

Regional Variations in Maternal Mortality and Health Workforce Availability in the United States

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Background: Skilled, high-quality health providers and birth attendants are important for reducing maternal mortality.

Objective: To assess whether U.S. regional variations in maternal mortality rates relate to health workforce availability.

Design: Comparison of regional variations in maternal mortality rates and women's health provider rates per population and identification of a relationship between these measures.

Setting: U.S. health system.

Participants: Women of child-bearing age and women's health providers, as captured in federal data sources from the Centers for Disease Control and Prevention, Census Bureau, and Health Resources and Services Administration.

Measurements: Regional-to-national rate ratios for maternal mortality and women's health provider availability, calculated per population for women of reproductive age. Provider availability was examined across occupations (obstetrician-gynecologists, internal medicine physicians, family medicine physicians, certified nurse-midwives), in service-based categories (birth-attending and primary care providers), and across the entire women's health workforce (all studied occupations).

Results: Maternal deaths per population increased nationally from 2009 to 2017 and, in 2017, were significantly higher in the South and lower in the Northeast ($P < 0.001$) than nationally. The occupational composition and per-population availability patterns of the women's health workforce varied regionally in 2017. The South had the lowest availability in the nation for nearly every health occupation and category studied, and the Northeast had the highest. This exploratory analysis suggests that subnational levels of provider availability across a region may be associated with higher maternal mortality rates.

Limitations: No causal relationship was established. Nationally representative maternal mortality and health workforce data sources have well-known limitations. Low numbers of observations limit statistical analyses.

Conclusion: Regional variations in maternal mortality rates may relate to the availability of birth-attending and primary care providers.

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The United States has one of the highest maternal mortality rates among developed nations, and this rate has increased markedly over the past several decades (1, 2). Limited access to high-quality prenatal and maternity care services contributes to mortality risks, particularly for lower-income individuals, members of racial and ethnic minority groups, and those living in rural areas distant from health care providers and facilities (3–9). Broader determinants of maternal mortality have been characterized into 3 categories: individual nonmedical risk factors (such as poverty and racial/ethnic inequities), social and economic context (such as women's societal status and legality of reproductive health services), and factors related to physical environment and health systems (such as number, quality, and distribution of health workers and facilities) (10).

Core to the mission of the Health Resources and Services Administration (HRSA) is improving health outcomes and addressing health disparities by strengthening access nationally to a skilled health workforce and quality health services, which are conceptually important factors for addressing maternal mortality (10–12). For example, sufficient access to obstetrician-gynecologists is critical for managing pregnancy complications and obstetric emergencies, and care by internists and other primary care providers is important for providing compre-

hensive chronic disease management before, during, and after pregnancy (13, 14). Obstetrician-gynecologists and primary care providers both provide core health services to women, with the latter appearing to play a particularly important role in rural areas and lower-birth volume hospitals (15, 16). Although international studies have correlated health worker access and maternal mortality, studies finding a direct association between availability of health care providers for women of reproductive age and maternal mortality in the United States are lacking (17–22).

A pair of reports from HRSA's National Center for Health Workforce Analysis have projected future shortages of primary care providers and women's health providers across multiple professions, both nationally and regionally (23, 24). A nationwide deficit of 23 640 primary care physicians and 4930 obstetrician-gynecologists is anticipated by 2025, with shortages distributed unevenly across U.S. census regions and the South having the greatest collective workforce shortfalls. In light of these findings, this study aimed to investigate whether there may be a geographic association between increased maternal mortality rates and decreased availability of key health care providers serving women of reproductive age across census regions. Preliminary identification of such a relationship would provide support for including directed health workforce

reinforcement as one component of a multifaceted strategic approach for addressing maternal mortality. For the purposes of this study, the health professions examined include allopathic and osteopathic physicians in the specialties of obstetrics-gynecology, family medicine, and internal medicine, as well as certified nurse-midwives. Regional availability patterns for nurse practitioners and physician assistants were also assessed.

