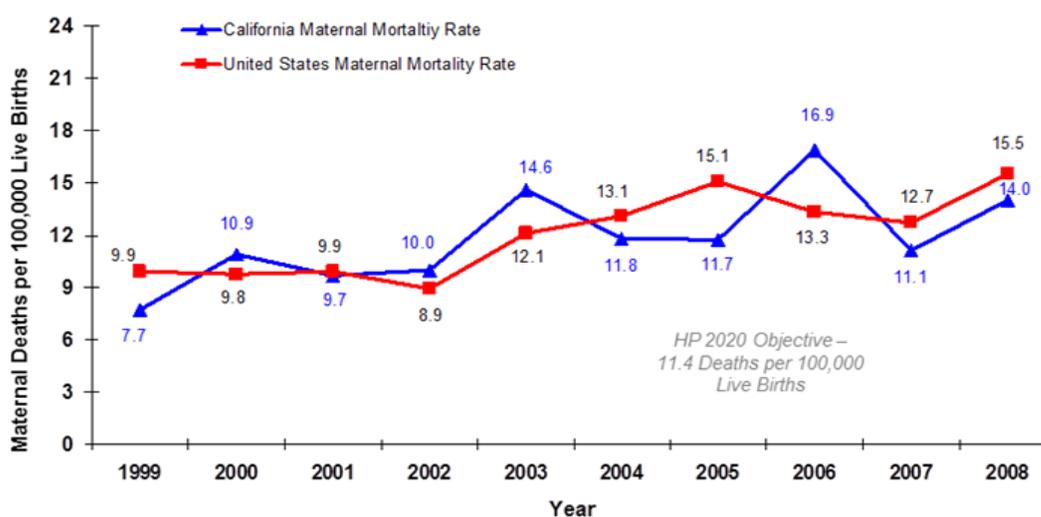
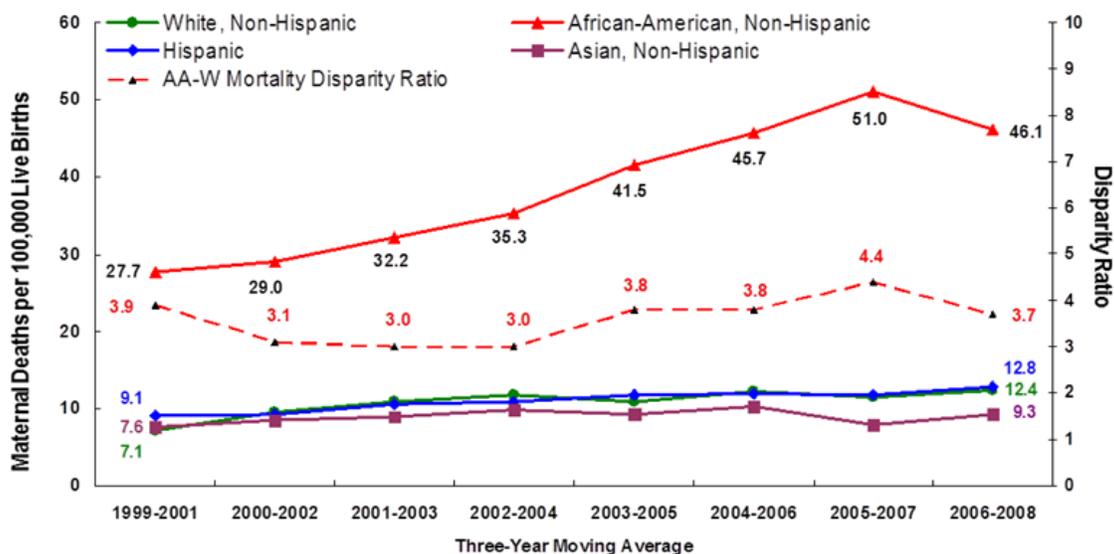


Figure 14: Disparities in Maternal Mortality Rates by Race/Ethnicity, California Residents, 1999-2008



Rates of maternal mortality increased with age, with women in the oldest group (ages 40-54 years) having three to five times the rates of maternal mortality compared to younger aged women (data not shown). In 2006-2008, women ages 40-54 had a maternal mortality rate of 51.7 deaths per 100,000 live births, compared to 16.3, 15.4, 12.1, and 11.7 deaths per 100,000 live births for women ages, 35-39, 30-34, 25-29, and 20-24 years, respectively.

What Caused the Rise in Maternal Mortality?

Four interrelated hypotheses may explain the observed rise in maternal mortality and associated racial/ethnic disparities. Where possible, we present evidence supporting these hypotheses, based upon our case review of six years of maternal deaths.

Are there better methods to identify pregnancy-related deaths?

Improvements to the coding of underlying cause of death in 1999, with the introduction of ICD-10 codes more specific to pregnancy-related causes of death, and an addition to the U.S. Standard Death Certificate in 2003, may account for increases in maternal mortality estimates. In 2003, the 'pregnancy check box' was added to California's death certificate to determine whether the decedent had been pregnant in the year prior to her death. States adopted this field at varying times between 2003 and 2016 and in varying formats, with California adopting the field in 2003 in a non-standard format (i.e., specifying only if the decedent was pregnant within the past year, and not delineating timeframes of pregnancy or postpartum). An early national study estimated that the addition of the pregnancy check box accounted for about 30% of the apparent increase in maternal deaths.³⁵ Recently, two studies examined the impact of states' adoption of the pregnancy check box on rising national maternal mortality rates and concluded that rates rose in correlation with the eventual adoption by all 50 states.^{36,37}

In California, maternal mortality rates rose 30% between 1999 and 2002 with the introduction of new ICD-10 codes. Rates further rose 46% between 2002 and 2003 once the pregnancy check box was introduced in 2003. Better data may account for some of the increase in maternal mortality; better data is unlikely to fully account for the additional increase

Through case reviews, CA-PAMR was able to find evidence that the rise in maternal mortality from 1999 through 2006 was related to the following:

- **Improvements to the coding of underlying cause of death**
- **Increasing maternal age or increasing prevalence of co-morbidities**
- **Social factors such as lower socioeconomic status, low levels of social support or coping skills, chronic exposure to social stressors such as racism, or differential access to health care**
- **Numerous quality of healthcare factors**

between 2003 and 2006. However, better data also reveals the degree to which pregnancy-related deaths were under-ascertained prior to 2003.

Are women entering pregnancy at greater risk due to older ages or with more chronic health conditions?

