

A Series of Anesthesia-related Maternal Deaths in Michigan, 1985-2003

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Background: Maternal Mortality Surveillance has been conducted by the State of Michigan since 1950, and anesthesia-related maternal deaths were most recently reviewed for the years 1972-1984.

Methods: Records for pregnancy-associated deaths between 1985 and 2003 were reviewed to identify 25 cases associated with a perioperative arrest or major anesthetic complication. Four obstetric anesthesiologists independently classified these cases, and disagreements were resolved by discussion. Precise definitions of anesthesia-related and anesthesia-contributing maternal death were constructed. Anesthesia-related deaths were reviewed to identify the chain of medical errors or care management problems that contributed to each patient death.

Results: Of 855 pregnancy-associated deaths, 8 were anesthesia-related and 7 were anesthesia-contributing. There were no deaths during induction of general anesthesia. Five resulted from hypoventilation or airway obstruction during emergence, extubation, or recovery. Lapses in either postoperative monitoring or anesthesiology supervision seemed to contribute to 5 of the 8 anesthesia-related deaths. Other characteristics common to these cases included obesity (n = 6) and African-American race (n = 6).

Conclusions: The 8 anesthesia-related and seven anesthesia-contributing maternal deaths in Michigan between 1985 and 2003 illustrate three key points. First, all anesthesia-related deaths from airway obstruction or hypoventilation took place during emergence and recovery, not during the induction of general anesthesia. Second, system errors played a role in the majority of cases. Of concern, lapses in postoperative monitoring and inadequate supervision by an anesthesiologist seemed to contribute to more than half of the deaths. Finally, this report confirms previous work that obesity and African-American race are important risk factors for anesthesia-related maternal mortality.

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§ Division of Reproductive Health: Activities: Maternal and Child Health Epidemiology Program; Participating State: Michigan. Center for Disease Control and Prevention. Available at: <http://www.cdc.gov/reproductivehealth/MCH/Epi/Michigan.htm>. Accessed August 8, 2006.

ANESTHETIC complication is the seventh leading cause of pregnancy-related mortality in the United States, accounting for 1.6% of all pregnancy-related deaths.¹ Although rare, anesthesia-related maternal mortality is potentially preventable.

The causes of anesthetic induced mortality have evolved over time. For example, obstetric deaths associated with regional anesthesia declined in the mid-1980s.² The decline was attributed the withdrawal of 0.75% bupivacaine, increased awareness of local anesthetic toxicity, and the use of test dosing for epidural catheters. In recent reviews, failed intubation during general anesthesia remains an important cause of anesthesia-related maternal death.³⁻⁵ In response, anesthetic practice has shifted to rely more heavily on regional anesthesia for cesarean delivery^{6,7} and thereby minimize the need for invasive airway management in obstetrics. Concomitant clinical and educational efforts have focused on strategies to manage the difficult airway.^{8,9}

Maternal Mortality Surveillance has been conducted by the State of Michigan since 1950, and anesthesia-related maternal deaths were most recently reviewed for the years 1972-1984.¹⁰ In this retrospective study, case files of all pregnancy-associated deaths recorded in the State of Michigan between 1985 and 2003 were reviewed to determine whether the recent focus on airway management in obstetric anesthesiology has influenced the causes of anesthesia-related maternal death for women in Michigan.

Materials and Methods

This protocol was approved by the University of Michigan Health System Privacy Board and the Michigan Department of Community Health. Maternal death reporting is not mandatory in Michigan. Since its inception in 1950,¹¹ Michigan Maternal Mortality Surveillance (MMMS) relied on voluntary reports by hospitals, medical examiners, other health and social service providers, and newspaper obituaries.¹⁰⁻¹⁵ Beginning in 1990, the Michigan Department of Community Health has matched death certificates for women of reproductive age (10-45 yr old) with live birth certificates for that year and the previous year.^{13,15,16} Starting in 1999, the Michigan Department of Community Health electronically linked women's death certificates with live birth certificates and fetal death files.^{13,16§}

A pregnancy-associated death is defined as the death of a woman while pregnant or within 1 yr of the termination of pregnancy, irrespective of cause.¹⁷ A pregnancy-

Table 1. Number of Postpartum Days during Which a Death Was Considered Pregnancy-associated and Included in Case Ascertainment Procedures by the State of Michigan