METHODS

To examine regional differences in maternal mortality, national vital statistics information on births and maternal deaths was analyzed using data collected by the Centers for Disease Control and Prevention (CDC) and made publicly available through the Wide-ranging ONline Data for Epidemiologic Research (WONDER) portal (25). WONDER provides access to many health-related data sets for use in epidemiology-focused public health research and is particularly useful for studying health care trends in highly populated areas, such as states, regions, or the nation as a whole (26). WONDER data were selected for study because of the availability of more recent years of maternal mortality data than other resources, and it also matched years for which health workforce data were available. Consistent with the CDC definition, maternal mortality events occurring up to 1 year after childbirth or pregnancy termination were retrieved from WONDER using relevant cause of death codes relating to pregnancy, childbirth, or the puerperium (**Appendix Table**, available at [Annals.org](https://www.annals.org)), defined since 1999 in the system using the International Classification of Diseases, 10th Revision (ICD-10) (27, 28). Maternal deaths were tabulated by U.S. census region for the period from 2009 to 2017. Census region was chosen as the geographic unit of analysis for alignment with available health workforce data and because other WONDER-based studies relating physician supply to mortality have identified regional patterns, presumably due to shared socioeconomic and population characteristics within regions (29).

To determine regional maternal mortality rates, data from the U.S. Census Bureau's American Community Survey from 2009 to 2017 were used to capture the total population of women of reproductive age (30). A common denominator of providers and maternal mortality events per 100 000 women aged 15 to 50 years was used for this study. Although maternal mortality is often reported in public health studies as the number of maternal deaths per a specified number (for example, 100 000) of live births, such an index would not have been appropriate for this workforce-focused study for 2 reasons. First, not all deaths attributed to pregnancy, childbirth, and the puerperium result in live births. Second, the health care providers essential to preventing and mitigating risks for maternal morbidity and mortality need to engage in the care of all women of reproductive age before or while contemplating pregnancy. For example, women with asthma or diabetes considering pregnancy should be engaged in comprehensive chronic disease management before preg-

nancy to mitigate their perinatal health risks; such care is often provided by an internist (14). This analytic approach ensures that provider availability is examined relative to the entire target population needing care before, during, and after pregnancy and correspondingly examines the rate of maternal deaths within this same population. A similar approach has been used by the CDC for provisional measurement of the U.S. fertility rate and by others researching access to prenatal and pregnancy care (31, 32).

Regional differences in women's health provider availability or density were estimated as the number of per-population providers for women of reproductive age by using 2017 health workforce data from HRSA's Area Health Resources Files for each studied occupation (33). Practitioners examined include obstetrician-gynecologists, family medicine physicians, and certified nurse-midwives, who directly attend deliveries, and primary care providers (such as internal medicine physicians), who typically do not. Estimates from the literature suggest that most U.S. births are attended by obstetrician-gynecologists, with family medicine physicians and certified nurse-midwives attending approximately 9.7% and 7.9% of all births, respectively (34, 35). However, around one third of pregnant women report receiving medical care from a family physician, and nearly two thirds report receiving care from a mix of clinicians, which can include obstetrician-gynecologists, family physicians, midwives, nurse practitioners, and physician assistants (36). The regional availability of nurse practitioners and physician assistants was considered separately in this study because data limitations prevented detailed differentiation of these providers by specialty area, such as primary care and women's health. Further, variability in state scope of practice regulations results in inconsistent levels of autonomy regionally with respect to diagnosis, treatment, and prescriptive authority (37).

Women's health occupations were examined individually and collectively ("all women's health providers") to determine whether any observed differences in the effect of health workforce supply on maternal mortality could be ascribed to the role of a specific specialty (such as obstetrician-gynecologist shortages) or overall provider access issues (such as broad workforce insufficiency). Additional categorical workforce groupings were developed to assess whether workforce supply effects might relate to a particular service need that can be provided by more than 1 occupation. Thus, obstetrician-gynecologists, family medicine physicians, and certified nurse-midwives were studied collectively ("direct childbirth providers") as the group primarily responsible for attending deliveries. The category "primary care physicians," which included nonspecialist family medicine and internal medicine physicians, was also studied.

