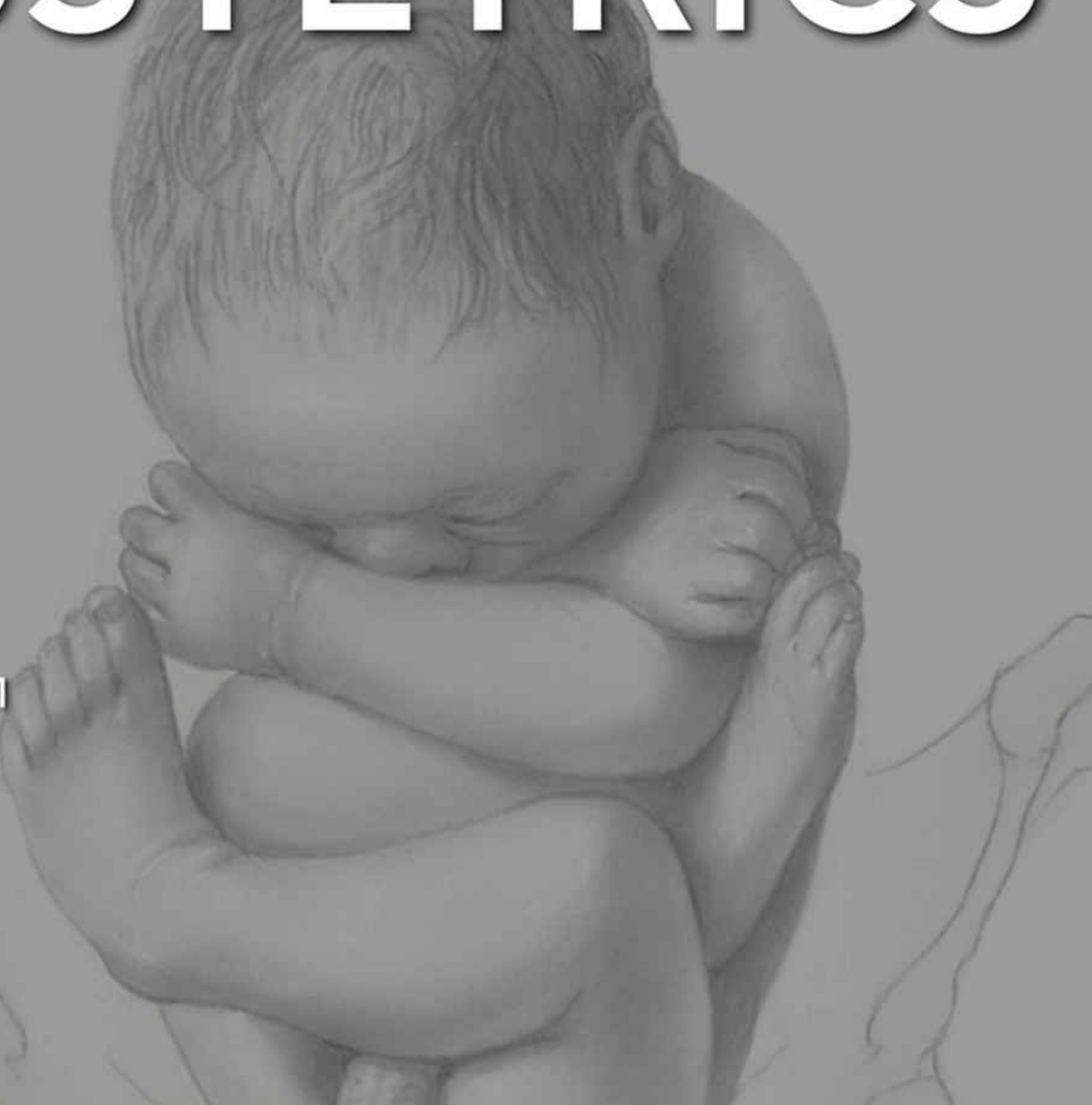
25TH EDITION

Williams OBSTETRICS



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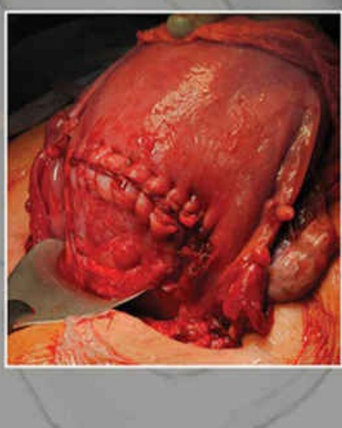

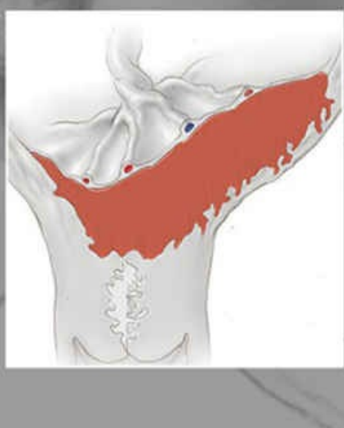

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Williams OBSTETRICS

25TH EDITION

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DEDICATION

To our mentors, who inspire us to strive for excellence in obstetrics,
To our colleagues, who are superb role models for obstetricians and gynecologists,
To our students and residents, who challenge us to be better teachers each day,
To our fellows, who dare us to think more boldly,
To our nurses, who encourage us to place patient needs first,
To our support staff, who allow us to respond efficiently in the face of emergencies, and
To our families, whose love and support make our endeavors possible.

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PREFACE

We celebrate this 25th edition of *Williams Obstetrics* with great appreciation for the insight and expertise that the early editors brought to this textbook. To pay tribute to the first author, J. Whitridge Williams, we begin each chapter with a passage from his 1st edition that complements the topic. During this selection process, we were inspired by the strides that modern obstetrics has made since that edition in 1903. Similarly, we were humbled by some of the classic challenges that still persist. Preterm labor, preeclampsia, and infections are some examples. That said, many of these advances were derived from rigorous, evidence-based research. And, we acknowledge and support the power of this academic ideal to further our specialty in the decades to come.

For this 25th edition, we continue to present the detailed staples of basic obstetrics such as maternal anatomy and physiology, preconceptional and prenatal care, labor, delivery, and the puerperium. These accompany detailed discussions of obstetrical complications exemplified by preterm labor, hemorrhage, hypertension, and many more. To emphasize the "M" in Maternal–Fetal Medicine, we continue to iterate the many medical and surgical disorders that can complicate pregnancy. And, our second patient—the fetus—has accrued especial attention with an entire section devoted to diagnosis and treatment of fetal disorders. For all of these, we once again emphasize the science-based underpinnings of clinical obstetrics with special emphasis on biochemical and physiological principles. As was the hallmark of previous editions, these dovetail with descriptions of evidence-based practices. Expert clinical pearls add depth to these discussions and are written for busy practitioners—those "in the trenches."

To accomplish these goals, the text has been updated with more than 3000 new literature citations through 2017. Many of the nearly 900 figures are new, and these graphs, sonograms, magnetic resonance images, photographs, photomicrographs, and data graphs are almost all in vivid color. Much of the original artwork was rendered by our own medical illustrators.

Also, as before, we continue to incorporate contemporaneous guidelines from professional and academic organizations such as the American College of Obstetricians and Gynecologists, the Society for Maternal–Fetal Medicine, the National Institutes of Health and the National Institute for Child Health and Human Development, the Centers for Disease Control and Prevention, and other authoritative sources. Many of these data are distilled into nearly 100 tables, in which information has been arranged in an easy read-and-use format. In addition, several diagnostic and management algorithms are available to quickly guide practitioners. Although we strive to cite numerous sources and provide multiple evidence-based options for such management schemes, we also include our own clinical experiences drawn from the large obstetrical service at Parkland Hospital. We are convinced that these are disciplined examples of evidence-based obstetrics but quickly acknowledge that they do not constitute the sole method of management.

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ACKNOWLEDGMENTS

During the creation and production of this textbook, we were fortunate to have the assistance and support of countless talented professionals both within and outside the Department of Obstetrics and Gynecology. To begin, we acknowledge that an undertaking of this magnitude would not be possible without the unwavering support provided by Dr. Barry Schwarz, Vice-Chairman, whose financial and academic endorsement has been essential.

This 25th edition shows a notable absence of three colleagues who provided valuable editorial assistance for prior editions of *Williams Obstetrics*. Colleagues from the University of Texas Southwestern Medical Center include Dr. George Wendel, Jr.—associate editor for the 22nd and 23rd editions—who has now assumed the important role of Executive Director of the American Board of Obstetrics and Gynecology. Dr. Jeanne Sheffield, with her especial expertise in obstetrical and perinatal infections, has left Dallas and is now the Division Director of Maternal–Fetal Medicine at Johns Hopkins University School of Medicine. From the University of Alabama at Birmingham, Dr. John Hauth, who served as an editor for the 21st through 23rd editions, provided valuable contributions to chapters on chronic hypertension, preterm labor, and labor induction, which have endured in updated forms in this edition.

We are especially grateful for the contributions of our two returning Associate Editors. Dr. Mala Mahendroo is a talented basic scientist who continues to perform a magnificent job of providing a coherent translational version of basic science aspects of human reproduction. Dr. Diane Twickler—the consummate radiologist—has been an invaluable mentor for our residents, fellows, and faculty. She adds her fantastic experiences and extensive knowledge regarding clinical and technological advances related to fetal and maternal imaging to add considerable depth to this textbook. Dr. Seth Hawkins served us well as an Associate Editor in this edition and brought additional strengths to the areas of clinical and academic Maternal–Fetal Medicine. His rigorous analysis of evidence-based data on topics of maternal physiology, fetal-growth disorders, obesity, liver disease, and labor induction has added new perspectives to these chapters.

To add academic breadths to our endeavor, we have enlisted new Contributing Editors—all from UT Southwestern Medical Center—each of whom has expertise in important areas of maternal and perinatal medicine. From the Division of Maternal–Fetal Medicine, Dr. C. Edward Wells adds his extensive clinical experience and his incredible skills with prior cesarean delivery and obstetrical sonography. Dr. April Bailey, with joint appointments in the Departments of Radiology and Obstetrics and Gynecology, shared her

tremendous knowledge regarding fetal and maternal imaging with sonography, radiography, computed tomography, and magnetic resonance techniques. Dr. David Nelson brings strong clinical knowledge regarding preterm labor, stillbirth, management of obstetrical hemorrhage, psychiatric disorders in pregnancy, and multifetal gestation. From the Department of Anesthesia, Dr. Weike Tao provided academic insight and clinical mastery in obstetrical anesthesia. Similarly, Dr. Erica Grant graciously and skillfully advanced the discussion of this topic. Dr. Myra Wyckoff, from the Department of Pediatrics, contributed greatly to chapters regarding the term and preterm newborn. Her expertise both in normal care and in treatment for the more vulnerable neonates has greatly strengthened the evidence-based content of these chapters. In toto, the strength of each contributor has added to create the sum total of our academic endeavor.