Years	Postpartum Days
1985–1986	42
1987–1989	90
1990–1991	180
1992–2003	365

related death is defined as the death of a woman while pregnant or within 1 yr of termination of pregnancy from any cause related to or aggravated by her pregnancy or its management, but not from accidental or incidental causes.¹⁷ The relevant postpartum interval used by the State of Michigan to define a pregnancy-associated death increased over the course of the study as illustrated in table 1. Once a pregnancy-associated death is identified, the MMMS coordinator requests available hospital records, autopsy reports, death certificates, and, when applicable, birth certificates. For deaths not attributed to cancer or injury, a senior obstetrician reviews all material and generates a standardized summary. These summaries are presented to the MMMS Medical Review Committee members, who categorize each death as to cause, preventability, and responsible factors (patient, physician, hospital, or community) and determine whether the death was pregnancy-associated or pregnancy-related.¹³ The primary records, case summaries, and committee data sheets comprise the case files.

Records for all pregnancy-associated deaths were reviewed by two authors to identify 25 cases in which an anesthetic complication (table 2) seemed to take place during the time the patient was under the care of an anesthesia provider. For each of the 25 cases, the authors extracted maternal age, race, marital status, insurance, highest level of education, gravidity, parity, height,

Table 2. Complications of Anesthesia

- Aspiration of gastric contents
- Failed intubation
- Esophageal intubation
- Other problems with the induction of general anesthesia
- Inadequate ventilation
- Airway obstruction
- Respiratory failure
- High spinal or massive epidural
- Neuraxial cardiac arrest
- Local anesthetic toxicity
- Drug reaction
- Anaphylaxis
- Overdose of sedatives
- Prolonged hypotension or hypertension
- Intraoperative cardiac arrest during anesthesia of undetermined etiology

Cases were identified for further review if one of the listed complications of anesthesia occurred while the patient was under the care of an anesthesia provider. Each complication has been previously recognized in reviews of anesthesia-related maternal mortality or in reviews of the American Society of Anesthesiologists Closed Claims Database.^{2,4,14–16}

weight, cause and timing of death relative to the termination of pregnancy, contributing causes leading to death, autopsy findings, and conclusions of the MMMS Medical Review Committee. An abbreviated narrative of the course of events included the surgical or obstetric procedure, urgency of the procedure, anesthetic management techniques, airway management techniques, and complications of anesthesia.

Four obstetric anesthesiologists independently reviewed and classified the 25 cases as anesthesia-related, anesthesia-contributing, or not related to anesthesia. Cases were initially categorized with reference to definitions published by Endler *et al.*¹⁰ in a previous review of anesthesia-related maternal death in Michigan. According to these definitions, “Primary cause was defined as a death attributable to anesthesia, either as the result of the medications used, method chosen, or the technical maneuvers performed, whether iatrogenic in origin or resulting from an abnormal patient response. A contributory factor was defined as death to which anesthesia contributed, but one that would likely have occurred even in the absence of an anesthetic intervention.”¹⁰

Disagreements among the four reviewers were resolved through an iterative process in which the reviewers sequentially refined the definitions of anesthesia-related and anesthesia-contributing maternal mortality and applied these definitions to the 25 cases as well as to examples in the literature.^{2,3,10,18,19} Discussion continued until all cases could be categorized with unanimous agreement. This resulted in a formal procedure to determine whether a case qualified as an anesthesia-related or anesthesia-contributing maternal death (fig. 1). Two obstetricians reviewed the definition procedure illustrated in figure 1 to ensure consistent terminology with the obstetric literature.

Last, anesthesia-related deaths were reviewed to identify the chain of medical errors or care management problems that contributed to each patient death. Medical errors were defined as the failure of a planned action to be completed as intended or the use of an inappropriate plan to achieve an aim.²⁰ Care management problems included actions or omissions by staff in the process of care, in which care deviated beyond safe limits of practice and in which the deviation had a direct or indirect effect on the eventual adverse outcome for the patient.²¹ In cases where the impact on the patient was unclear, it was determined to be sufficient in our study that the care management problem had a potentially adverse effect.²¹

The Health Data Development Section of the Michigan Department of Community Health provided data on the proportion of live births to African-American women.