Increasing maternal age or increasing prevalence of co-morbidities, including obesity, could have also contributed to the rise in maternal mortality. Table 8 shows changes in age and the prevalence of select conditions among childbearing women in California during the years of rising maternal mortality. There was a slight increase (4%) in the proportion of births to women over 40 years of age, although the average age remained roughly the same from 2002 to 2007. Additionally, during the six-year span when maternal mortality increased, obesity prevalence increased 10.5%, diabetes increased by 27.6%, primarily driven by increases in gestational diabetes, and hypertension increased by 13.8%, largely driven by increases in chronic hypertension.⁵

Table 8: Prevalence of Maternal Morbidity among California Hospital Deliveries, 2002-2007

Maternal Morbidity and Age	Year		Percent Change
	2002 %	2007 %	
Births among women ages 40 and over* (proportion of all California births)	3.4	3.5	+4.0%
Obesity: BMI >30kg/m ² **	14.3	15.8	+10.5%
Diabetes***			
Any diabetes	5.8	7.4	+27.6%
Preexisting diabetes	0.81	0.80	-1.2%
Gestational diabetes	5.0	6.7	+32.0%
Hypertension***			
Any hypertension	5.8	6.6	+13.8%
Chronic hypertension	0.7	1.2	+71.4%
Gestational hypertension	4.7	4.9	+19.5%
Cardiovascular disease***	0.66	0.55	-16.7%

Data sources:

* State of California, Department of Public Health, Birth Records <http://www.cdph.ca.gov/data/statistics/Documents/VSC-2007-0201.pdf>

** From the Maternal and Infant Health Assessment (MIHA). See Technical Notes for a description of MIHA.

*** Percent of all hospital deliveries with conditions listed in the patient discharge dataset in California.⁵

Technical Notes provide additional detail on ICD-9 CM codes for diabetes, hypertension, and cardiovascular disease, and MIHA.

The observed changes in population-based risk factors are reflected in our findings of increased mortality among older women ([Table 3](#), [Figure 5](#)), obese women ([Figure 7](#), [Figure 8](#)), and women with

comorbidities, which were included in our aggregate medical risk classification ([Table 5](#)). For example, among the 235 women identified as having medical risk factors (i.e., not-low-risk) at the time of birth hospitalization, the prevalence of diabetes was double that of the childbearing population for any diabetes (16.2%) and was almost four times higher for any hypertension (24.3%). Importantly, when these conditions were present, the Committee determined that diabetes and hypertension contributed to 72% and 74% of the deaths respectively. The prevalence of cardiovascular disease among childbearing women actually lowered during the CA-PAMR review period, but was nearly 15 times more prevalent in the CA-PAMR cohort (8.9%) and proved to be the leading cause of pregnancy-related deaths.

Are social and economic factors playing a role?

In addition to medical factors, social factors such as lower socioeconomic status, low levels of social support or coping skills, chronic exposure to social stressors such as racism, or differential access to health care may have played an important role in the increase of maternal mortality. Our findings point to the impact of poverty, drug use, potential lack of social support, homelessness, intimate partner violence and incarceration. Women who died were more likely to be African-American, lack a partner, have public insurance (Medi-Cal), have lower educational attainment, and, use alcohol, tobacco or illegal drugs during pregnancy ([Table 6](#)). Nearly 10% of the women were homeless or incarcerated while pregnant, and 12% had a mental illness diagnosis noted in the medical record. Mental illness is a medical issue, and one which likely exacerbates many of the social risk factors noted among this population.

The effect of social determinants on health is increasingly established within public health. Our findings suggest that data on social factors should be considered when examining contributors to maternal mortality.^{38,39} While we do not have baseline population comparisons for all factors, and are unclear whether there was increased prevalence of significant social risk factors among women entering pregnancy, we observed that pregnancy-related deaths among women in California likely involved non-medical, as well as medical factors.

Are factors related to quality of care playing a role?

The CA-PAMR data demonstrate that numerous healthcare factors were present and contributory in the 2002-2007 pregnancy-related deaths. Many of the key findings from CA-PAMR point to the presence of contributing factors and quality improvement opportunities that come under the purview of healthcare facilities and healthcare clinicians—nurses and physicians as well as other clinical care providers. The identified provider issues include delayed response to clinical warning signs, ineffective care and misdiagnosis ([Figure 10](#)), while facility issues involved poor coordination of care between various departments and specialties, and inadequate knowledge of appropriate treatment protocols ([Figure 11](#)). Insights gleaned from CA-PAMR case reviews regarding the role of provider, facility, and patient issues have

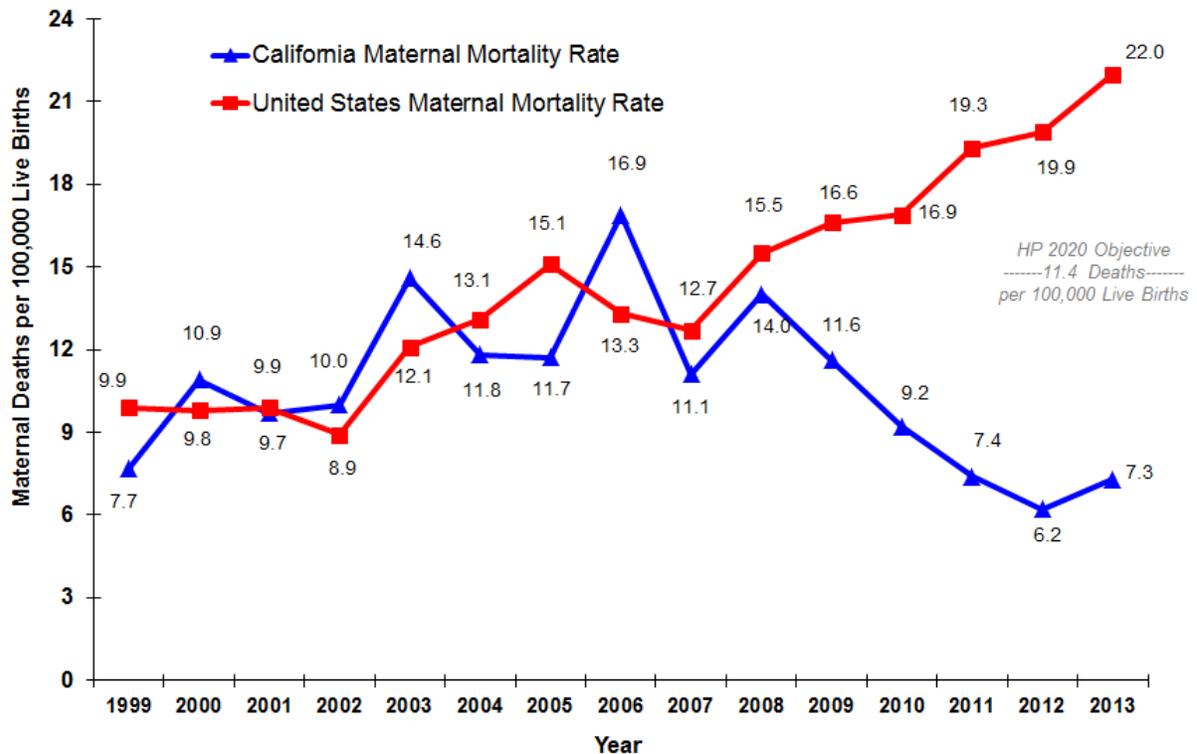
Fourteen percent (14%) of all pregnancy-related deaths were determined to be at least partially attributed to cesarean sections.