In constructing such an expansive academic compilation, the expertise of many colleagues was needed to add vital and contemporaneous information. It was indeed fortuitous for us to have access to a pantheon of collaborators from here and from other academic medical centers. From our own Department of Obstetrics and Gynecology, our nationally known pelvic anatomist, Dr. Marlene Corton, prepared graphic masterpieces for the anatomy chapter. Dr. Elysia Moschos contributed a number of sonographic images of early pregnancy and uterine malformations. Drs. Claudia Werner and William Griffith lent valuable insight into the management of cervical dysplasia. Dr. Emily Adhikari was an invaluable source in the construction of the chapters on maternal and perinatal infections. Finally, clinical photographs were contributed by many faculty and fellows, who include Drs. Patricia Santiago-Muñoz, Julie Lo, Elaine Duryea, Jamie Morgan, Judith Head, David Rogers, Kimberly Spoonts, and Emily Adhikari. From the Department of Radiology, Drs. Michael Landy, Jeffrey Pruitt, and Douglas Sims added insights and provided computed tomographic and magnetic resonance images. From the Department of Pathology, Dr. Kelley Carrick generously donated exemplary photomicrographs. Dr. Kathleen Wilson, director of the cytogenomic microarray analysis laboratory, graciously assisted us in updating our cytogenomic nomenclature.

We are also indebted to contributions made by our national and international colleagues. Experts in placental pathology who shared their expertise and images include Drs. Kurt Benirschke, Ona Marie Faye-Petersen, Mandolin Ziadie, Michael Conner, Brian Levenson, Jaya George, and Erika Fong. Input for hypertensive disorders was provided by Drs. John Hauth, Marshall Lindheimer, and Gerda Zeeman; for operative vaginal delivery by Dr. Edward Yeomans; and seminal images were contributed by Drs. Kevin Doody, Timothy Crombleholme, Michael Zaretsky, Togas Tulandi, Edward Lammer, Charles Read, Frederick Elder, April Bleich, Laura Greer, and Roxane Holt.

In addition to these contributors, we relied heavily on our colleagues in the Division of Maternal–Fetal Medicine. These professionals, in addition to providing expert content, graciously assisted us by covering clinical duties when writing and editing were especially time consuming. These include Drs. Scott Roberts, Oscar Andujo, Vanessa Rogers, Charles Brown, Julie Lo, Robyn Horsager, Patricia Santiago-Muñoz, Shivani Patel, Elaine Duryea, Jamie Morgan, Morris Bryant, Shena Dillon, Denisse Holcomb, Robert Stewart, Stephan

Shivvers, Ashley Zink, and Mark Peters. In addition, warm thanks go to our Residency Director, Dr. Vanessa Rogers, and her Associate Program Director, Dr. Stephanie Chang, who have created a nurturing environment for our residents to flourish. Similarly, our Maternal–Fetal Medicine (MFM) Division Associate Fellowship Director, Dr. Charles Brown, has aided our work through his talented mentoring of our MFM fellows.

We also emphasize that production of *Williams Obstetrics* would not be feasible without the help of our Maternal–Fetal Medicine fellows and our residents in Obstetrics and Gynecology. Their insatiable curiosity serves to energize us to find new and effective ways to convey age-old truths, new data, and cutting-edge concepts. Their logical and critical questions lead us to weaknesses in the text, and thereby, always help us to improve our work. In addition, we sincerely thank them for their vigilance in capturing photographs of spectacular examples of both obstetrical pathology and normal findings. For example, included in this edition are photographs contributed by Drs. Devin Macias, Maureen Flowers, Paul Slocum, Jonathan Willms, Stacey Thomas, Kara Ehlers, Nidhi Shah, Abel Moron, Angela Walker, and Elizabeth Mosier.

This edition is heavily populated with seminal examples of sonographic findings. We are grateful for the mentorship and talent of Drs. Diane Twickler and April Bailey; Mary Gibbs, RDMS; Rafael Levy, RDMS; Michael Davidson, RDMS; and the many talented sonographers at Parkland Hospital.

Thanks to generous funding from McGraw-Hill Education, this 25th edition now contains more than 200 color illustrations. Most of these were crafted by several skilled medical illustrators who include Ms. Marie Sena, Ms. Erin Frederickson, Mr. Jordan Pietz, Ms. SangEun Cha, and Ms. Jennifer Hulsey. All of these talented artists trained here at UT Southwestern under the tutelage of Mr. Lewis Calver. Additional artistic support came from Mr. Jason McAlexander and Ms. Suzanne Ghuzzi, of MPS North America LLC, who provided the full-color graphs and line art used to enhance this edition. Their team tirelessly coordinated efforts between author and artist and graciously accommodated our numerous changes and tweaks.

Production of the 5000-page manuscript would not have been possible without a dedicated team to bring these efforts together. Once again, we are deeply indebted to Ms. Dawn Wilson and Ms. Melinda Epstein for their untiring efforts with manuscript production. Ms. Mercedes Salinas also provided excellent, conscientious manuscript assistance. Information technology support was provided by the very knowledgeable and responsive Mr. Charles Richards and Mr. Thomas Ames. For these and many more that go unnamed, we could not have done our job without their expertise.

It again has been a privilege and a pleasure to work with the dedicated professionals from McGraw-Hill Education. Mr. Andrew Moyer has brought his considerable intelligence, unwavering work ethic, and creativity to this edition of *Williams Obstetrics*. His dedication to creating the best textbook possible equaled our efforts, and we are in awe of his productive, gracious style. His assistant, Ms. Jessica Gonzalez, provided professional, timely, and ever-sunny aid. Mr. Richard Ruzycka served as production supervisor for this edition of the textbook. He skillfully kept our project on track through an array of potential hurdles. Last, we have had the pleasure to work with Mr. Armen Ovsepyan in coordinating the artwork for many of our editions. His organization and efficiency are unrivaled.

Our text took its final shape under the watchful care of our compositors at Aptara, Inc. We thank Ms. Indu Jawwad for her talents in graciously and masterfully coordinating and overseeing composition. Her dedicated attention to detail and organization were vital to completion of our project. Also, at Aptara, Mr. Mahender Singh performed a crucial task of quality control. He also assisted, along with Mr. Surendra Mohan Gupta and Mr. Anil Varghese, in creating beautiful chapter layouts to highlight our content aesthetically and informatively. This edition's chapters, for the first time, were posted and available online for use prior to print publication. We thank Mr. Braj Bhushan and Mr. Ashish Kumar Sharma for preparing this content so brilliantly. Special thanks go to Ms. Kristin Landon. As copyeditor for now several editions of both *Williams Obstetrics* and *Williams Gynecology*, Kristin has added precision and clarity to our efforts. Her endurance and pleasant professionalism through many challenging chapters has made our text better.

Finally—but certainly not last—we acknowledge our significant debt to the women who have entrusted themselves and their unborn children to us for obstetrical care. The clinical expertise and many graphic illustrations presented in this text would not have been possible without their collaborative spirit to help us advance obstetrical knowledge. We also offer enthusiastic and heartfelt appreciation to our families and friends. Without their patience, generosity, love, and encouragement, this task would have been impossible.

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SECTION 1

OVERVIEW

CHAPTER 1

Overview of Obstetrics

> *In the following pages I have attempted to set forth, as briefly as seemed to be consistent with thoroughness, the scientific basis for and the practical application of the obstetrical art. At the same time, I have endeavored to present the more practical aspects of obstetrics in such a manner as to be of direct service to the obstetrician at the bedside.*
>
> —J. Whitridge Williams (1903)

So reads the introduction to Williams' first edition of this textbook, *Obstetrics—A Text-Book for the Use of Students and Practitioners.* In this 25th edition, we strive to follow the tenets described by Williams. And, each chapter begins with a quote from his original textbook.

The science and clinical practice of obstetrics is concerned with human reproduction. Through quality perinatal care, the specialty promotes the health and well-being of the pregnant woman and her fetus. Such care entails appropriate recognition and treatment of complications, supervision of labor and delivery, initial care of the newborn, and management of the puerperium. Postpartum care promotes health and provides family planning options.

The importance of obstetrics is reflected by the use of maternal and neonatal outcomes as an index of the quality of health and life among nations. Intuitively, indices that reflect poor obstetrical and perinatal outcomes would lead to the assumption that medical care for the entire population is lacking. With those thoughts, we now provide a synopsis of the current state of maternal and newborn health in the United States as it relates to obstetrics.

VITAL STATISTICS

The National Vital Statistics System of the United States is the oldest and most successful example of intergovernmental data sharing in public health. This agency collects statistics through vital registration systems that operate in various jurisdictions. These systems are legally responsible for registration of births, fetal deaths, deaths, marriages, and divorces.

Legal authority resides individually with the 50 states; two regions—the District of Columbia and New York City; and five territories—American Samoa, Guam, the Northern Mariana Islands, Puerto Rico, and the Virgin Islands.

The standard birth certificate was revised in 1989 to include more information on medical and lifestyle risk factors and obstetrical practices. In 2003, an extensively revised Standard Certificate of Live Birth was implemented in the United States. The enhanced data categories and specific examples of each are summarized in Table 1-1. By 2013, 35 states had implemented the revised birth certificate representing 76 percent of all births (MacDorman, 2015). Importantly, the 2003 version of the population death certificate contains a pregnancy checkbox to eventually be implemented by all states (Joseph, 2017).

TABLE 1-1. General Categories of New Information Added to the 2003 Revision of the Birth Certificate

Risk factors in pregnancy—Examples: prior preterm birth, prior eclampsia
Obstetrical procedures—Examples: tocolysis, cerclage, external cephalic version
Labor—Examples: noncephalic presentation, glucocorticoids for fetal lung maturation, antibiotics during labor
Delivery—Examples: unsuccessful operative vaginal delivery, trial of labor with prior cesarean delivery
Newborn—Examples: assisted ventilation, surfactant therapy, congenital anomalies

Definitions

The uniform use of standard definitions is encouraged by the World Health Organization as well as the American Academy of Pediatrics and the American College of Obstetricians and Gynecologists (2017). Such uniformity allows data comparison not only between states or regions of the country but also between countries. Still, not all definitions are uniformly applied. For example, the American College of Obstetricians and Gynecologists recommends that reporting include all fetuses and neonates born weighing at minimum 500 g, whether alive or dead. But, not all states follow this recommendation. Specifically, 28 states stipulate that fetal deaths beginning at 20 weeks' gestation should be recorded as such; eight states report all products of conception as fetal deaths; and still others use a minimum birthweight of 350 g, 400 g, or 500 g to define fetal death. To further the confusion, the National Vital Statistics Reports tabulates fetal deaths from gestations that are 20 weeks or older (Centers for Disease Control and Prevention, 2016). This is problematic because the 50th percentile for fetal weight at 20 weeks approximates 325 to 350 g—considerably less than the 500-g definition. Indeed, a birthweight of 500 g corresponds closely with the 50th percentile for 22 weeks' gestation.

Definitions recommended by the National Center for Health Statistics and the Centers for Disease Control and Prevention are as follows:

Perinatal period. The interval between the birth of a neonate born after 20 weeks' gestation and the 28 completed days after that birth. When perinatal rates are based on birthweight, rather than gestational age, it is recommended that the perinatal period be defined as commencing at the birth of a 500-g neonate.