Results

From 1985 through 2003, 855 pregnancy-associated deaths were reported to the State of Michigan (fig. 2). Of

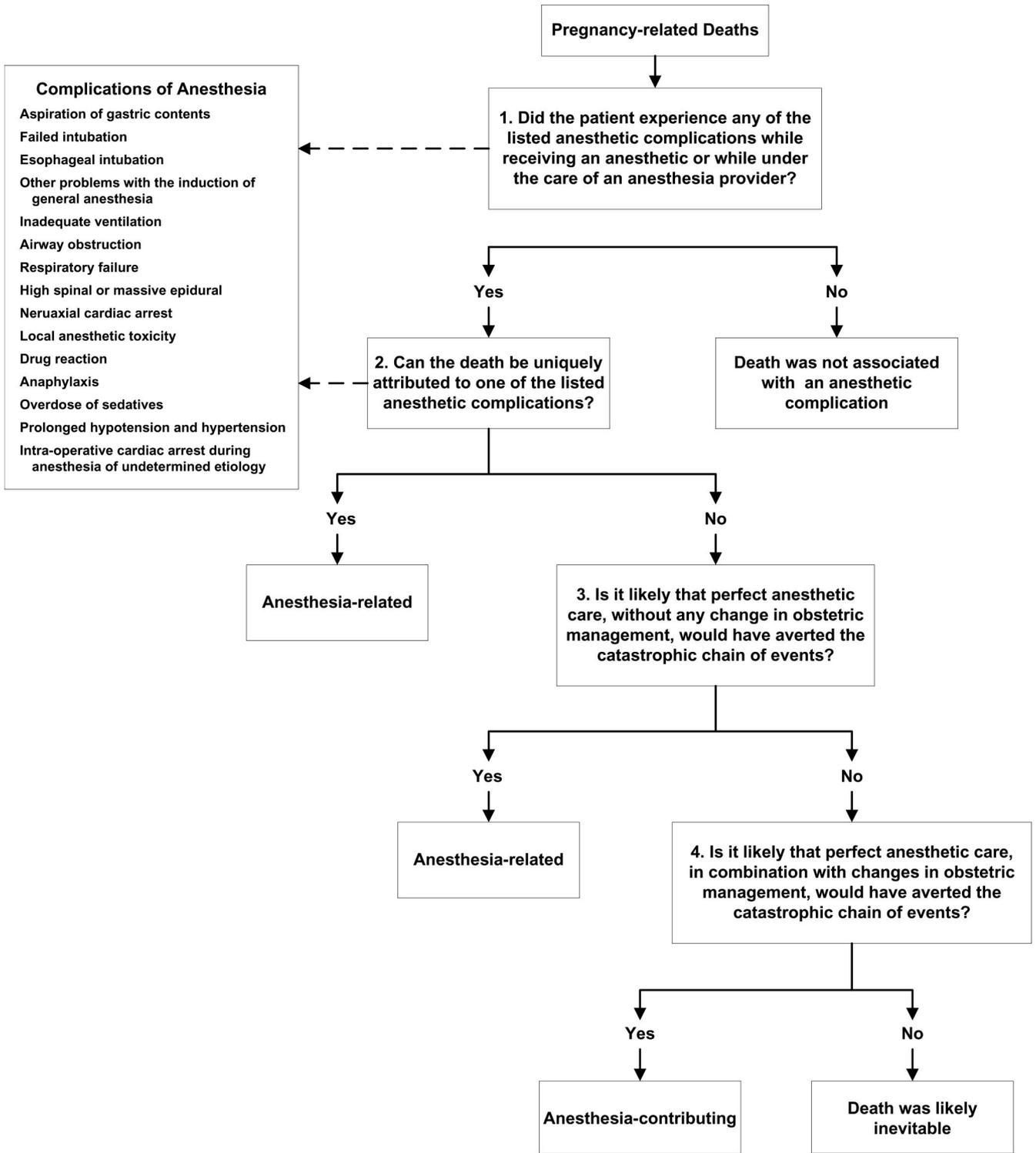


Fig. 1. Four questions to categorize pregnancy-related deaths as anesthesia-related, anesthesia-contributing, or not relevant to obstetric anesthesia.

these pregnancy-associated deaths, 349 were pregnancy-related. The procedure to categorize a case as an anesthesia-related maternal death is presented in figure 1. There were eight such fatalities, accounting for 2.3% of all pregnancy-related deaths.