informed the development and statewide implementation of the California Toolkits to Transform Maternity Care series. The toolkits, described in Chapter 7, aim to improve facility and clinician readiness to recognize and respond to pregnancy and birth complications for leading and preventable causes of pregnancy-related death such as hemorrhage, preeclampsia, venous thromboembolism and cardiovascular disease.

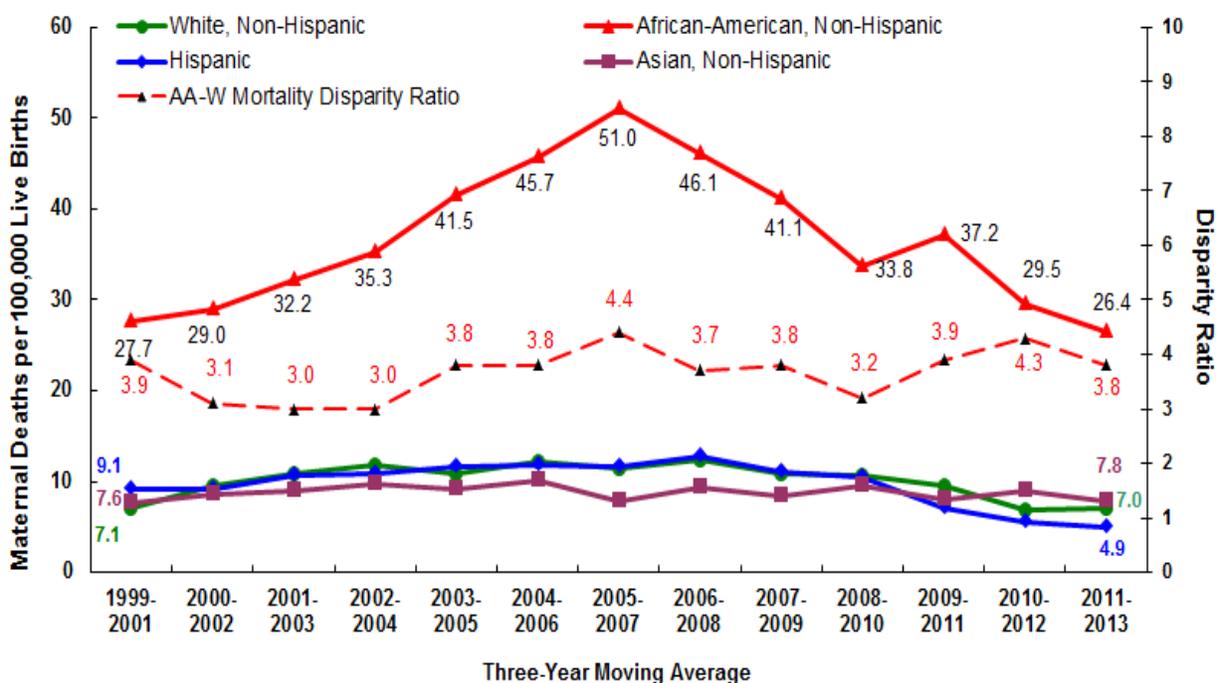
CA-PAMR also looked at the reasons why women had cesareans and the contribution of this mode of delivery to the increase in pregnancy-related deaths. We found that the majority of cesareans performed were for women who were in critical condition or to save the life of the fetus while the woman was undergoing resuscitation. Cesareans, whether current or prior, were determined to be contributory to the woman's death (i.e., for typical postoperative complications such as blood clots and infection) in 14% of all pregnancy-related deaths. Midway through this review period, we asked whether labor inductions (any method) played a role in increasing mortality, and found this obstetrical procedure to contribute to deaths in five percent of women who were induced. The Committee did not assess the reasons for the inductions, but found a correlation between labor induction and over half of the amniotic fluid embolism deaths and a third of the venous thromboembolism deaths.

What Is Contributing to the Decline in California Maternal Mortality?

After a steady rise in maternal mortality from 1999-2006, California observed a sustained decline in maternal mortality since 2008. In 2013, the rate was nearly half at 7.3 deaths per 100,000 live births compared to 2008 (Figure 15). With this decline, California has achieved and surpassed the Healthy People 2020 objective for maternal mortality rate of 11.4 deaths per 100,000 live births. The decline in mortality rates continued during 2009 and 2010 despite the H1N1 influenza epidemic, which disproportionately affected pregnant women. Although California accounts for one in eight births nationally, U.S. maternal mortality rates increased while California's decreased. By 2013, U.S. rates were estimated to be triple those of California.

Figure 15: Maternal Mortality Rates, California Residents and U.S., 1999-2013

California's maternal mortality rates declined 51% when comparing three-year average rates; rates dropped from 14.0 deaths per 100,000 live births in 2006-2008 to 6.9 deaths per 100,000 live births in 2011-2013 ($p < 0.0001$). Hispanic and African-American women had the sharpest declines in mortality among racial/ethnic groups. Mortality rates declined 62% and 43% among Hispanic and African-American women, respectively, between 2006-2008 and 2011-2013 ($p < 0.001$, $p = 0.009$). Rates for women in the oldest age group (ages 40-54 years) showed sharp declines in mortality with a 52% reduction between 2006-2008 and 2011-2013, resulting in a rate of 22.4 deaths per 100,000 live births in 2011-2013 ($p < 0.001$). Even when excluding these three populations (older women, African-American and Hispanic women) from the statewide mortality rate, the decline in California's maternal mortality rate remained significant ($p = 0.003$). Statistically significant declines occurred among all race/ethnicities except Asian/Pacific Islander women, all age groups except for women <25 years, across all education levels, and among both U.S.- and foreign-born women. Despite such progress, African-American women continued to be 3.8 times more likely to die in 2011-2013, compared to White women (Figure 16).