Birth. The complete expulsion or extraction from the mother of a fetus after 20 weeks' gestation. As described above, in the absence of accurate dating criteria, fetuses weighing <500 g are usually not considered as births but rather are termed *abortuses* for purposes of vital statistics.

Birthweight. The weight of a neonate determined immediately after delivery or as soon thereafter as feasible. It should be expressed to the nearest gram.

Birth rate. The number of live births per 1000 population.

Fertility rate. The number of live births per 1000 females aged 15 through 44 years.

Live birth. The term used to record a birth whenever the newborn at or sometime after birth breathes spontaneously or shows any other sign of life such as a heartbeat or definite spontaneous movement of voluntary muscles. Heartbeats are distinguished from transient cardiac contractions, and respirations are differentiated from fleeting respiratory efforts or gasps.

Stillbirth or fetal death. The absence of signs of life at or after birth.

Early neonatal death. Death of a liveborn neonate during the first 7 days after birth.

Late neonatal death. Death after 7 days but before 29 days.

Stillbirth rate or fetal death rate. The number of stillborn neonates per 1000 neonates born, including live births and stillbirths.

Neonatal mortality rate. The number of neonatal deaths per 1000 live births.

Perinatal mortality rate. The number of stillbirths plus neonatal deaths per 1000 total births.

Infant death. All deaths of liveborn infants from birth through 12 months of age.

Infant mortality rate. The number of infant deaths per 1000 live births.

Low birthweight. A newborn whose weight is <2500 g.

Very low birthweight. A newborn whose weight is <1500 g.

Extremely low birthweight. A newborn whose weight is <1000 g.

Term neonate. A neonate born any time after 37 completed weeks of gestation and up until 42 completed weeks of gestation (260 to 294 days). The American College of Obstetricians and Gynecologists (2016b) and Society for Maternal–Fetal Medicine endorse and encourage specific gestational age designations. *Early term* refers to neonates born at 37 completed weeks up to $38^{6/7}$ weeks. *Full term* denotes those born at 39 completed weeks up to $40^{6/7}$ weeks. Last, *late term* describes neonates born at 41 completed weeks up to $41^{6/7}$ weeks.

Preterm neonate. A neonate born before 37 completed weeks (the 259th day). A neonate born before 34 completed weeks is early preterm, whereas a neonate born between 34 and 36 completed weeks is late preterm.

Postterm neonate. A neonate born anytime after completion of the 42nd week, beginning with day 295.

Abortus. A fetus or embryo removed or expelled from the uterus during the first half of gestation—20 weeks or less, or in the absence of accurate dating criteria, born weighing <500 g.

Induced termination of pregnancy. The purposeful interruption of an intrauterine pregnancy that has the intention other than to produce a liveborn neonate and that does not result in a live birth. This definition excludes retention of products of conception following fetal death.

Direct maternal death. The death of the mother that results from obstetrical complications of pregnancy, labor, or the puerperium and from interventions, omissions, incorrect treatment, or a chain of events resulting from any of these factors. An example is maternal death from exsanguination after uterine rupture.

Indirect maternal death. A maternal death that is not directly due to an obstetrical cause. Death results from previously existing disease or a disease developing during pregnancy, labor, or the puerperium that was aggravated by maternal physiological adaptation to pregnancy. An example is maternal death from complications of mitral valve stenosis.

Nonmaternal death. Death of the mother that results from accidental or incidental causes not related to pregnancy. An example is death from an automobile accident or concurrent malignancy.

Maternal mortality ratio. The number of maternal deaths that result from the reproductive process per 100,000 live births. Used more commonly, but less accurately, are the terms *maternal mortality rate* or *maternal death rate.* The term *ratio* is more accurate because it includes in the numerator the number of deaths regardless of pregnancy outcome—for example, live births, stillbirths, and ectopic pregnancies—whereas the denominator includes the number of live births.

Pregnancy-associated death. The death of a woman, from any cause, while pregnant or within 1 calendar year of termination of pregnancy, regardless of the duration and the site of pregnancy.

Pregnancy-related death. A pregnancy-associated death that results from: (1) complications of pregnancy itself, (2) the chain of events initiated by pregnancy that led to death, or (3) aggravation of an unrelated condition by the physiological or pharmacological effects of pregnancy and that subsequently caused death.

PREGNANCY RATES IN THE UNITED STATES

According to the Centers for Disease Control and Prevention (CDC), the fertility rate of women aged 15 to 44 years in the United States in 2015 was 62.5 live births per 1000 women (Martin, 2017). This rate began slowly trending downward in 1990 and has now dropped below that for replacement births. This indicates a population decline (Hamilton, 2012). There were 3.98 million births in 2015, and this constituted the lowest birth rate ever recorded for the United States—12.3 per 1000 population. The birth rate decreased for all major ethnic and racial groups, for adolescents and unmarried women, and for those aged 20 to 24 years. For women older than 30 years, the birth rate rose slightly. Almost half of newborns in 2010 in the United States were minorities: Hispanic—25 percent, African-American—14 percent, and Asian—4 percent (Frey, 2011).

The total number of pregnancies and their outcomes in 2015 are shown in Table 1-2. According to the Guttmacher Institute (2016b), 45 percent of births in the United States are unintended at the time of conception. Importantly, the overall proportion of unintended births has declined only slightly since 2001. Unmarried women, black women, and women with less education or income are more likely to have unplanned pregnancies.

TABLE 1-2. Total Pregnancies and Outcomes in the United States in 2015

Outcome	Number or Percent
Births	3,988,076
Cesarean deliveries	32.2%
Preterm births (<37 weeks)	9.5%
Low birthweight (<2500 g)	8.0%
Induced abortions	664,435
Total pregnancies[a]	4,652,511

[a]Excludes spontaneous abortions and ectopic pregnancies.
Data from Martin, 2017.

In Table 1-2, induced abortion information derives from CDC abortion surveillance data from 45 states combined with Guttmacher Institute data on induced abortion. These data have been collected beginning in 1976. Since *Roe v. Wade* legalization of abortion, more than 46 million American women have chosen legalized abortions. As discussed later, this provides a compelling argument for easily accessible family planning.

MEASURES OF OBSTETRICAL CARE

■ Perinatal Mortality

Several indices are used to assess obstetrical and perinatal outcomes as measures of medical care quality. As noted, the perinatal mortality rate includes the numbers of stillbirths and neonatal deaths per 1000 total births. In 2013, the perinatal mortality rate was 9.98 per 1000 births (Fig. 1-1) (MacDorman, 2015). There were 25,972 fetal deaths at gestational ages of 20 weeks or older. Fetal deaths at 28 weeks or more have been declining since 1990, whereas rates for those between 20 and 27 weeks are static (Fig. 1-2). By way of comparison, there were a total of 19,041 neonatal deaths in 2006—meaning that nearly 60 percent of the perinatal deaths in the United States were fetal.

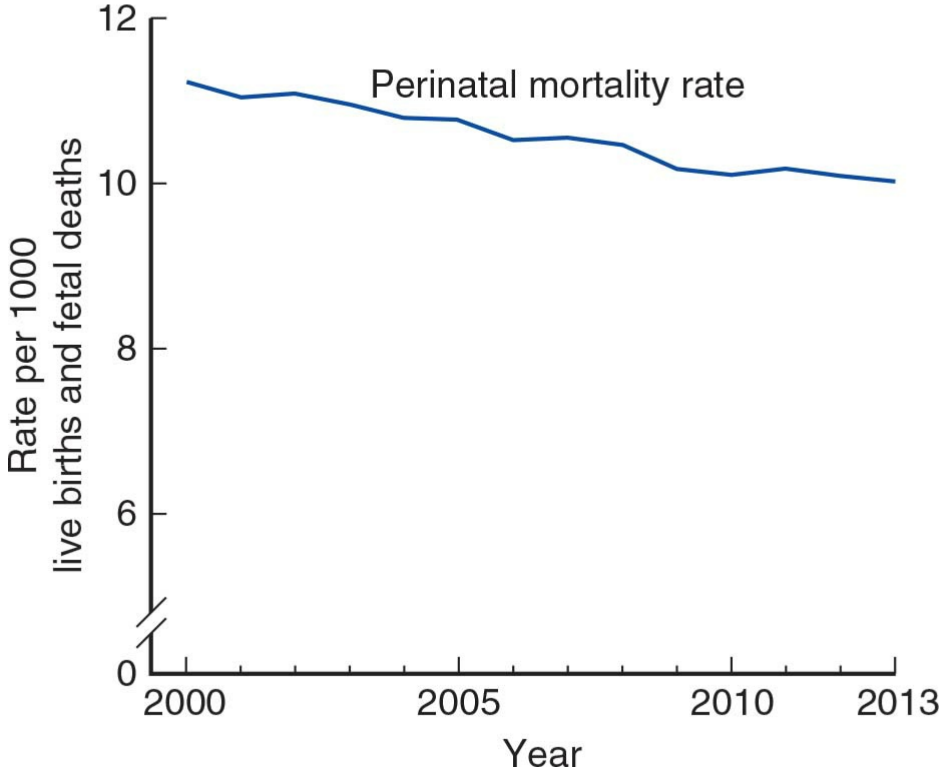

FIGURE 1-1 Perinatal mortality rates: United States, 2000–2013. (Reproduced with permission from MacDorman MF, Gregory EC: Fetal and perinatal mortality: United States, 2013. Natl Vital Stat Rep. 2015 Jul 23;64(8):1–24.)

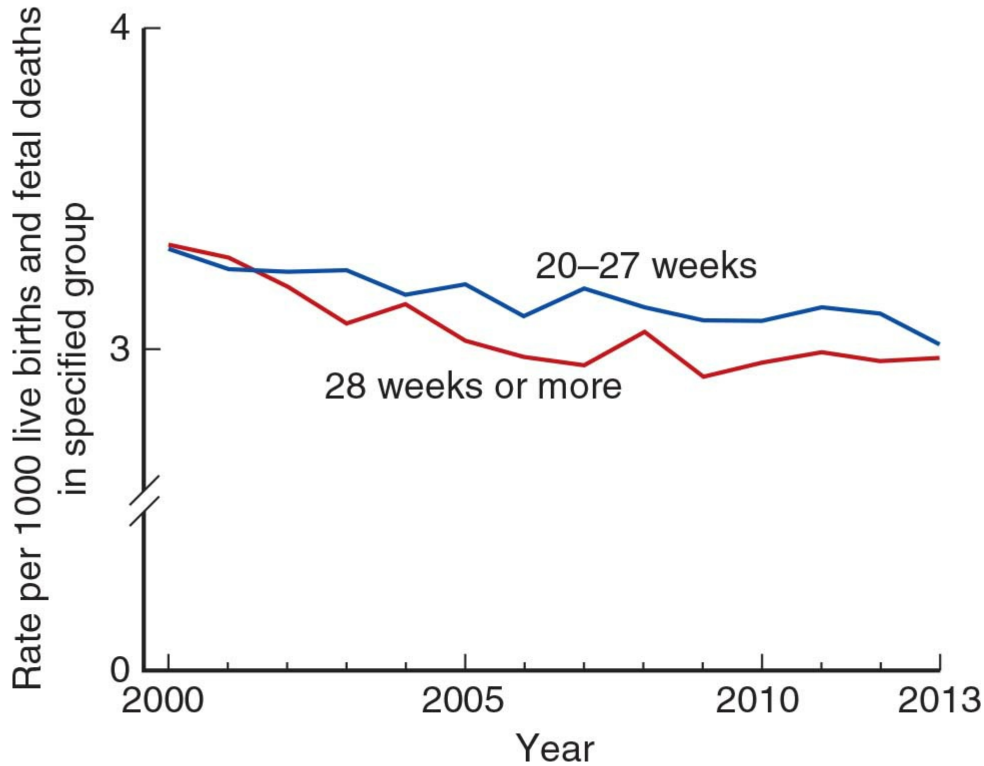

FIGURE 1-2 Fetal and neonatal deaths: United States, 2000–2013. (Modified with permission from MacDorman MF, Gregory EC: Fetal and perinatal mortality: United States, 2013. Natl Vital Stat Rep. 2015 Jul 23;64(8):1–24.)