Demographic data are presented in table 3. The mean

age of the eight patients who died was 31.2 yr, and 75% were African-American. From 1985 through 2003, 17.8% of live births in the State of Michigan were to African-American women.

Details of each anesthesia-related maternal death are provided in table 4. There were no deaths associated

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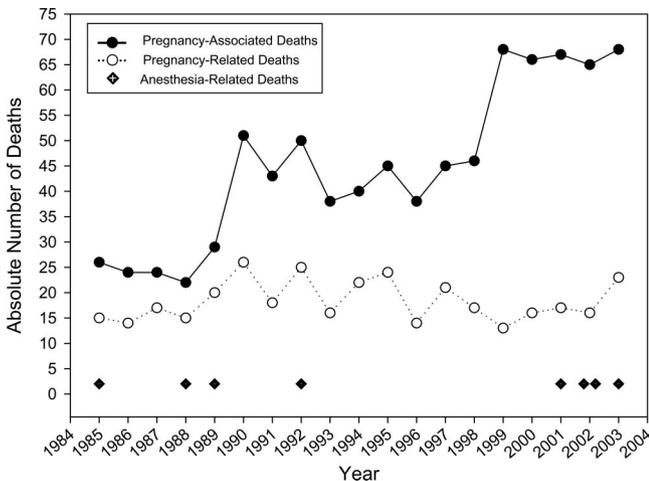


Fig. 2. Maternal deaths in Michigan from 1985 through 2003.

with a labor epidural for successful vaginal delivery. Three cases were true surgical emergencies due to maternal hemorrhage or nonreassuring fetal heart tones.

Six women who died were obese (body mass index [BMI] 30–39.9 kg/m²) or morbidly obese (BMI ≥ 40 kg/m²).

These eight anesthesia-related deaths occurred at seven different care facilities. In two of the eight deaths, care was provided by a nurse anesthetist supervised by the operating obstetrician, and in the remaining six of eight deaths, care was provided by a nurse anesthetist supervised by an anesthesiologist. In two cases, an anesthesiologist was present at the time of the primary anes-

Table 3. Demographics of Eight Patients Who Experienced Anesthesia-related Death

Characteristic	Mean (Range), yr
Maternal age	31.2 (16–39)
Education*	11.0 (10–16)
	Frequency
Marital status	
Never married	4
Married	2
Divorced	1
Not available	1
Occupation	
Employed	4
Unemployed	3
Student	1
Insurance	
Private	2
Public	3
Not available	3
Residence	
Detroit	6
Other	2
Prenatal care initiated	
First trimester	2
Second trimester	2
None	2
Unknown	1
Elective termination	1

* High school graduation is equivalent to 12 years of education.

thetic event. Medical records revealed 19 specific medical errors or care management problems, listed in table 5.

Anesthesia was considered a contributing factor in seven additional deaths (table 6). Among this group, three were African-American and four were white. Mean age and BMI of this group were not different than mean age and BMI of the group with anesthesia-related death (mean age 30.3 yr [SD = 5.4] vs. 31.1 yr [SD = 7.6], unpaired *t* test *P* = 0.81; mean BMI 32.1 kg/m² [SD = 5.2] vs. 37.9 kg/m² [SD = 7.6], unpaired *t* test *P* = 0.22).

Discussion

This review identified eight anesthesia-related and seven anesthesia-contributing maternal deaths in Michigan between 1985 and 2003. The pattern of deaths illustrates three key points. First, all anesthesia-related deaths from airway obstruction or hypoventilation took place during emergence and recovery, not during the induction of general anesthesia. Second, system errors contributed the majority of deaths. Of concern, lapses in standard postoperative monitoring and inadequate supervision by an anesthesiologist seemed to contribute to at least half of all deaths. Finally, this report confirms previous work that obesity and African-American race are important risk factors for anesthesia-related maternal mortality.^{1,3,10}

Airway disaster during the induction of general anesthesia remains one of the most recognized causes of anesthesia-related maternal mortality.^{2–5} Yet in this study of more than 850 maternal deaths, we were unable to identify a single case of failed intubation during elective or emergent induction of general anesthesia. In contrast, there were five cases of hypoventilation or airway obstruction during emergence, extubation, and recovery. Judgment and vigilance in monitoring oxygenation and ventilation are important throughout the perioperative period. Continuing medical education courses on airway management should remind perioperative and peripartum providers of this basic standard of care.