Figure 16: Disparities in Maternal Mortality Rates by Race/Ethnicity, California Residents, 1999-2013

What changed in California?

CDPH MCAH allocated Title V MCH funds to improve maternal health through numerous mechanisms; we have confidence that the decline in maternal mortality likely reflects the collective impact of these public health investments. Specifically, in 2006 CDPH MCAH convened the in-depth CA-PAMR maternal mortality review, funded the launch of the California Maternal Quality Care Collaborative (CMQCC), and implemented a statewide Preconception Health Program. In 2010, CDPH funded two large county Maternal Health programs to address maternal mortality issues most affecting their childbearing population. As described in Chapter 7, CDPH MCAH funded the development and dissemination of a series of Toolkits to Transform Maternity Care by translating CA-PAMR findings into actionable steps; the first toolkit was released in 2010.

The decline in maternal mortality also likely reflects the strong engagement of California care providers that was facilitated by CMQCC leadership. Several large-scale quality improvement initiatives have led to improvements in the quality of obstetric care overall and particularly improved clinician and facility readiness to respond to emergent situations at the time of labor and delivery. This engagement took multiple forms including hospital quality improvement learning collaboratives, toolkits and the task forces that developed them, as well as increased awareness among a wide range of maternity care leaders, insurers, and facility stakeholders throughout the state.

The strong partnerships with care providers in California occurred within a larger context of heightened national attention to rising maternal mortality by federal health partners at the CDC Division of Reproductive Health, Health Resources and Services Administration Maternal and Child Health Bureau, and by national professional organizations such as The Joint Commission, the American Congress of Obstetricians and Gynecologists, the Society for Maternal-Fetal Medicine, and the Association of Women's Health, Obstetric and Neonatal Nurses. Many organizations concerned with maternal health outcomes have focused their attention and developed initiatives to address the growing problem of maternal mortality and morbidity. Key stakeholders, including many California leaders, met frequently to increase collaborative and cross-organizational efforts to improve maternal outcomes. These national efforts have likely also contributed to declines in maternal mortality in California.

The decline in California's maternal mortality rate reflects the collective impact of:

- **Public health investments**
- **Strong leadership of maternity care providers**
- **Increased attention to the issue by partners and press**

Are social and economic factors playing a role?

The U.S. economic recession from 2008-2014 likely played a role in California's decline in that California suffered severe economic setbacks and was one of the last states to recover from the recession.⁴⁰ The overall birth rate decreased and poor, at risk women have been shown to use more secure methods of contraception during economic uncertainty,⁴¹ although this is a phenomena that is likely to have been a variable in all U.S. states.

If rates went up because of better reporting, were there other coding or ascertainment changes that could explain the current decline in rates?

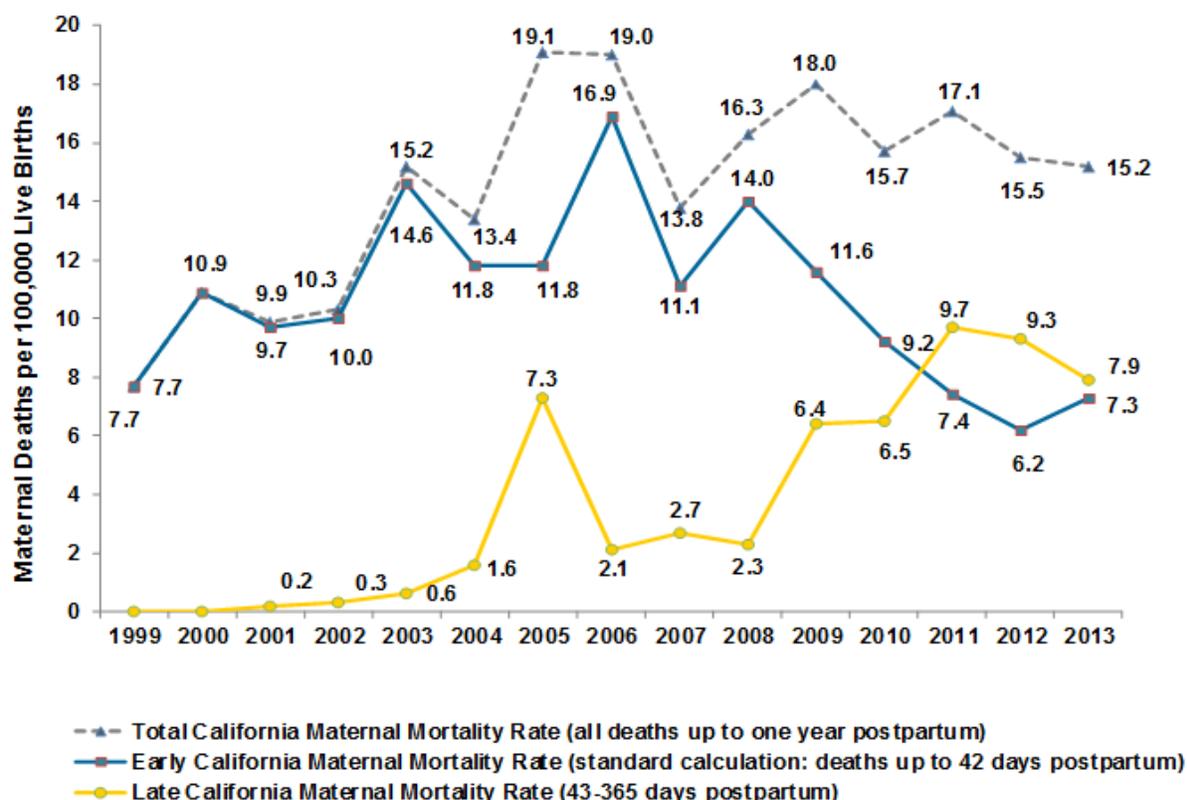
While better ascertainment contributed to some part of the observed rise in maternal mortality, we verified that the decline in maternal mortality was not an artifact of vital statistics coding. The codes used to calculate maternal mortality rates are supposed to correspond to the designated timeframe 'while pregnant or ≤ 42 days postpartum.' However, from experience and from linkage of vital records, CA-PAMR knew that some 'early' deaths in California were actually coded as late deaths (43-365 days postpartum) and therefore were not reflected in the maternal mortality rate. We checked the accuracy of time to death through the linkage of birth and maternal and fetal death records, and recalculated trends in maternal mortality rates (data not shown). Even after this methodological correction, a statistically significant decline in maternal mortality of roughly the same magnitude (47% reduction, $p < 0.0001$) was observed between 2008 and 2013.