Infant Deaths

There were 6.1 infant deaths per 1000 live births in 2013 compared with 6.8 in 2001 (MacDorman, 2015). The three leading causes of infant death—congenital malformations, low birthweight, and sudden infant death syndrome—accounted for almost half of all deaths (Heron, 2015). Infants born at the lowest gestational ages and birthweights add substantively to these mortality rates. For example, more than half of all infant deaths in 2005 were in the 2 percent of infants born before 32 weeks' gestation. Indeed, the percentage of infant deaths related to preterm birth increased from 34.6 percent in 2000 to 36.5 percent in 2005. When analyzed by birthweight, two thirds of infant deaths were in low-birthweight neonates. Of particular interest are infants with birthweights <500 g, for whom neonatal intensive care can now be offered.

Maternal Mortality

As shown in Figure 1-3, maternal mortality rates dropped precipitously in the United States during the 20th century. Pregnancy-related deaths are so uncommon as to be measured per 100,000 births. The CDC (2017a) has maintained data on pregnancy-related deaths since 1986 in its Pregnancy Mortality Surveillance System. In the latest report, Creanga and coworkers (2017) described 2009 pregnancy-related deaths during the period from 2011 to 2013. Approximately 5 percent were early-pregnancy deaths due to ectopic gestation or abortive outcomes. The deadly obstetrical triad of hemorrhage, preeclampsia, and infection has accounted for a third of all deaths (Fig. 1-4). Thromboembolism, cardiomyopathy, and other cardiovascular disease together accounted for another third. Other significant contributors were amnionic fluid embolism (5.3 percent) and cerebrovascular accidents (6.2 percent). Anesthesia-related deaths were at an all-time low—only 0.7 percent. Similar causes were reported for selected cohorts for years 2008 to 2009 and 2013 to 2014 (MacDorman, 2017).

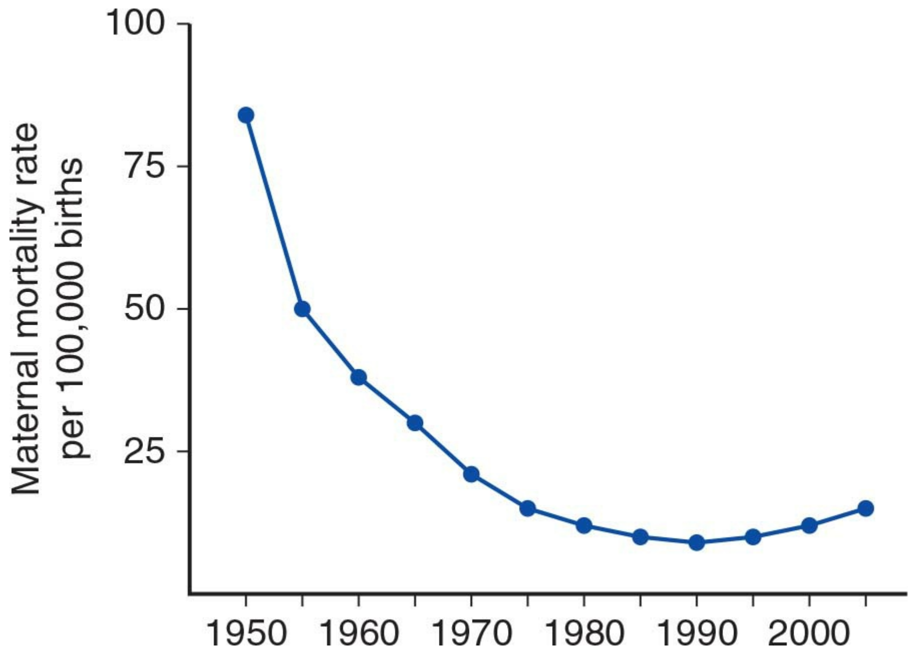

FIGURE 1-3 Maternal mortality rates for the United States, 1950–2003. (Data from Berg, 2010; Hoyert, 2007.)

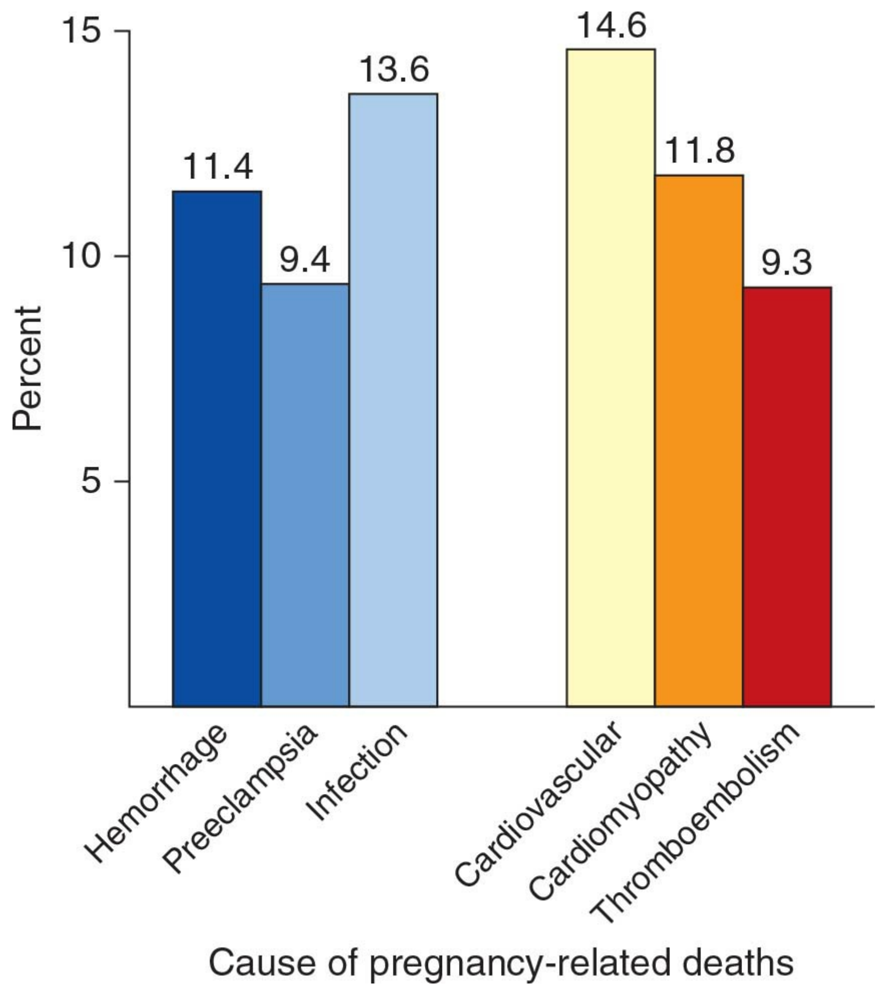

FIGURE 1-4 Six common causes of pregnancy–related deaths for the United States, 2006–2010. (Data from Creanga, 2015.)

Shown in Figure 1-5, the pregnancy-related mortality ratio of 23.8 per 100,000 live births in 2014 is the highest during the previous 40 years. And, according to the Institute of Health Metrics, it was 28 per 100,000 in 2013 (Tavernise, 2016). This rise simply may be that more women are dying, however, other factors explain this doubling of the rate from 1990 to 2013 (Joseph, 2017). The first is an artificial elevation caused by the International Statistical Classification of Diseases, 10th Revision (ICD-10), implemented in 1999. Second, improved reporting definitely contributes to the rise (MacDorman, 2016b, 2017). In the past, maternal deaths were notoriously underreported (Koonin, 1997). Third, and related to the second explanation, the rate of rise is at least partially due to the revised death certificate and its pregnancy checkbox described earlier (Main, 2015). Fourth, the number of pregnant women with severe chronic health conditions, which place women at higher risk, is greater (Centers for Disease Control and Prevention, 2017a). Finally, the increased proportion of births to women older than 40 years contribute to higher mortality rates (MacDorman, 2017).

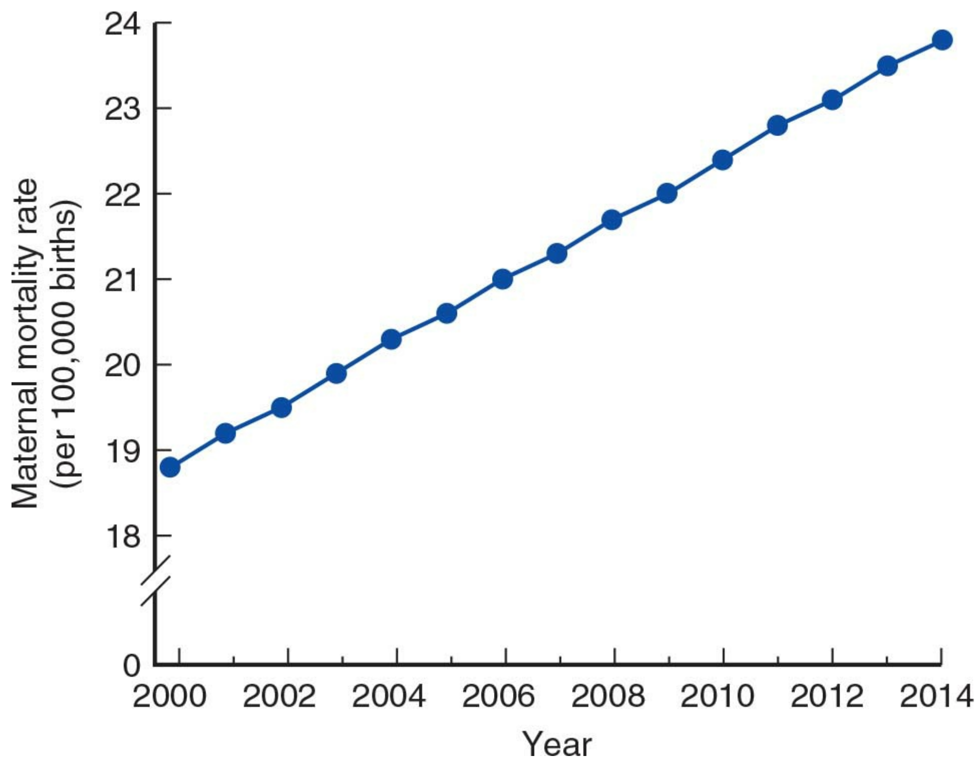

FIGURE 1-5 Estimated maternal mortality rates in 48 states and the District of Columbia. (Data from MacDorman, 2016.)