In seven of eight anesthesia-related maternal deaths, 19 specific medical errors or care management problems could be identified from the medical record (table 5). The errors listed were identified by the authors and were determined based on the authors' clinical judgment without the use of a validated instrument. Furthermore, ideal care may not have prevented the deaths in this series, and similar errors or care management problems may not necessarily lead to deaths in future patients. Further research is needed to evaluate the epidemiology of medical errors in obstetric anesthesia and to measure the association between specific errors and a range of patient outcomes including adverse events, near-miss events, and completely benign patient outcomes.

Although some of the care management problems

Table 4. Details of Anesthesia-related Maternal Deaths, 1985–2003

Patient	Maternal Condition	BMI, kg/m ²	Race	Procedure (Urgency)	Anesthesia Type; Airway Management; Postoperative Care	Most Likely Complication of Anesthesia; Presentation	a) Immediate Cause of Death b) Time of Death if Delayed c) Autopsy Findings
1	Term pregnancy with NRFHT*; refused spinal anesthesia	33	Black	Cesarean delivery (emergent for NRFHT)	GA; ETT	Airway obstruction; CP arrest during emergence from GA	a) CP arrest, failed resuscitation
2	24-week spontaneous vaginal stillbirth of twins; retained placenta	37	Black	Dilation and curettage (emergent for hemorrhage)	GA; ETT; extubated before transfer to PACU	Hypoventilation or airway obstruction; 25 min after arrival in PACU, patient found to be apneic and bradycardic	a) CP arrest, failed resuscitation
3	Undesired pregnancy in the first trimester	29	Black	Vacuum aspiration (elective)	Deep sedation; SV	Hypoventilation or airway obstruction; 25 min after arrival in PACU, patient found to be pulseless and apneic	a) CP arrest, failed resuscitation
4	Term pregnancy with chronic hypertension, polysubstance abuse	32	Black	Cesarean delivery (elective repeat)	Spinal	Hypoventilation or airway obstruction; apneic and bradycardic on arrival PACU	a) CP arrest, failed resuscitation c) Dilated cardiomyopathy; toxicology positive for cocaine
5	At 30 weeks' gestation, severe preeclampsia, symptoms of sleep-disordered breathing	42	White	Cesarean delivery (unscheduled for BP and liver enzymes)	Spinal; postoperative PCA	Airway obstruction; 9 h postoperative in hospital room, patient found to be pulseless and apneic	a) Failed resuscitation with difficult intubation during code attempt c) Morphine level 79 ng/ml
6	Term pregnancy, 39 years old, tobacco, untreated hypertension	50	Hispanic	Cesarean delivery (elective repeat)	Epidural; converted to GA with ETT; extubated before transfer to PACU	High spinal; CP arrest after epidural test dose	a) Second CP arrest, failed resuscitation b) Postoperative day 1 c) Acute MI, previous MI, CAD
7	Term pregnancy	42	Black	Cesarean delivery (elective repeat and breech)	Spinal; converted to GA with ETT; transferred to ICU intubated	Neuraxial cardiac arrest; bradycardia, then CP arrest 17 min after SAB placement	a) Unplanned extubation in the ICU b) 26 days postpartum c) Anoxic encephalopathy
8	At 15 weeks' gestation, fetal demise; maternal "heart enlargement," systolic murmur, lateral ST changes on electrocardiogram; induced delivery with retained placenta	WNL	Black	Dilation and curettage (emergent for hemorrhage)	GA; ETT	CP arrest; ST depression preceded pulseless arrest during emergence from GA	a) CP arrest, failed resuscitation c) Cardiomyopathy

* Nonreassuring fetal heart tones (NRFHT) in case 1 included repetitive episodes of fetal bradycardia 60–100 beats/min.

BMI = body mass index; BP = blood pressure; CAD = coronary artery disease; CP = cardiopulmonary; ETT = endotracheal tube; GA = general anesthesia; ICU = intensive care unit; MI = myocardial infarction; PACU = postanesthesia care unit; PCA = patient-controlled analgesia; SAB = subarachnoid block; SV = spontaneous ventilation; WNL = within normal limits.

listed in table 5 could be attributed solely to the anesthesia provider, most represent system-level failures of prenatal care, patient education, or peripartum patient safety. Organizational accidents such as patient deaths typically result from a concatenation of contributing factors, including latent failures in organizational processes and environmental conditions, as well as active failures such as individual unsafe acts.^{22,23} Proposals to improve patient safety in obstetric anesthesiology must attend to the broader context of maternity care and not be limited to the specific actions performed by the individual anesthesiologist or nurse anesthetist.