If pregnancy-related and pregnancy-associated mortality includes deaths up to one year, but maternal mortality rates only cover through 42 days postpartum, what happens to the 'late' maternal mortality rate after 42 days postpartum?

Overall, when both early (<42 days postpartum) and late (43-365 days postpartum) maternal deaths are included, the combined mortality rate (0-365 days postpartum) during 2008 and 2013 decreased

by 20% ($p=NS$). However, 'late' maternal deaths, as defined solely by coding on the death certificate (43-365 days postpartum), have increased since 2008 while early deaths have decreased in California. Late maternal deaths increased significantly by an alarming 274% from a three-year moving average of 2.4 deaths per 100,000 live births in 2006-2008 to 9.0 deaths in 2011-2013 ($p<0.0001$) (Figure 17). Increases were greatest among older (>40 years), U.S.-born, African-American, and women with lower educational attainment (<high school or GED) (data not shown). This finding remains even when correcting for possible miscoding in the ICD-10 codes and pregnancy check box response, as described above.

Figure 17: Early, Late and Total Maternal Mortality, California Residents, 1999-2013



Maternal mortality may be shifting to encompass more late postpartum deaths among older women, or as chronic diseases, like hypertension and cardiovascular disease, play an increasingly prominent role affecting women's underlying health status. Peripartum cardiomyopathy, a type of cardiovascular disease unique to pregnancy which typically occurs in the last month of pregnancy through the fifth month postpartum needs to be monitored to assess its contribution to the increase in late maternal deaths.^{4,10,42} Better care at the time of labor and delivery may reduce deaths related to an acute, serious medical event but deaths may be occurring later due to complications of the severe event such as sepsis or cerebral vascular accident (stroke). Also, pregnancy is a qualifying condition for Medi-Cal coverage for women who might not be on Medi-Cal full-time. This temporary Medi-Cal coverage for pregnancy expires after 60 days however, and increased late deaths may reflect a lack of access to care

or a change in the quality of care during the 2008 to 2013 time period. [Note: the Affordable Care Act, including Medicaid expansion, was implemented in California in October, 2013.] The rise in late maternal deaths occurs among women with both private and public health insurance however, and underscores the need for appropriate discharge planning, the importance of postpartum check-ups, and identification of any services needed beyond the typical six-week window for postpartum visits.

The rise in late maternal deaths underscores the need for appropriate discharge planning, the importance of postpartum check-ups, and the urgency to identify any services needed beyond the typical six-week window for postpartum visits.

Data trends regarding late maternal mortality are as important to monitor as early maternal deaths in order to understand the true epidemiology of maternal mortality up to one year postpartum, to learn whether certain causes of death have improved or emerged, and to develop effective prevention strategies.

Conclusion

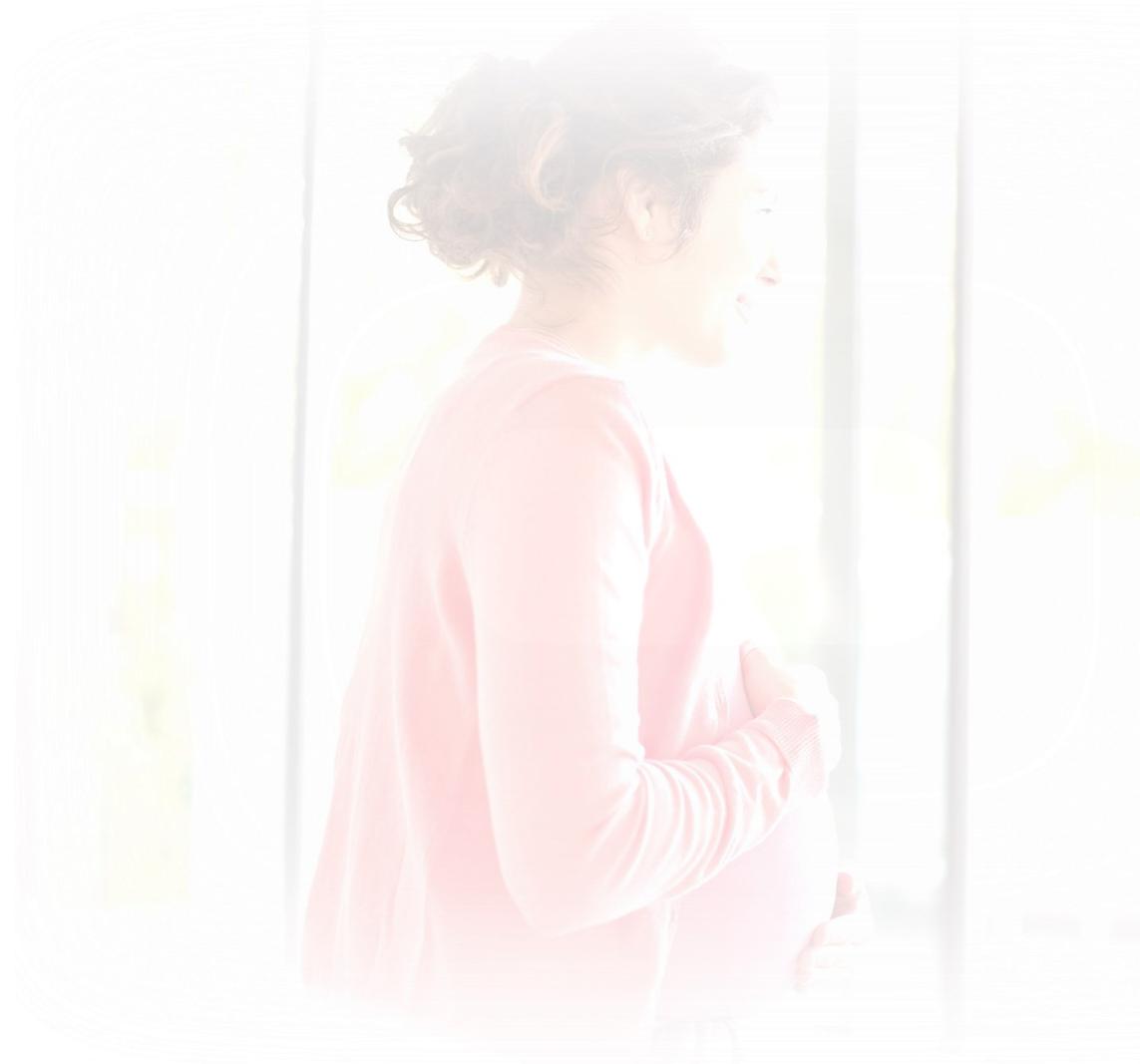
California has made significant progress in reducing maternal deaths while a woman is pregnant or within six weeks postpartum, but there is considerable opportunity to reduce postpartum maternal deaths occurring later (43-365 days). Additional analysis is needed in order to understand whether certain obstetric causes of death were reduced in response to the quality improvement initiatives that have been implemented aimed at improving recognition and response to obstetric hemorrhage preeclampsia, cardiovascular disease and venous thromboembolism. Further efforts will be needed to better understand the factors that lead to persistent disparities in maternal mortality and morbidity among African-American women in California. Lastly, CA-PAMR will continue to monitor and evaluate emerging issues such as Zika virus infection, the impact of the current opioid epidemic and recent legalization of cannabis in California on health outcomes for pregnant and postpartum women. Deaths related to pregnancy should be a rare and reportable event, and when they occur, their investigation can lead to valuable insight and intervention to save lives.