Rate ratios were calculated to examine differences in each census region, relative to national levels, for both maternal mortality rates and women's health provider density in 2017. For example, a maternal mortality rate ratio of 1 would suggest that the rate for a given census region is the same as the national rate and that

there is no unique regional variation from the country as a whole. A rate ratio lower than 1 suggests a lower regional mortality rate than the national average, and a ratio higher than 1 suggests a higher rate. A rate ratio approach has been used by others to examine maternal mortality risks where risk varies geographically (38). Despite a low number of observations available for statistical analysis, exploring whether regional mortality and workforce density were markedly different from the nation as a whole was central to this investigation and can suggest possible mortality-workforce relationships (29). As such, further analysis with exact Poisson tests was conducted using SAS, version 9.4 (SAS Institute), and R, version 3.5.1 (R Foundation). Maternal mortality and workforce analyses were also replicated using 2016 data.

Institutional Review Board Approval

Analysis of deidentified, publicly available, population-level data does not require institutional review board approval.

Role of the Funding Source

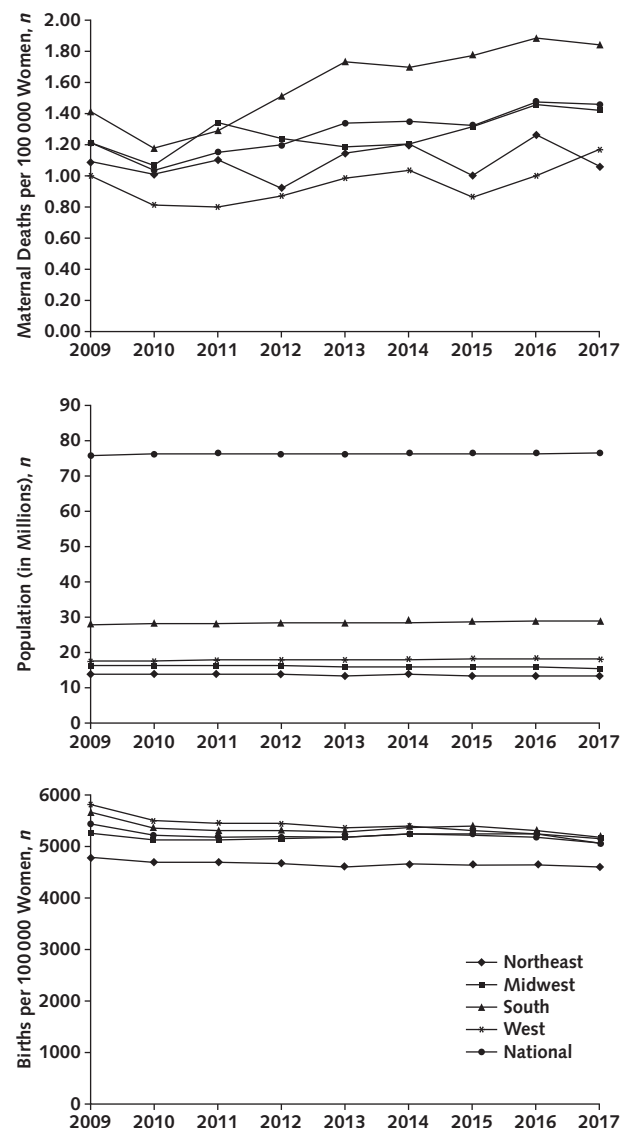
The study received no funding.