Whatever the cause, the apparent sharp rise of the maternal mortality rates has galvanized the obstetrical community to action (Chescheir, 2015). According to Barbieri (2015), the Joint Commission has recommended that birthing centers establish standardized protocols and implement simulation efforts. D'Alton and colleagues (2016) described efforts of a working group to lower morbidity and mortality rates.

Another consideration is the obvious disparity of higher mortality rates among black, Hispanic, and white women as shown in Figure 1-6. Racial disparities translate to health care availability, access, or utilization (Howell, 2016; Moaddab, 2016). And, maternal mortality is disparately high in rural compared with metropolitan areas (Maron, 2017).

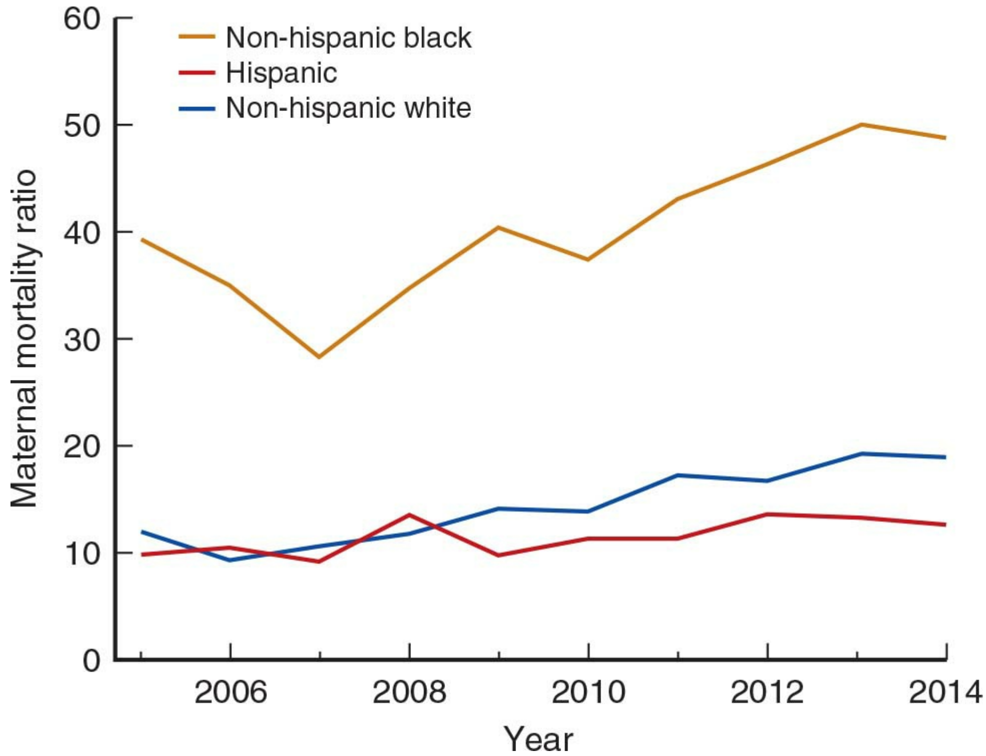

FIGURE 1-6 Trends in maternal mortality ratio (per 100,000 live births) by race: United States, 2005–2014. (Data from Moaddab, 2016.)

Importantly, many of the reported maternal deaths are considered preventable. Berg and colleagues (2005) estimated that this may be up to a third of pregnancy-related deaths in white women and up to half of those in black women. In one evaluation of an insured cohort, 28 percent of 98 maternal deaths were judged preventable (Clark, 2008). Thus, although significant progress has been made, further efforts are imperative for obstetrics in the 21st century.

■ Severe Maternal Morbidity

This serves as another measure to guide prevention efforts. Lowering medical error rates serves to diminish risks for maternal mortality or severe maternal morbidity. The terms *near misses* or *close calls* were introduced and defined as unplanned events caused by error that do not result in patient injury but have the potential to do so (Institute for Safe Medication Practices, 2009). These are much more common than injury events, but for obvious reasons, they are more difficult to identify and quantify. Systems designed to encourage reporting have been installed in various institutions and allow focused safety efforts (Clark, 2012; Main, 2017; Shields, 2017). The American College of Obstetricians and Gynecologists and the Society for Maternal–Fetal Medicine (2016f) have provided lists of suggested screening topics for this purpose.

Several data systems now measure indicators of unplanned events caused by errors that have injurious potential. This evolution followed inadequacies in the ability of hospitalization coding to reflect the severity of maternal complications. Thus, coding indicators or modifiers are used to allow analysis of serious adverse clinical events (Clark, 2012; King, 2012). Such a system was implemented by the World Health Organization. It has been validated in Brazil and accurately reflects maternal death rates (Souza, 2012). Similar systems are in use in Britain as the *UK Obstetric Surveillance System—UKOSS* (Knight, 2005, 2008). In the United States, one example is the National Partnership for Maternal Safety (D'Alton, 2016; Main, 2015).

To study severe morbidity, the CDC analyzed more than 50 million maternity records from the Nationwide Inpatient Sample from 1998 to 2009 (Callaghan, 2012). They used ICD-9-CM codes and reported that 129 per 10,000 of these gravidas had at least one indicator for severe morbidity (Table 1-3). Thus, for every maternal death, approximately 200 women experience severe morbidity. The CDC (2017b) estimates that 65,000 women per year have such maternal morbidity. These numbers are greatest in smaller hospitals with <1000 deliveries annually (Hehir, 2017). Finally, as with mortality rates, there are serious racial and ethnic disparities for severe maternal morbidity, and black women are disproportionately affected (Creanga, 2014).

TABLE 1-3. Severe Maternal Morbidity Indicators

Acute myocardial infarction
Acute renal failure
Adult respiratory distress syndrome
Amnionic fluid embolism
Cardiac arrest/ventricular fibrillation
Disseminated intravascular coagulation
Eclampsia
Heart failure during procedure
Injuries of thorax, abdomen, and pelvis
Intracranial injuries
Puerperal cerebrovascular disorders
Pulmonary edema
Severe anesthesia complications
Sepsis
Shock
Sickle-cell crisis
Thrombotic embolism
Cardiac monitoring
Conversion of cardiac rhythm
Hysterectomy
Cardiac surgery
Tracheostomy

Ventilation
Summarized from the Centers for Disease Control and Prevention, 2017b.

TIMELY TOPICS IN OBSTETRICS

Various topics have been in the forefront for obstetrical providers in the 4 years since the last edition of this textbook. In the following, we discuss several of these topics.

U.S. Health Care in Crisis

Obamacare and Medicaid

In a 2016 issue of the *Journal of the American Medical Association (JAMA),* then-President Barack Obama presented a summary of the Affordable Care Act (ACA), so-called Obamacare. He described the successes, the challenges ahead, and the policy implications of the policy (Bauchner, 2016). He summarized three lessons from his experiences with the ACA. First, change is especially difficult in the face of hyperpartisanship. Second, special interests pose a continued obstacle to change. Third, he stressed the importance of pragmatism. Here, he was referring to the pragmatism necessary when the ACA did not work effectively on day 1 of implementation.

At this same time, draconian cuts to Medicaid were being proposed, and President Obama ended his JAMA report with a quotation from John Kasich, the Republican governor of Ohio. "For those that live in the shadows of life, those who are the least among us, I will not accept the fact that the most vulnerable in our state should be ignored. We can help them."

These potential effects to Medicaid ripple into the specialty of obstetrics. In 2010, it was estimated that Medicaid insured 48 percent of the births in the United States (Markus, 2013). Importantly, Medicaid covered a disproportionate number of complicated births. Specifically, Medicaid insured more than half of all hospital stays for preterm and low-birthweight infants and approximately 45 percent of infant hospital stays due to birth defects.

Repeal and Replace

The young, healthy Americans who were expected to financially bolster the ACA ultimately enrolled in insufficient numbers to ensure long-term ACA sustainability. Thus, long-term options included repair or repeal of the ACA. Throughout Donald Trump's campaign for the presidency of the United States, he made repeal of the ACA a focus of his candidacy. As of this writing, both the United States House of Representatives and the Senate have grappled with "repeal and replace" for 6 months. According to the Congressional Budget Office, this action would result in 23 million Americans losing health care insurance and cuts in Medicaid dollars (Fiedler, 2017). The latter was to be accomplished by transferring funding of Medicaid from the Federal government to the states. These potential outcomes have prompted considerable debate among voters, and "repeal and replace" has become politically charged. Currently, the Senate has been unable to recruit sufficient Republican votes for Senate passage of such a bill. We suggest that the health care crisis should be reframed and redirected instead to a critical analysis of health care costs and resource utilization.

Maternal and Infant Health Care Costs

The Centers for Medicare and Medicaid Services estimated that spending on health care in the United States in 2015 accounted for 17.8 percent of the gross domestic product—GDP (Voelker, 2010). The total amount of health-care spending—$3.2 trillion—equated to an estimated $10,000 per person. Moreover, compared with 12 other high-income countries, health-care spending in the United States as a proportion of GDP was approximately 50 percent more than the next highest country. Yet, health-care outcomes, which included infant mortality rates, were worse in the United States. And, approximately two thirds of U.S. infant deaths result from complications stemming from preterm births (Matthews, 2015). Indeed, in its 2010 annual global Premature Birth Report Card, the United States garnered a grade of "D" from the March of Dimes for its recognition and prevention of preterm labor in the more than 540,000 neonates born annually before 37 weeks' gestation.

Causes for the excessive health care costs in the United States are attributed, in part, to greater use of medical technology and excessive prices (Squires, 2017). Two recent studies demonstrate the detrimental effect of obstetrics on health care costs. The first report by Nelson and coworkers (2017) described the ineffectiveness of 17-alpha hydroxyprogesterone caproate (17-OHP-C) to prevent recurrent preterm birth. Methodology for this trial is presented in Chapter 42 (p. 817). Several lessons can be learned from this investigation. First, use of 17-OHP-C was legitimized in the United States by a national consensus committee using expert opinion. These opinions were promulgated, despite FDA reservations that the evidence was lacking in several important respects. However, once approved, 17-OHP-C was sold by one pharmaceutical company for $1500 for a single, 250-mg injectable dose. Remarkably, this same dose could be compounded and purchased for $25 from local pharmacies. In the subsequent price-gouging controversy, members of the United States Congress intervened to permit continued use of the less expensive 17-OHP-C.