For example, antenatal anesthesiology evaluation has the potential to address preexisting conditions before delivery, but requires a robust system to identify patients who may benefit. Maternal deaths are now more likely to result from exacerbation of preexisting disease (indirect deaths) than from conditions specific to pregnancy (direct deaths).³ In the current series, half of the anesthesia-related deaths may have been related to unrecognized coexisting disease. In France, an antenatal anesthetic visit has been mandatory for all pregnant women since 1998²⁴ and is usually completed in the eighth month of

pregnancy. Mandatory evaluation is not currently required or recommended in the United States. Research is needed to define the cost effectiveness of mandatory anesthesiology evaluation. If mandatory evaluation is not cost effective, research should focus on establishing clear indications for selective antenatal anesthesiology evaluation and the method by which patients are best identified.

Standard postoperative monitoring may have prevented at least three of these deaths. Among these, two women died of airway obstruction or apnea in postanesthesia care units without continuous pulse oximetry, including the most recent death in 2003. The American Society of Anesthesiologists guideline for postoperative care suggests that pulse oximetry is associated with early detection of hypoxemia, and recommends periodic assessment of airway patency, respiratory rate, and oxygen saturation measured by pulse oximetry during emergence and recovery.²⁵ Continuous pulse oximetry may further improve detection of hypoxemia, particularly for African-American patients in whom cyanosis may be more difficult to detect by visual inspection alone.¹⁰

Inadequate supervision of care contributed to at least

Table 5. Medical Errors and Care Management Problems in Anesthesia-related Deaths

Medical Errors and Care Management Problems	Case Numbers
Insufficient preanesthesia evaluation or preparation	
Missed diagnosis (cardiomyopathy, ischemic heart disease, sleep apnea)	4, 5, 6, 8
No cardiology or anesthesiology consultation before induction of labor in a patient with documented signs of cardiac disease	8
Insufficient preoperative evaluation and preparation	8
Patient factors	
Refused spinal anesthesia	1
Failed to report recent cocaine use	4
Medication error	
Multiple medications with the potential for respiratory suppression administered within a short time interval (2 mg midazolam, 0.125 mg droperidol, 50 mg diphenhydramine)	4
PCA morphine settings exceeded safe dosing for a patient with symptoms of sleep disordered breathing (2-mg bolus every 8 min with 1-mg/h infusion)	5
Epidural test dose exceeded a safe dose with inadvertent intrathecal administration (150 mg 2-chloroprocaine)	6
Naloxone administered in the setting of new ST depression	8
Inadequate supervision	
Nurse anesthetist supervised by the operating obstetrician	3, 8
Anesthesiologist absent for emergence from general anesthesia	1
Inadequate postoperative monitoring	
Patient apnea not recognized during transport from the OR to the PACU	4
No PACU pulse oximetry	2, 3
Postoperative level of care not sufficient given the patient's condition	5, 6
No care management problems identified	7

OR = operating room; PACU = postanesthesia care unit; PCA = patient-controlled analgesia.

three anesthesia-related deaths (table 5), including two cases in which the nurse anesthetist was supervised by the operating obstetrician. In addition, four women died of postcesarean intraperitoneal hemorrhage without the benefit of an anesthesiologist to suggest concealed bleeding or to ensure sufficient intravascular access and resuscitation (table 6). As perioperative physicians, anesthesiologists are uniquely qualified to supervise the anesthesia care team, to manage and minimize anesthesia-related maternal risk, to provide peripartum medical diagnosis and treatment, to facilitate life-saving surgical interventions with efficient and safe anesthesia, and to lead prompt, coordinated, and effective resuscitation efforts. An anesthesiologist may not always be immediately available. However, as much as possible, workforce policies should ensure the appropriate involvement of anesthesiologists in developing clinical protocols and in delivering patient care.