RESULTS

Analysis of death rates for women of reproductive age attributed to pregnancy, childbirth, and the puerperium from 2009 to 2017 revealed variations between national and regional trends (Figure 1, top). The maternal mortality rate in the United States increased during this period and was 20.24% higher in 2017 than in 2009 (1.46 vs. 1.21 maternal deaths per 100 000 women aged 15 to 50 years). The nation's most populous census region, the South, had both the highest regional maternal mortality rate and the largest interval rate increase, being 30.40% higher in 2017 (1.84) than in 2009 (1.41). Northeast mortality rates dropped slightly during this same period (2.69%). To further examine the higher per-population mortality rate in the South, 2 other analyses were performed to assess whether the study population size and birth rates changed during the study period, nationally and across census regions. Population growth for women of child-bearing age in the United States (0.82%) and the South (4.20%) was negligible to modest during the same period of study (Figure 1, middle). Further, a similar slight decrease in the birth rate was observed in this population during this same interval in the nation and each census region (Figure 1, bottom).

When examining the regional availability patterns for the various health care providers essential in the care of women of reproductive age in 2017, the overall workforce composition varied geographically (Figure 2). The Northeast had the highest provider density nationally for obstetrician-gynecologists, certified nurse-midwives, internal medicine physicians, and the group categories of primary care physicians and all women's health providers (Table 1). The Northeast was the 1 region in the nation where internal medicine was the predominantly available physician specialty overall and

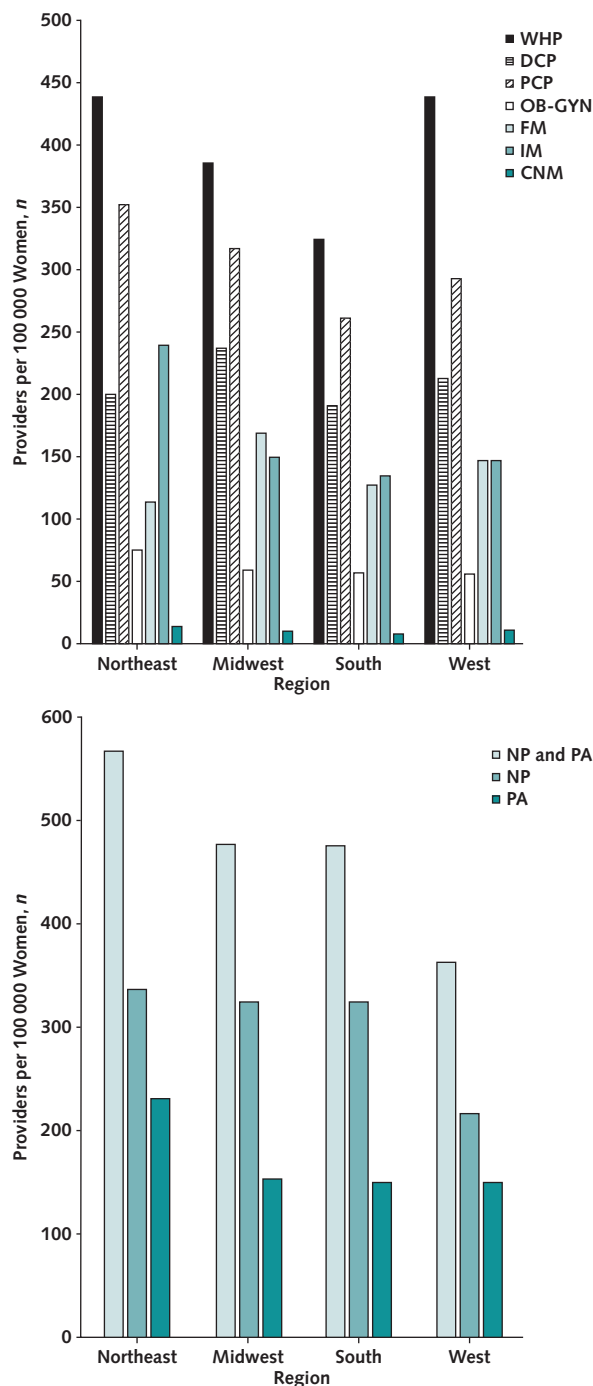
Figure 1. National and regional maternal death rates, population size, and birth rates for women aged 15 to 50 y in the United States from 2009 to 2017.