The second study is a multisite prospective trial of the effectiveness of transvaginal sonography to screen for cervical-length shortening to predict preterm birth (Esplin, 2017). A total of 9410 nulliparous women were studied. The Society for Maternal-Fetal Medicine and the American College of Obstetricians and Gynecologists (2016d) both legitimized *universal* cervical-length screening in their joint Committee Opinion (Bloom, 2017). And, by 2015, one survey of 78 Maternal-Fetal Medicine fellowship programs showed that 68 percent were using universal cervical-length screening to predict preterm birth (Khalifeh, 2017). It was estimated that a modest Medicaid rate of $237 per cervical-length ultrasound would result in approximately $350 million in added health care costs. But, Esplin and associates (2017) found that *routine* screening for a short cervix was not beneficial. That is, a widely used intervention was actually ineffective. This is a clear example of how unproven technology can seep into widespread practice.

These two reports highlight a substantial problem in U.S. health care, namely, ineffective yet expensive interventions introduced into broad use without robust evidence. These two reports also speak to a demand for robust scientific evidence. Scrutiny of other ingredients in the health-care paradigm such as prices for hospitalization, prices for surgical procedures, and prices charged by health insurance companies may illuminate similar contributions to the health care fiscal crisis.

Cesarean Delivery Rate

In past editions of this textbook, the rising cesarean delivery rate was considered problematic. This rate has leveled, but there are still imperatives in progress to help lower this rate. One collateral source of cesarean delivery morbidity is from the growing incidence of morbidly adherent placentas encountered in women with a prior hysterotomy incision, discussed in Chapters 31 and 41.

Genomic Technology

Breakthroughs in fetal testing and diagnosis continue to stun. By 2012, prenatal gene microarray techniques were used for clinical management (Dugoff, 2012). The advantages of these techniques are outlined in Chapters 13 and 14. Wapner and coworkers (2012) compared chromosomal microarray analysis of maternal blood with karyotyping for chromosomal anomalies. Reddy and associates (2012) applied this technology to stillbirth evaluation and reported it to be superior to karyotyping. Another report by Talkowski and colleagues (2012) described whole-genome sequencing of a fetus using maternal blood.

Screening for fetal aneuploidy using cell-free DNA (cfDNA) was first introduced in 2011. The technique is described in Chapter 14 (p. 284), and it is based on isolation of free fetal (placental) DNA in maternal blood. In a landmark study, Norton and associates (2015) found that cfDNA had a higher sensitivity and specificity compared with standard prenatal screening for trisomy 21 fetuses. Still, invasive testing is currently necessary to confirm a positive cfDNA test result (Chitty, 2015; Snyder, 2015).

The Ob/Gyn Hospitalist

The term "hospitalist" was coined in the 1990s and referred to physicians whose primary professional focus was generalized care of hospitalized patients. From this concept came the obstetrical and gynecological hospitalist whose primary role was to care for hospitalized obstetrical patients and to help manage their emergencies. These physicians could also provide urgent gynecological care and emergency department consultation. Alternative terms include "obstetrical hospitalist" or "laborist," but the preferred standardized term by the American College of Obstetricians and Gynecologists (2016e) is "Ob/Gyn hospitalist."

Although not a recognized subspecialty of obstetrics and gynecology, the Ob/Gyn hospitalist movement has gained momentum. The Society of Ob-Gyn Hospitalists had 528 members in 2017 (Burkard, 2017). Various practice models are described to fit the needs of a wide spectrum of obstetrical volumes (McCue, 2016). In addition to providing lifestyle modifications, Ob/Gyn hospitalists are used by some hospitals to improve the quality and safety of their women's services and to reduce adverse events. Aside from a possible lowering of the labor induction rate, studies are needed to demonstrate improved outcomes with these providers (American College of Obstetricians and Gynecologists, 2016e; Srinivas, 2016).

Medical Liability

The American College of Obstetricians and Gynecologists periodically surveys its fellows concerning the effect of liability on their practice. The 2015 Survey on Professional Liability is the 12th such report since 1983 (Carpentieri, 2015). From this survey, it appears that there is still a "liability crisis," and the reasons for it are complex. Because it is largely driven by money and politics, a consensus seems unlikely. Although some interests are diametrically opposite, other factors contribute to the problem's complexity. For example, each state has its own laws and opinions on tort reform. In some states, annual premiums for obstetricians approach $300,000—expenses that at least partially are borne by the patient and certainly by the entire health-care system. In 2011, all tort costs in the United States totaled nearly $265 billion. This is an astounding 1.8 percent of the gross domestic product and averages to a cost of $838 per citizen (Towers Watson, 2015).

The American College of Obstetricians and Gynecologists (2016a,c) has taken a lead in adopting a fair system for malpractice litigation—or *maloccurrence litigation*. And nationally, there is the possibility of federal tort reform under the Trump administration (Lockwood, 2017; Mello, 2017).

Home Births

Following a slight decline from 1990 through 2004, the percentage of out-of-hospital births in the United States increased from 0.86 to 1.5 percent—almost 75 percent—through 2014 (MacDorman, 2016a). Of these home births, only a third are attended by nurse midwives certified by the American Midwife Certification Board (Grünebaum, 2015; Snowden, 2015).

Proponents of home births cite successes derived from laudatory observational data from England and The Netherlands (de Jonge, 2015; Van der Kooy, 2011). Data from the United States, however, are less convincing and indicate a higher incidence of perinatal morbidity and mortality (Grünebaum, 2014, 2015; Snowden, 2015; Wasden, 2014; Wax, 2010). These latter findings have led Chervenak and coworkers (2013, 2015) to question the ethics of participation in planned home births. Greene and Ecker (2015) take a broader view. Given data from these more recently cited studies, they are of the view that these data empower women to make a rational decision regarding home delivery. The American

College of Obstetricians and Gynecologists (2017b) believes that hospitals and accredited birth centers offer the safest settings, but that each woman has the right to make a medically informed decision regarding delivery.

Family Planning Services

Politics and religion over the years have led to various governmental interferences with the reproductive rights of women. These intrusions have disparately affected indigent women and adolescents. This is despite all reports of the overwhelming success of such programs. One example is the exclusion of Planned Parenthood affiliates from the Texas Medicaid fee-for-service family planning program. In some groups of women served, there was discontinuation of contraception and an increased rate of Medicaid births (Stevenson, 2016).

According to the Guttmacher Institute (2016a), publicly funded family planning services are needed by 20 million American women. In 2014, such services prevented nearly 2 million unintended pregnancies and 700,000 abortions in the United States. The fate of family planning services is not fully determined, while waiting for decisions regarding provisions within the 2017 American Health Care Act (AHCA), or "Trumpcare." In his response to news that the AHCA may dismantle contraceptive coverage, American College of Obstetricians and Gynecologists President Dr. Haywood Brown (2017) called this a deep disregard for women's health.

Opioid Abuse in Pregnancy

According to the CDC (2014), there were 259 million prescriptions written in 2012 for opioid medications. In 2013, more than a third of American adults reported prescription opioid use (Han, 2017). These freely available—albeit requiring a prescription—addictive drugs are associated with *opioid use disorders*. It remains uncertain if opioid use is teratogenic (Lind, 2017). Still, their abuse by pregnant women has caused an unprecedented rise in the *neonatal abstinence syndrome,* described further in Chapters 12 (p. 248) and 33 (p. 625). Treatment of opioid abuse in pregnancy and its sequelae result in $1.5 billion annually in hospital charges.

For obstetrical providers to better deal with opioid-addicted pregnant women and their fetus–newborns, the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development convened a workshop in 2016 to study many aspects of the problem (Reddy, 2017). The Workshop was cosponsored by the American College of Obstetricians and Gynecologists, the American Academy of Pediatrics, the Society for Maternal–Fetal Medicine, the CDC, and the March of Dimes. Several topics were addressed, and hopefully implementation of these findings will help improve maternal treatment and neonatal outcomes (American College of Obstetricians and Gynecologists, 2017a).

Brave New World

The bold new concept of in-vitro fertilization (IVF) produced the first IVF baby in Britain in 1978. This was soon followed in 1981 with an American success. After four decades, the Society for Assisted Reproductive Technology (SART) reports that more than 1 million babies have been born in the United States using assisted reproductive technologies (ART) offered by 440 clinics (Fox, 2017).

After 15 years of experimental preparation, the promise of a successful human uterine transplant was finally realized with an IVF-conceived liveborn neonate in Sweden (Brännström, 2015). During pregnancy, the mother was treated with tacrolimus, azathioprine, and corticosteroids and underwent cesarean delivery at 32 weeks for preeclampsia and abnormal fetal heart rate testing. This was followed by uterine transplantation programs at the Cleveland Clinic and Baylor Medical Center in Dallas (Flyckt, 2016, 2017; Testa, 2017). In 2017, the Swedish team had completed a nine-patient trial, in which seven women had become pregnant and five had successful deliveries (Kuehn, 2017). Also, in Dallas, the first such newborn in the United States was born (Rice, 2017).

Meanwhile, researchers at Children's Hospital of Philadelphia pursued a 20-year goal in search of an artificial womb (Yuko, 2017). Using incubator technology, the team devised an artificial amnionic sac. Through this, the umbilical vessels were perfused and drained, and the blood was returned to systems that performed extracorporeal membrane oxygenation and dialysis. To date, lamb fetuses have been kept alive for as long as 1 month. Adverse effects of cerebrovascular hypotension and hypoxemia are conjectural but highly worrisome.

The ethical and legal challenges of these new technologies are daunting. Of those that arose from IVF, most are settled. For the other two endeavors, there are likely many years of ethical and legal milestones ahead.