Consistent with previous literature,^{1,10} the majority of deaths in this series were in African-American women. Although medical errors and care management problems seemed to contribute the majority of the deaths identified in this series, it is not clear whether African-American women are more likely to experience an error or whether such errors have more severe consequences for this population. African-Americans represent a high risk group with increased rates of chronic hypertension,²⁶⁻²⁸ pregnancy induced hypertension,²⁹ preeclampsia,²⁹⁻³⁴ obesity,³⁵⁻³⁹ peripartum cardiomyopathy,⁴⁰ and overall pregnancy-related mortality.^{1,41} In most⁴²⁻⁴⁴ but not all studies,⁴⁵ African-American women are more likely to

deliver by cesarean delivery and therefore are more likely to require a surgical anesthetic.

This review is also consistent with previous reports that anesthesia-related maternal death is associated with maternal obesity.^{3,10} An association between obesity and anesthetic risk is concerning because the prevalence of obesity and morbid obesity among nonpregnant women of childbearing age in the United States has increased from 11.7% and 1.8%, respectively, in 1972⁴⁶ to 28.9% and 8%, respectively, in 2003.⁴⁷ Strategies to maximize anesthetic safety for obese and morbidly obese pregnant women have been described.^{48,49}

Observations from this retrospective case review must be interpreted with caution for three reasons. First, approximately 40% of pregnancy-associated deaths may have been missed over the duration of the study. The major limitations to identifying every maternal death⁵⁰ were that (1) the MMMS system does not review hospital records and autopsy reports of all women of reproductive age; (2) death certificates were not matched to neonatal death certificates before 1990; (3) death certificates were not matched to fetal death records before 1999; (4) the pregnancy check box on the Michigan death certificate⁵¹ was implemented in 2004, after the final year of this study; and (5) maternal death reporting is not mandatory in Michigan.

Second, the complete medical record may not capture everything known about the anesthetic event at the time it occurred. Analysis of the temporal relation between specific anesthetic maneuvers and hemodynamic outcomes is not always possible using a standard anesthetic

Table 6. Details of Maternal Deaths in Which Anesthesia Was a Contributing Factor, 1985–2003

Patient	Maternal Condition	Procedure (Urgency); Anesthesia Type; Airway Management; Postoperative Care	Most Likely Complication of Anesthesia; Presentation	a) Cause of Death b) Time of Death if Delayed c) Autopsy Findings if Available
9	MVC at 34 weeks with ankle fracture repaired under epidural, clavicle fracture, and CSF leak from left ear; absent fetal movement 18 days later	CD for chronic placental abruption with stillborn fetus (emergent); GA; ETT; to PACU extubated	Aspiration in PACU; stomach contents noted during laryngoscopy and reintubation	a) ARDS, SIRS; blood, urine and CSF cultures drawn on admission positive for <i>Klebsiella</i> b) 21 days after hysterotomy
10	Sickle cell crisis with joint and chest pain at 30 weeks; NRFHT*; transfused 1 unit packed erythrocytes preoperatively	CD (emergent); epidural; intraoperative pain and dyspnea prompted conversion to GA with ETT	Cardiovascular collapse; CP arrest upon induction of GA	a) CP arrest c) Vasooclusive crisis, hemorrhagic diathesis, bilateral pulmonary emboli
11	Diabetes with nephropathy; preeclampsia; dyspnea, hypoxemia; NRFHT† at 32 weeks	CD (emergent); GA; ETT; to ICU intubated	Cardiovascular collapse; CP arrest upon induction of GA	a) ARDS b) 4 days postpartum c) ARDS, hypoxic encephalopathy
12	Postpartum after term CD for breech during spinal anesthesia complicated by intraoperative lower uterine segment laceration requiring repair	CD (elective); spinal; to PACU; second surgery 8 h later: exploratory laparotomy (perimortem); GA; ETT	Prolonged hypotension; hypotension first documented in PACU 3 h after CD with CP arrest in PACU 5 h later	a) Postpartum hemorrhage and CP arrest b) During exploratory laparotomy c) Retroperitoneal hematoma; biventricular hypertrophy and cardiac dilation
13	Postpartum after SOL with twins at 36 weeks; forceps vaginal delivery of twin A; epidural converted to GA for emergent CD for twin B	CD (emergent); GA; ETT; to PACU extubated; second surgery 5 h later: exploratory laparotomy (emergent); GA; ETT; to ICU intubated	Prolonged hypotension; hypotensive post-CD for 2 h in PACU + 3 h on perinatal floor before return to OR for exploratory laparotomy	a) Postpartum hemorrhage and CP arrest during exploratory laparotomy; subsequent DIC and CP arrest b) 8 days postpartum c) Intraperitoneal fluid; pulmonary edema; focal myocardial necrosis
14	Postpartum after elective repeat CD at 38 weeks during GA for failed spinal	CD (elective); GA; ETT; to PACU extubated; second surgery 8 h later: exploratory laparotomy (emergent); GA; ETT	Prolonged hypotension; hypotensive on perinatal floor after CD for 90 min before return to OR	a) Postpartum hemorrhage and CP arrest b) During exploratory laparotomy c) Extensive intraabdominal hemorrhage
15	Postpartum after urgent repeat CD at 37 weeks for SOL during general anesthesia; maternal polysubstance abuse	CD (urgent); GA; ETT; to PACU extubated; second surgery 16 h later: exploratory laparotomy (emergent); GA; ETT	Prolonged hypotension; hypotensive after CD for 6 h in PACU + 10 h in ICU before return to OR	a) Postpartum hemorrhage and CP arrest b) During exploratory laparotomy c) Hemoperitoneum; left lateral uterine segment laceration