Data are from the Centers for Disease Control and Prevention's WONDER portal (23) and the U.S. Census Bureau (27). **Top.** National and regional deaths attributed to pregnancy, childbirth, and the puerperium per 100 000 women aged 15 to 50 y from 2009 to 2017. During this period, per-population maternal death rates increased by 20.24% nationally; decreased by 2.69% in the Northeast; and increased by 17.72% in the Midwest, 30.40% in the South, and 17.47% in the West. **Middle.** National and regional population of women aged 15 to 50 y from 2009 to 2017. During this period, the population increased by 0.82% nationally; decreased by 3.36% in the Northeast and 4.86% in the Midwest; and increased by 4.20% in the South and 4.10% in the West. **Bottom.** National and regional number of births per 100 000 women aged 15 to 50 y from 2009 to 2017. During this period, the per-population birth rate decreased by 7.42% nationally, 3.98% in the Northeast, 2.06% in the Midwest, 8.57% in the South, and 12.74% in the West.

also where internal medicine physician density exceeded family medicine within the field of primary care. A preponderance of per-population family medicine physicians in the Midwest drove this region to have the

Figure 2. Regional workforce composition for women's health providers in 2017.



Each occupation/specialty and grouping represent workforce availability, defined as the number of available providers per 100 000 U.S. women aged 15 to 50 y. CNM = certified nurse-midwives; DCP = direct childbirth providers; FM = family medicine physicians; IM = internal medicine physicians; NP = nurse practitioners; OB-GYN = obstetrician-gynecologists; PA = physician assistants; PCP = primary care physicians (includes family medicine and internal medicine physicians); WHP = all women's health providers.

highest national provider density for the category of direct childbirth providers. The South had the lowest per-population availability in the nation for certified nurse-midwives and internal medicine physicians, as well as for the group categories of primary care physicians, direct childbirth providers, and all women's health providers, and had the second lowest obstetrician-gynecologist density among the census regions. Another way to look at these findings is that there was approximately 1 obstetrician-gynecologist for every 1345 women of reproductive age in the Northeast versus 1 for every 1768 women in the South. One internal medicine physician was available for approximately every 418 women of reproductive age in the Northeast versus 1 for every 749 women in the South. The regional patterns of availability for nurse practitioners were generally similar in the Northeast, Midwest, and South but much lower in the West. Physician assistant density was highest in the Northeast but similar in other regions.

Rate ratios were calculated to determine whether regional workforce availability differed markedly from the national level for all occupations except nurse practitioners and physician assistants, which was found to be the case across most physician specialties and categorical workforce groupings. Notably, all regional differences in the availability of direct childbirth providers and all women's health providers are unlikely to be due to chance alone ($P < 0.001$). Further, the unique patterns of provider densities in the Northeast and South also reached statistical significance.

A similar analytic approach, using rate ratios, was applied to determine whether regional maternal mortality rates differed markedly from the national level in 2017. The South was the only region where the estimated mortality rate was statistically higher than the national rate ($P < 0.001$). In contrast, the maternal mortality rate was significantly lower in the Northeast than nationally ($P < 0.001$). Findings were similar when we examined 2016 provider and maternal mortality data using the same analytic approach (Table 2).

To explore whether the regional workforce patterns for individual provider types might be associated with those for maternal mortality, the calculated rate ratios were plotted graphically (Figure 3). In 2017, regional maternal mortality rates exceeded the national level only in the South. In this region, all provider rate ratios were less than 1, indicating lower levels of provider availability for each studied occupation compared with national levels. In contrast, maternal mortality rates were lower than the national level in the other 3 census regions, and provider densities exceeded the national levels (rate ratios >1) for at least 2 of the 4 individual provider occupations in each region.