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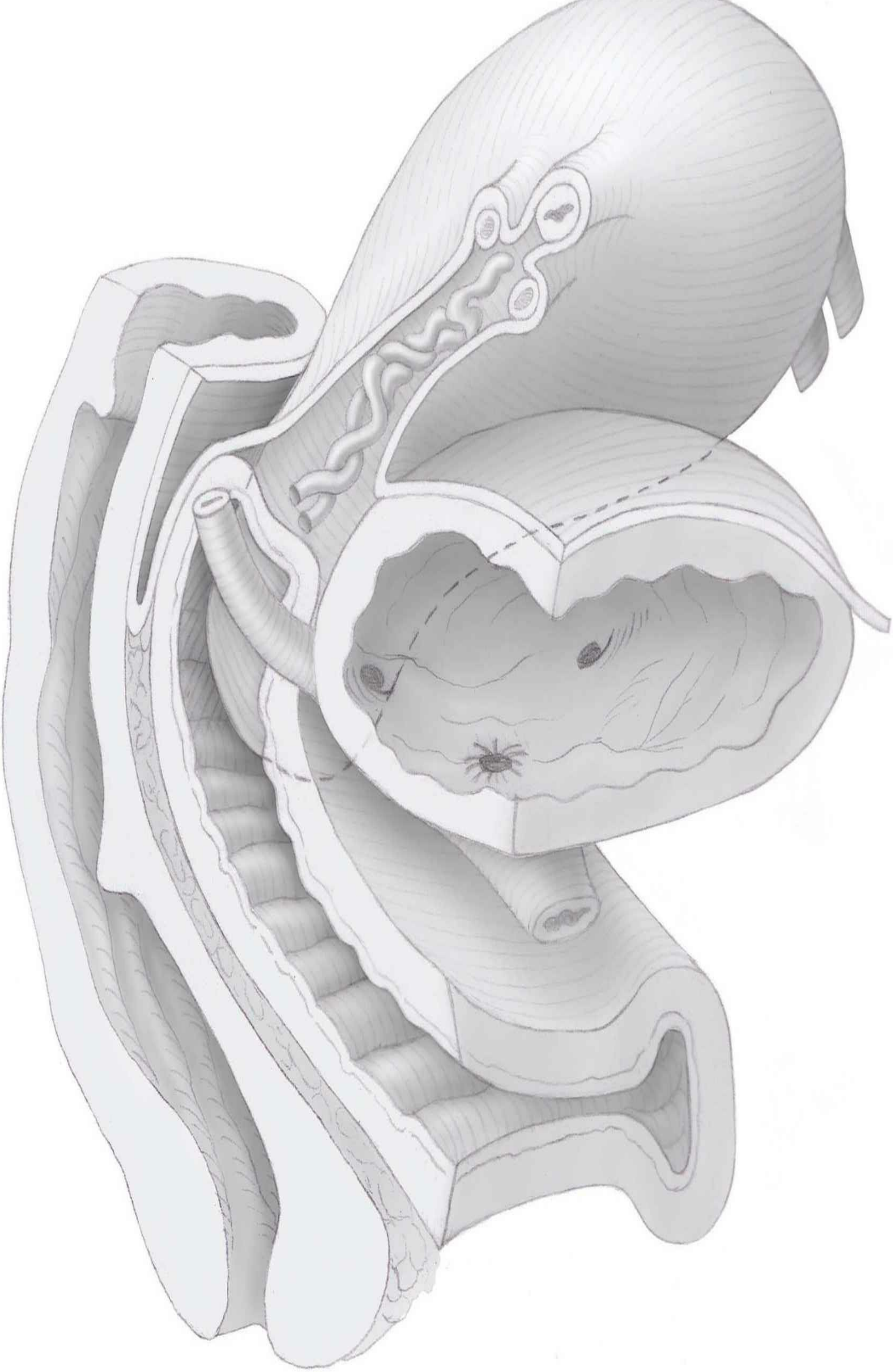
SECTION 2

MATERNAL ANATOMY AND PHYSIOLOGY



CHAPTER 2

Maternal Anatomy

ANTERIOR ABDOMINAL WALL

EXTERNAL GENERATIVE ORGANS

INTERNAL GENERATIVE ORGANS

LOWER URINARY TRACT STRUCTURES

MUSCULOSKELETAL PELVIC ANATOMY

> *As the mechanism of labour is essentially a process of accommodation between the foetus and the passage through which it must pass, it is apparent that obstetrics lacked a scientific foundation until the anatomy of the bony pelvis and of the soft parts connected with it was clearly understood.*
>
> —J. Whitridge Williams (1903)

ANTERIOR ABDOMINAL WALL

Skin, Subcutaneous Layer, and Fascia

The anterior abdominal wall confines abdominal viscera, stretches to accommodate the expanding uterus, and provides surgical access to the internal reproductive organs. Thus, a comprehensive knowledge of its layered structure is required to surgically enter the peritoneal cavity.

Langer lines describe the orientation of dermal fibers within the skin. In the anterior abdominal wall, they are arranged transversely. As a result, vertical skin incisions sustain greater lateral tension and thus, in general, develop wider scars. In contrast, low transverse incisions, such as the Pfannenstiel, follow Langer lines and lead to superior cosmetic results.

The subcutaneous layer can be separated into a superficial, predominantly fatty layer—Camper fascia, and a deeper membranous layer—Scarpa fascia. Camper fascia continues onto the perineum to provide fatty substance to the mons pubis and labia majora and then to blend with the fat of the ischioanal fossa. Scarpa fascia continues inferiorly onto the perineum as Colles fascia, described on page 19.

Beneath the subcutaneous layer, the anterior abdominal wall muscles consist of the midline rectus abdominis and pyramidalis muscles as well as the external oblique, internal oblique, and transversus abdominis muscles, which extend across the entire wall (Fig. 2-1). The fibrous aponeuroses of these three latter muscles form the primary fascia of the anterior abdominal wall. These fuse in the midline at the linea alba, which normally measures 10 to

15 mm wide below the umbilicus (Beer, 2009). An abnormally wide separation may reflect diastasis recti or hernia.

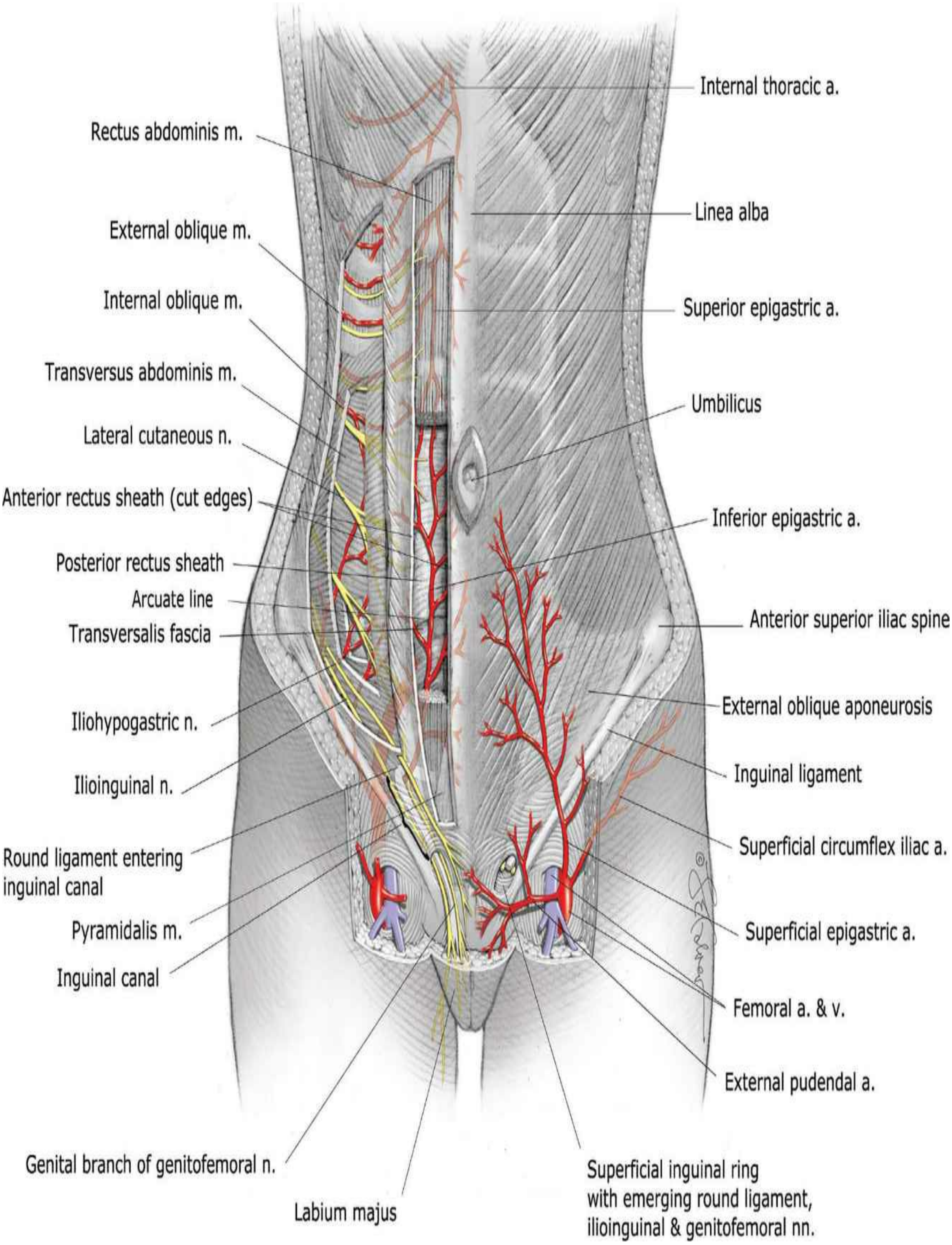


FIGURE 2-1 Anterior abdominal wall anatomy. (Modified with permission from Corton MM: Anatomy. In Hoffman BL, Schorge JO, Bradshaw KD, et al (eds): Williams Gynecology, 3rd ed. New York, McGraw-Hill Education, 2016.)

These three aponeuroses also invest the rectus abdominis muscle as the rectus sheath. The construction of this sheath varies above and below a boundary, termed the arcuate line (see Fig. 2-1). Cephalad to this border, the aponeuroses invest the rectus abdominis bellies on both dorsal and ventral surfaces. Caudal to this line, all aponeuroses lie ventral or superficial to the rectus abdominis muscle, and only the thin transversalis fascia and peritoneum lie beneath the rectus (Loukas, 2008). This transition of rectus sheath composition can be seen best in the upper third of a midline vertical abdominal incision.

The paired small triangular pyramidalis muscles originate from the pubic crest and insert into the linea alba. These muscles lie atop the rectus abdominis muscle but beneath the anterior rectus sheath.

Blood Supply

The superficial epigastric, superficial circumflex iliac, and superficial external pudendal arteries arise from the femoral artery just below the inguinal ligament within the femoral triangle (see Fig. 2-1). These vessels supply the skin and subcutaneous layers of the anterior abdominal wall and mons pubis. Of these three, the superficial epigastric vessels are surgically important to the obstetrician and course diagonally from their origin toward the umbilicus. With a low transverse skin incision, these vessels can usually be identified at a depth halfway between the skin and the anterior rectus sheath. They lie above Scarpa fascia and several centimeters from the midline. Ideally, these vessels are identified and surgically occluded.

In contrast, the inferior "deep" epigastric vessels are branches of the external iliac vessels and supply anterior abdominal wall muscles and fascia. Of surgical relevance, the inferior epigastric vessels initially course lateral to, then posterior to the rectus abdominis muscles, which they supply. Above the arcuate line, these vessels course ventral to the posterior rectus sheath and lie between this sheath and the posterior surface of the rectus muscles. Near the umbilicus, the inferior epigastric vessels anastomose with the superior epigastric artery and vein, which are branches of the internal thoracic vessels. Clinically, when a Maylard incision is used for cesarean delivery, the inferior epigastric vessels may be lacerated lateral to the rectus belly during muscle transection. Preventively, identification and surgical occlusion are preferable. These vessels rarely may rupture following abdominal trauma and create a rectus sheath hematoma (Tolcher, 2010; Wai, 2015).

On each side of the lower anterior abdominal wall, Hesselbach triangle is the region bounded laterally by the inferior epigastric vessels, inferiorly by the inguinal ligament, and medially by the lateral border of the rectus abdominis muscle. Hernias that protrude through the abdominal wall in Hesselbach triangle are termed direct inguinal hernias. In contrast, indirect inguinal hernias do so through the deep inguinal ring, which lies lateral to this triangle, and then may exit out the superficial inguinal ring.