References

1. California Department of Public Health. *The California Pregnancy-Associated Mortality Review. Report from 2002 and 2003 Maternal Death Reviews*. Sacramento, CA. 2011.
2. Creanga AA, Syverson C, Seed K, Callaghan WM. Pregnancy-Related Mortality in the United States, 2011-2013. *Obstet Gynecol*. 2017;130(2):366-373.
3. Cantwell R, Clutton-Brock T, Cooper G, et al. Saving Mothers' Lives: Reviewing maternal deaths to make motherhood safer: 2006-2008. The Eighth Report of the Confidential Enquiries into Maternal Deaths in the United Kingdom. *BJOG*. 2011;118 Suppl 1:1-203.
4. Hameed AB, Lawton ES, McCain CL, et al. Pregnancy-related cardiovascular deaths in California: beyond peripartum cardiomyopathy. *Am J Obstet Gynecol*. 2015;213(3):379 e371-310.
5. Fridman M, Korst LM, Chow J, Lawton E, Mitchell C, Gregory KD. Trends in maternal morbidity before and during pregnancy in California. *Am J Public Health*. 2014;104 Suppl 1:S49-57.
6. Kuklina EV, Tong X, Bansil P, George MG, Callaghan WM. Trends in pregnancy hospitalizations that included a stroke in the United States from 1994 to 2007: reasons for concern? *Stroke*. 2011;42(9):2564-2570.
7. Institute of Medicine. *Weight Gain During Pregnancy: Reexamining the Guidelines*. Rasmussen KM, Yaktine AL, eds. Washington, DC. 2009.
8. Menacker F, Hamilton BE. Recent trends in cesarean delivery in the United States. *NCHS data brief, no. 35*. Hyattsville, MD: National Center for Health Statistics. 2010.
9. California Department of Public Health. *MIHA Report 2013-2014: Data from the Maternal and Infant Health Assessment (MIHA) Survey*. Sacramento, CA. 2016.
10. Clark SL, Belfort MA, Dildy GA, Herbst MA, Meyers JA, Hankins GD. Maternal death in the 21st century: causes, prevention, and relationship to cesarean delivery. *Am J Obstet Gynecol*. 2008;199(1):36 e31-35; discussion 91-32 e37-11.
11. Clark SL, Koonings PP, Phelan JP. Placenta previa/accreta and prior cesarean section. *Obstet Gynecol*. 1985;66(1):89-92.
12. Clark SL, Miller DD, Belfort MA, Dildy GA, Frye DK, Meyers JA. Neonatal and maternal outcomes associated with elective term delivery. *Am J Obstet Gynecol*. 2009;200(2):156 e151-154.
13. Knight M, Kurinczuk JJ, Spark P, Brocklehurst P, United Kingdom Obstetric Surveillance System Steering C. Cesarean delivery and peripartum hysterectomy. *Obstet Gynecol*. 2008;111(1):97-105.
14. Declercq E, Barger M, Cabral HJ, et al. Maternal outcomes associated with planned primary cesarean births compared with planned vaginal births. *Obstet Gynecol*. 2007;109(3):669-677.
15. Kuklina EV, Meikle SF, Jamieson DJ, et al. Severe obstetric morbidity in the United States: 1998-2005. *Obstet Gynecol*. 2009;113(2 Pt 1):293-299.
16. Spong CY. Prediction and prevention of recurrent spontaneous preterm birth. *Obstet Gynecol*. 2007;110(2 Pt 1):405-415.
17. Wen SW, Rusen ID, Walker M, et al. Comparison of maternal mortality and morbidity between trial of labor and elective cesarean section among women with previous cesarean delivery. *Am J Obstet Gynecol*. 2004;191(4):1263-1269.
18. American College of Obstetricians and Gynecologists. *ACOG Committee Opinion no. 560: Medically Indicated Late-Preterm and Early-Term Deliveries*. April 2013. <https://www.acog.org/Resources-And-Publications/Committee-Opinions/Committee-on-Obstetric-Practice/Medically-Indicated-Late-Preterm-and-Early-Term-Deliveries>. Accessed July 15, 2017.