DISCUSSION

This investigation demonstrates that the per-population rate of deaths among women of reproductive age attributed to pregnancy, childbirth, and the puerperium in the United States increased between

Table 1. Maternal Mortality Rates and Women's Health Provider Availability in 2017, by U.S. Census Region and Nationally

Variable	Rate per 100 000 Women Aged 15-50 Years (95% CI)				
	National	Northeast	Midwest	South	West
Maternal mortality	1.46 (1.37-1.54)	1.06 (0.9-1.24)	1.42 (1.25-1.62)	1.84 (1.69-2.00)	1.17 (1.02-1.33)
Women's health provider availability					
Direct childbirth providers	206.77 (205.76-207.79)	199.73 (197.36-202.13)	236.97 (234.58-239.38)	190.94 (189.36-192.53)	211.04 (208.94-213.15)
Obstetrician-gynecologists	59.65 (59.10-60.19)	74.35 (72.90-75.81)	58.53 (57.35-59.73)	56.57 (55.71-57.44)	54.72 (53.65-55.79)
Family medicine physicians	137.62 (136.79-138.45)	112.91 (111.13-114.72)	168.78 (166.77-170.82)	126.63 (125.34-127.92)	146.31 (144.57-148.07)
Certified nurse-midwives	9.51 (9.29-9.73)	12.47 (11.89-13.08)	9.66 (9.19-10.15)	7.75 (7.43-8.07)	10.01 (9.56-10.47)
Primary care physicians*	295.55 (294.33-296.77)	351.89 (348.73-355.08)	317.15 (314.38-319.94)	260.12 (258.27-261.98)	291.83 (289.37-294.31)
Internal medicine physicians	157.93 (157.04-158.82)	238.98 (236.38-241.60)	148.37 (146.48-150.28)	133.50 (132.17-134.83)	145.52 (143.78-147.27)
All women's health providers	364.71 (363.35-366.06)	438.71 (435.18-442.27)	385.34 (382.29-388.41)	324.44 (322.37-326.52)	356.56 (353.83-359.30)
Variable	Regional-National Rate Ratio (95% CI)				
	National	Northeast	Midwest	South	West
Maternal mortality	1.00 (reference)	0.73 (0.61-0.87)†	0.98 (0.84-1.13)	1.26 (1.14-1.40)†	0.80 (0.69-0.93)
Women's health provider availability					
Direct childbirth providers	1.00 (reference)	0.97 (0.95-0.98)†	1.15 (1.13-1.16)†	0.92 (0.91-0.93)†	1.02 (1.01-1.03)†
Obstetrician-gynecologists	1.00 (reference)	1.25 (1.22-1.27)†	0.98 (0.96-1.00)	0.95 (0.93-0.97)†	0.92 (0.90-0.94)†
Family medicine physicians	1.00 (reference)	0.82 (0.81-0.83)†	1.23 (1.21-1.24)†	0.92 (0.91-0.93)†	1.06 (1.05-1.08)†
Certified nurse-midwives	1.00 (reference)	1.31 (1.24-1.38)†	1.02 (0.96-1.07)	0.81 (0.78-0.85)†	1.05 (1.00-1.11)
Primary care physicians*	1.00 (reference)	1.19 (1.18-1.20)†	1.07 (1.06-1.08)†	0.88 (0.87-0.89)†	0.99 (0.98-1.00)
Internal medicine physicians	1.00 (reference)	1.51 (1.49-1.53)†	0.94 (0.93-0.95)†	0.85 (0.84-0.86)†	0.92 (0.91-0.93)†
All women's health providers	1.00 (reference)	1.20 (1.19-1.21)†	1.06 (1.05-1.07)†	0.89 (0.88-0.90)†	0.98 (0.97-0.99)†

* Includes family medicine physicians and internal medicine physicians.

† Regional results differed from national results at a level unlikely to be due to chance alone ($P < 0.001$), as determined by exact Poisson tests.