Innervation

The entire anterior abdominal wall is innervated by intercostal nerves (T_{7-11}), the subcostal nerve (T_{12}), and the iliohypogastric and the ilioinguinal nerves (L_1). Of these, the intercostal and subcostal nerves are anterior rami of the thoracic spinal nerves and run along the lateral and then anterior abdominal wall between the transversus abdominis and internal oblique muscles (Fig. 2-2). This space, termed the transversus abdominis plane, can be used for postcesarean analgesia blockade (Chap. 25, p. 500) (Fusco, 2015; Tawfik, 2017). Others report rectus sheath or ilioinguinal-iliohypogastric nerve blocks to decrease postoperative pain (Mei, 2011; Wolfson, 2012).

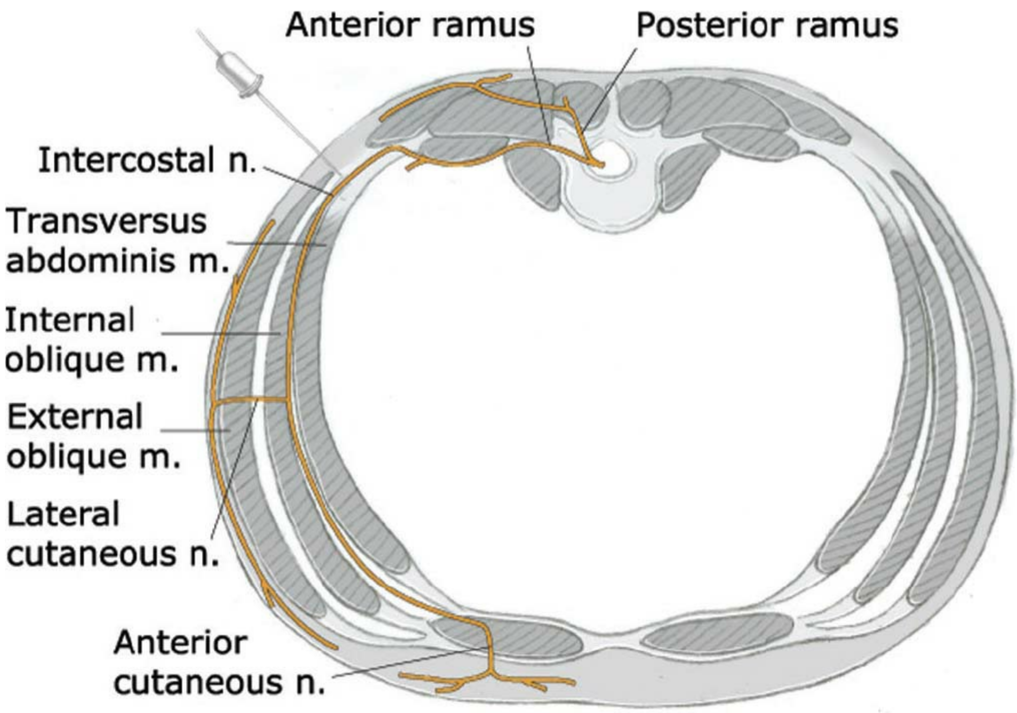


FIGURE 2-2 Intercostal and subcostal nerves are the anterior rami of spinal nerves. In this figure, an intercostal nerve extends ventrally between the transversus abdominis and internal oblique muscles. During this path, the nerve gives rise to lateral and anterior cutaneous branches, which innervate the anterior abdominal wall. As shown by the inserted needle, the transversus abdominis plane (TAP) block takes advantage of this anatomy. (Modified with permission from Hawkins JL: Anesthesia for the pregnant woman. In Yeomans ER, Hoffman BL, Gilstrap LC III, et al: Cunningham and Gilstraps's Operative Obstetrics, 3rd ed. New York, McGraw Hill Education, 2017.)

Near the rectus abdominis lateral borders, anterior branches of the intercostal and subcostal nerves pierce the posterior sheath, rectus muscle, and then anterior sheath to reach the skin. Thus, these nerve branches may be severed during a Pfannenstiel incision creation during the step in which the overlying anterior rectus sheath is separated from the rectus abdominis muscle.

In contrast, the iliohypogastric and ilioinguinal nerves originate from the anterior ramus of the first lumbar spinal nerve. They emerge lateral to the psoas muscle and travel retroperitoneally across the quadratus lumborum inferomedially toward the iliac crest. Near this crest, both nerves pierce the transversus abdominis muscle and course ventromedially. At a site 2 to 3 cm medial to the anterior superior iliac spine, the nerves then pierce the internal oblique muscle and course superficial to it toward the midline (Whiteside, 2003). The iliohypogastric nerve perforates the external oblique aponeurosis near the lateral rectus border to provide sensation to the skin over the suprapubic area (see Fig. 2-1). The ilioinguinal nerve in its course medially travels through the inguinal canal and exits through the superficial inguinal ring, which forms by splitting of external abdominal oblique aponeurosis fibers. This nerve supplies the skin of the mons pubis, upper labia majora, and medial upper thigh.

The ilioinguinal and iliohypogastric nerves can be severed during a low transverse incision or entrapped during closure, especially if incisions extend beyond the lateral borders of the rectus abdominis muscle (Rahn, 2010). These nerves carry sensory information only, and injury leads to loss of sensation within the areas supplied. Rarely, chronic pain may develop (Whiteside, 2005).

The T_{10} dermatome approximates the level of the umbilicus. Analgesia to this level is suitable for labor and vaginal birth. Regional analgesia for cesarean delivery or for puerperal sterilization ideally extends to T_4.

EXTERNAL GENERATIVE ORGANS

■ Vulva

Mons Pubis, Labia, and Clitoris

The pudenda—commonly designated the vulva—includes all structures visible externally from the symphysis pubis to the perineal body. This includes the mons pubis, labia majora and minora, clitoris, hymen, vestibule, urethral opening, greater vestibular or Bartholin glands, minor vestibular glands, and paraurethral glands (Fig. 2-3). The vulva receives innervations and vascular support from the pudendal nerve (p. 22).

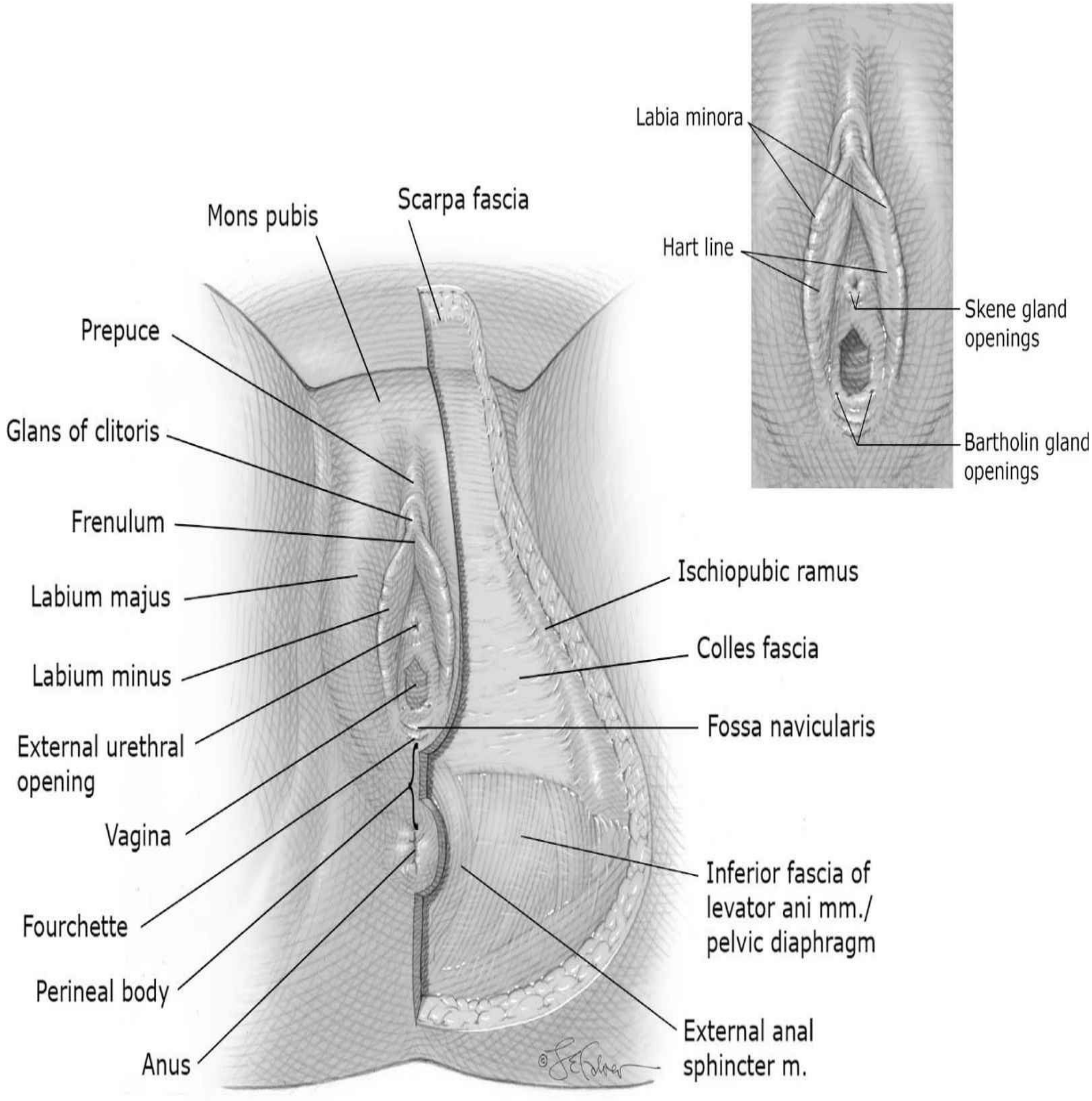


FIGURE 2-3 Vulvar structures and subcutaneous layer of the anterior perineal triangle. Note the continuity of Colles and Scarpa fasciae. Inset: Vestibule boundaries and openings onto vestibule. (Reproduced with permission from Corton MM: Anatomy. In Hoffman BL, Schorge JO, Bradshaw KD, et al (eds): Williams Gynecology, 3rd ed. New York, McGraw-Hill Education, 2016.)

The mons pubis is a fat-filled cushion overlying the symphysis pubis. After puberty, the mons pubis skin is covered by curly hair that forms the triangular escutcheon, whose base aligns with the upper margin of the symphysis pubis. In men and some hirsute women, the escutcheon extends farther onto the anterior abdominal wall toward the umbilicus.

Labia majora usually are 7 to 8 cm long, 2 to 3 cm wide, and 1 to 1.5 cm thick. They are continuous directly with the mons pubis superiorly, and the round ligaments terminate at their upper borders. Hair covers the labia majora, and apocrine, eccrine, and sebaceous glands are abundant. Beneath the skin, a dense connective tissue layer is nearly void of