* Nonreassuring fetal heart tones (NRFHT) in case 10 included recurrent late decelerations with absent fetal movement on ultrasound examination. † NRFHT in case 11 included sustained bradycardia less than 90 beats/min.

ARDS = adult respiratory distress syndrome; CD = cesarean delivery; CHF = congestive heart failure; CP = cardiopulmonary; CSF = cerebrospinal fluid; DIC = disseminated intravascular coagulation; ETT = endotracheal tube; GA = general anesthesia; ICU = intensive care unit; LVH = left ventricular hypertrophy; MVC = motor vehicle crash; OR = operating room; PACU = postanesthesia care unit; PIH = pregnancy induced hypertension; SIRS = systemic inflammatory response syndrome; SOL = spontaneous onset of labor.

record. In several cases, the anesthesiologists carefully documented the relevant sequence of events. In other cases, the patients arrested under the care of a nurse anesthetist or postanesthesia nurse, neither of whom recorded notes detailing their observations leading up to the arrest. Therefore, in some cases, the mechanism of death is unproven and represents a best estimate based on the records available.

Third, portions of the medical record for each case may be missing, leading to inaccurate judgments about cause of death. However, significant omissions are unlikely for the following reasons. The Michigan Depart-

ment of Community Health is required by state statute to investigate pregnancy-associated deaths and receives a very high percentage of requested records. The MMMS coordinator confirmed that all birthing hospitals supply medical records when requested; however, prenatal care records are not always available. Redaction, when observed on the medical records, was limited to patient and professional identifiers.

Despite these limitations, this report is notable for two reasons. First, by reviewing primary medical records and case documents, we were able to ascertain cases that would not have been identified using the vital records

alone. Primary records also allowed us to report the probable mechanism of death. Second, we developed a structured definition procedure to categorize a death as an anesthesia-related maternal mortality. A similar procedure is recommended by the Centers for Disease Control and Prevention to define a pregnancy-related death.¹⁷ The definition of anesthesia-related maternal mortality presented in this study was generated through an iterative process with reference to 25 cases as well as additional cases in the published literature. Future work is needed to test the interrater reliability of this definition of anesthesia-related maternal death.

Over the past 50 yr, anesthesiologists have achieved a remarkable reduction in the number of anesthesia-related maternal deaths.^{3,4} However, African-American and obese women continue to face unacceptably high risks for anesthesia-related maternal mortality.^{1,3,10} The following actions might further reduce mortality: (1) recognize the relatively high potential for anesthetic disaster during emergence and recovery from general anesthesia; (2) ensure appropriate monitoring throughout the perioperative period, particularly for postoperative hypoventilation and airway obstruction; (3) use strategies to maximize safety for obese and morbidly obese women; and (4) advocate for workforce policies that ensure appropriate involvement of anesthesiologists in developing clinical protocols and in delivering patient care. Future research is needed to evaluate the epidemiology of care management problems in obstetric anesthesiology and the efficacy of systems solutions to improve peripartum maternal safety.

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