19. Dekker RL, Morton CH, Singleton P, Lyndon A. Women's Experiences Being Diagnosed With Peripartum Cardiomyopathy: A Qualitative Study. *J Midwifery Womens Health*. 2016;61(4):467-473.
20. Patel H, Berg M, Barasa A, Begley C, Schaufelberger M. Symptoms in women with peripartum cardiomyopathy: a mixed method study. *Midwifery*. 2016;32:14-20.
21. Lyndon A, Lagrew DC, Shields LE, Main EK, Cape V. *Improving Health Care Response to Obstetric Hemorrhage*. 2015. Stanford University, California Maternal Quality Care Collaborative; Palo Alto, CA.
22. Creanga AA, Bateman BT, Butwick AJ, et al. Morbidity associated with cesarean delivery in the United States: is placenta accreta an increasingly important contributor? *Am J Obstet Gynecol*. 2015;213(3):384 e381-311.
23. Hawkins JL. Anesthesia-related maternal mortality. *Clin Obstet Gynecol*. 2003;46(3):679-687.
24. Mhyre JM, Riesner MN, Polley LS, Naughton NN. A series of anesthesia-related maternal deaths in Michigan, 1985-2003. *Anesthesiology*. 2007;106(6):1096-1104.
25. Mhyre JM, D'Oria R, Hameed AB, et al. The maternal early warning criteria: a proposal from the national partnership for maternal safety. *J Obstet Gynecol Neonatal Nurs*. 2014;43(6):771-779.
26. Shields LE, Wiesner S, Fulton J, Pelletreau B. Comprehensive maternal hemorrhage protocols reduce the use of blood products and improve patient safety. *Am J Obstet Gynecol*. 2015;212(3):272-280.
27. Lipman S, Cohen S, Einav S, et al. The Society for Obstetric Anesthesia and Perinatology consensus statement on the management of cardiac arrest in pregnancy. *Anesth Analg*. 2014;118(5):1003-1016.
28. Healy ME, Kozubal DE, Horn AE, Vilke GM, Chan TC, Ufberg JW. Care of the critically ill pregnant patient and perimortem cesarean delivery in the emergency department. *J Emerg Med*. 2016;51(2):172-177.
29. American College of Obstetricians and Gynecologists. *Obstetric Care Consensus. Levels of Maternal Care*. March 2015. <https://www.acog.org/Resources-And-Publications/Obstetric-Care-Consensus-Series/Levels-of-Maternal-Care>. Accessed July 15, 2017.
30. Callaghan WM, Creanga AA, Kuklina EV. Severe maternal morbidity among delivery and postpartum hospitalizations in the United States. *Obstet Gynecol*. 2012;120(5):1029-1036.
31. Creanga AA, Berg CJ, Ko JY, et al. Maternal mortality and morbidity in the United States: where are we now? *J Womens Health (Larchmt)*. 2014;23(1):3-9.
32. American College of Obstetricians and Gynecologists. *ACOG Practice Bulletin. Diagnosis and Management of Preeclampsia and Eclampsia*. Number 33, January 2002. Also appears in *Int J Gynaecol Obstet*. 2002 Apr; 77(1):67-75.
33. Creanga AA, Berg CJ, Syverson C, Seed K, Bruce FC, Callaghan WM. Pregnancy-related mortality in the United States, 2006-2010. *Obstet Gynecol*. 2015;125(1):5-12.
34. Druzin M, Shields LE, Peterson NL, Cape V. *Improving Health Care Response to Preeclampsia*. 2014. Stanford University, California Maternal Quality Care Collaborative; Palo Alto, CA.
35. Hoyert DL. Maternal mortality and related concepts. *Vital Health Stat 3*. 2007(33):1-13.
36. MacDorman MF, Declercq E, Cabral H, Morton C. Recent increases in the U.S. maternal mortality rate: disentangling trends from measurement issues. *Obstet Gynecol*. 2016;128(3):447-455.
37. Joseph KS, Lisonkova S, Muraca GM, et al. Factors underlying the temporal increase in maternal mortality in the United States. *Obstet Gynecol*. 2017;129(1):91-100.
38. Institute of Medicine: *Unequal Treatment: Confronting Racial and Ethnic Disparities in Health Care*. Smedley BD, Stith AY, Nelson AR, eds. Washington, DC. 2003.

39. Knight M, Kurinczuk JJ, Spark P, Brocklehurst P, Ukoss. Inequalities in maternal health: national cohort study of ethnic variation in severe maternal morbidities. *BMJ*. 2009;338:b542.
40. Allegretto SA, Reidenbach, L. Shrunken Public Sector Stunts California's Recovery. *California Public Employee Relations Journal Online* 2012; <http://irle.berkeley.edu/files/2012/Shrunken-Public-Sector-Stunts-Californias-Recovery.pdf>. Accessed July 30, 2017.
41. Finer LB, Zolna MR. Declines in unintended pregnancy in the United States, 2008–2011. *New England Journal of Medicine*. 2016;374(9):843-852.
42. Kuklina EV, Callaghan WM. Cardiomyopathy and other myocardial disorders among hospitalizations for pregnancy in the United States: 2004-2006. *Obstet Gynecol*. 2010;115(1):93-100.
43. Mitchell C, Lawton E, Morton C, McCain C, Holtby S, Main E. California Pregnancy-Associated Mortality Review: mixed methods approach for improved case identification, cause of death analyses and translation of findings.
44. Main EK, McCain CL, Morton CH, Holtby S, Lawton ES. Pregnancy-related mortality in California: causes, characteristics, and improvement opportunities. *Obstet Gynecol*. 2015;125(4):938-947.



Appendix: Technical Notes

Data Sources

The following data sources were gathered and synthesized to support the mortality review.

Data Source	Purpose
<ul style="list-style-type: none"> CDPH Statistical Master Birth file CDPH Statistical Master Death file CDPH Statistical Master Fetal Death file CDPH Birth Cohort file: Contains data for all live births that occurred in a calendar year and death information for those infants who were born in that year but subsequently died within 12 months of birth. California Office of Statewide Health Planning and Development (OSHPD), Patient Discharge Dataset (PDD) 	To identify the pregnancy-associated cohort, time to death, birth and other hospitalizations if applicable
<ul style="list-style-type: none"> Coroner/Medical Examiner investigations, autopsy and toxicology reports 	To confirm evidence of pregnancy, identify manner of death, and provide pathological evidence to confirm causes of death
<ul style="list-style-type: none"> Medical records for all prenatal, delivery admission, and postpartum encounters 	To build the chronological case summary
<ul style="list-style-type: none"> Anesthesia records, echocardiogram results, Emergency Department records 	To inform specific causes of death and deaths occurring at particular sites of care

Comparisons of the general population of women who gave birth in California during the study period were made with the pregnancy-associated cohort and the pregnancy-related deaths.

Data Source	Purpose
<ul style="list-style-type: none"> CDPH Statistical Master Birth file CDPH Birth Cohort file 	To compare demographic characteristics, gestational age, adequacy of prenatal care
<ul style="list-style-type: none"> The Maternal and Infant Health Assessment Surveys (MIHA).⁸ MIHA is an annual representative statewide survey of over 6,800 postpartum women. It is the California equivalent of the CDC's Pregnancy Risk Assessment Monitoring Survey (PRAMS). Positive toxicology results 	To compare behavioral data, social risk factors and prevalence of obesity

Case Ascertainment

Maternal and fetal death certificates, infant birth certificates, and patient hospital discharge records were linked to identify the pregnancy-associated cohort for 2002 to 2007. Once this initial linkage was conducted, coroner reports were requested for all cases and further confirmation was done to ensure that all of the identified cases did indeed fall within one year of a pregnancy or birth. This process, which we refer to as ‘core enhanced surveillance,’ has been previously described.^{43,44} From this, the final cohort of pregnancy-associated deaths is created. The cohort is comprised of women whose deaths occurred during or within a year of pregnancy and includes all causes of death. For this review, we screened for deaths likely to be pregnancy-related due to obstetric and medical causes and then built case summaries for Committee review. We excluded deaths from homicide, suicide, drug overdose, and motor vehicle and other accidental deaths, because of limited resources and the large number of births and deaths in the state.

Maternal Mortality Calculations

The maternal mortality rate measures obstetric deaths while pregnant or within 42 days postpartum per 100,000 live births. Rates are calculated in a standard manner by public health authorities at the local, state, national (e.g., the National Center for Health Statistics of the Centers for Disease Control, Healthy People 2020) and international (e.g., the World Health Organization) levels.

- Numerator: The number of deaths with the underlying cause of death on the death certificate (for 1999 to present) with the following ICD-10 codes A34, O00-O95, O98-O99.
- Denominator: The number of live births, per year.
- Rate: [number of maternal deaths (defined in the numerator) / number of live births] x 100,000

U.S. rates were published through 2007 and obtained from CDC WONDER (<https://wonder.cdc.gov>) system thereafter.

Codes for Pregnancy-Associated Cohort

The following codes correspond to data presented on the pregnancy-associated cohort in Figure 2.

Obstetric Deaths

- Preeclampsia/eclampsia: O11, O13-O16
- Obstetric hemorrhage: O20, O44-O66, O67, O72; D65-D69
- Amniotic fluid embolism: O22.3, O88
- Cardiovascular disease: O90.3, O99.4
- Sepsis/infection: O01-O5.5, O85
- Liver-related: O26.6
- Non-specific causes
 - Other direct obstetric: O10, O12, O21-O43, O47-O66, O68-O71, O73-O75
 - Other unspecified obstetric: O95

- Other indirect obstetric: O98-O99, excluding O99.4
- Other complications pertaining to the pregnancy and puerperium: O85-O87, O89-O92 (excluding O90.3; O97)

Non-Obstetric Deaths

- Other medical conditions:
 - Any codes not otherwise listed in obstetric and non-obstetric causes of death
- Motor vehicle and other accidental deaths:
 - ICD-10 Group numbers: 295-311, and 312,326, 328, 330
- Homicide: ICD-10 Group number 338-346
- Alcohol and other drug-related causes: ICD-10 Group numbers 327, 347
- Suicide: ICD-10 Group numbers 331-337
- Undetermined: ICD-10 Group numbers 348-352

Codes for Maternal Morbidity Data

Maternal morbidity data presented in Table 12 are identified by International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes present at the delivery hospitalization and are obtained from the Office of Statewide Planning and Development hospital discharge dataset.

Notes:

- For the ICD-9-CM codes listed below, those lacking a first and second numeral after the decimal point include all potential subcategories.
- For identification of cardiovascular disease, ICD-9-CM codes included diagnoses made during hospitalization or conditions were present on admission (POA)

Diabetes

- Any diabetes: 250, 648.0, 648.8
- Preexisting diabetes: 250, 648.0
- Gestational diabetes: 648.8

Hypertension

- Any hypertension: 401-405, 642.0-642.7, 642.9
- Chronic hypertension: 401-405, 642.0-642.7
- Gestational hypertension: 642.3-642.6

Cardiovascular Disease

Rheumatic heart disease	390-398 + POA for all	Acute myocarditis	422 + POA
Congenital heart disease	648.5	Other pericardial	423 + POA
Other heart disease	414, 416, 417, 424, 429	Cardiomyopathy	425 + POA
Acute myocardial infarction	410-411 + POA	Conduction disorders	426 + POA
Angina	413 + POA	Dysrhythmias	427 + POA
Acute pulmonary heart disease	415 + POA	Heart failure	428 + POA
Acute pericarditis	420 + POA	Operations on heart and pericardium	35-37, 39
Acute/subacute pericarditis	421 + POA		

Maternal Infant Health Assessment (MIHA)⁹

MIHA is an annual, statewide-representative survey of women with a recent live birth in California. MIHA participants are English- or Spanish-speaking women aged 15 years and older who have had a live birth. From 1999 through 2009, approximately 3,500 women participated each year. Beginning in 2010 the number of MIHA participants increased to nearly 7,000, which allows data to be available for the 20 counties with the largest number of births. Starting in 2013, the sampling plan was expanded to include the top 35 counties with the largest number of births. MIHA data are weighted to represent all eligible women in California with a live birth during each survey year. MIHA has maintained a response rate of approximately 70%. Data are collected by mail with telephone follow-up to non-respondents. The questionnaire covers a wide range of maternal and infant experiences, and maternal attitudes and behaviors before, during and shortly after pregnancy.

The MIHA questionnaire and methods are similar to those used by the Centers for Disease Control and Prevention (CDC) in conducting the multi-state Pregnancy Risk Assessment Monitoring System (PRAMS). Some local health jurisdictions in California also conduct similar surveys, such as the Los Angeles Mommy and Baby Survey and the Shasta County Mother Infant Health Survey.

Confidentiality and Institutional Review Board Approval

All CA-PAMR Committee members and persons involved in data procurement and analysis signed confidentiality agreements and a recusal policy before reviewing any material related to the maternal deaths. The Committee for the Protection of Human Subjects of the State of California Health and Human Services Agency approved all CA-PAMR protocols, data abstraction forms and contact letters. The Institutional Review Boards of the Public Health Institute and Stanford University deemed the study exempt. All protocols comply with the Health Insurance Portability and Accountability Act (HIPAA) privacy rules. All data regarding patients, providers and hospitals were de-identified within the documents available to reviewers.



VISIT THE CALIFORNIA DEPARTMENT OF PUBLIC HEALTH:

<http://www.cdph.ca.gov>

VISIT MATERNAL, CHILD AND ADOLESCENT HEALTH:

<https://www.cdph.ca.gov/Programs/CFH/DMCAH>

CONNECT WITH US:

<http://twitter.com/CAPublicHealth>

<https://www.youtube.com/user/CAPublicHealth>

<https://www.facebook.com/CAPublicHealth>