1999 and 2017 but changed variably across census regions. The South had the highest overall maternal mortality rates and experienced a larger interval rate increase than any other census region, driving up the magnitude of the overall national-level increases observed. The availability patterns for the health care providers essential in caring for women of reproductive age also varied by region in 2017, the most recent year studied. The South had the lowest provider density nationally for nearly every health occupation studied. Further, lower than national levels of provider availability

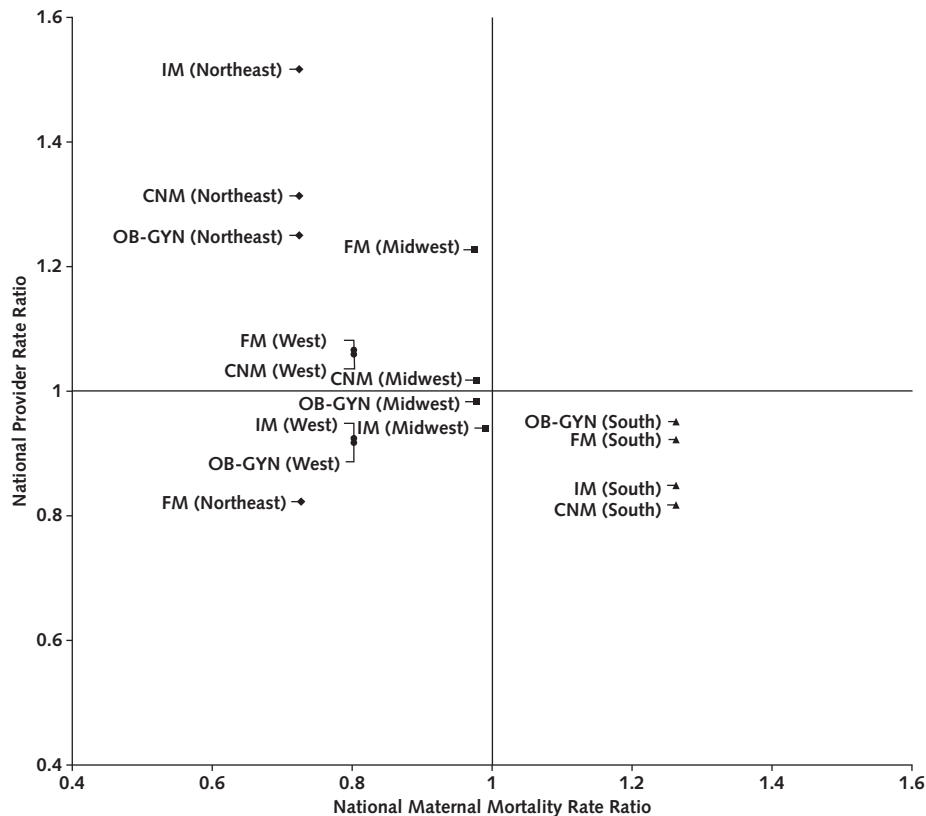
across a region seem to be associated with higher maternal mortality rates. In contrast to the findings in the South, the Northeast had higher workforce availability levels for nearly all of the studied professions and a much lower maternal mortality rate. Although data limitations precluded an investigation of a potential relationship between the regional availability of nurse practitioners and physician assistants and maternal mortality rates, regional workforce patterns were present. These providers play an important role in delivering primary care and other health services

Table 2. Maternal Mortality Rates and Women's Health Provider Availability in 2016, by U.S. Census Region and Nationally

Variable	Rate per 100 000 Women Aged 15-50 Years (95% CI)				
	National	Northeast	Midwest	South	West
Maternal mortality	1.48 (1.39-1.56)	1.26 (1.09-1.46)	1.46 (1.28-1.65)	1.89 (1.73-2.05)	1.00 (0.87-1.15)
Women's health provider availability					
Direct childbirth providers	204.06 (203.05-205.07)	197.77 (195.41-200.16)	234.39 (232.02-236.79)	188.87 (187.29-190.46)	206.44 (204.37-208.54)
Obstetrician-gynecologists	58.76 (58.22-59.31)	73.47 (72.03-74.92)	57.40 (56.23-58.59)	55.90 (55.04-56.77)	53.60 (52.55-54.67)
Family medicine physicians	136.24 (135.41-137.07)	112.49 (110.71-114.29)	167.85 (165.84-169.88)	125.60 (124.31-126.90)	143.22 (141.49-144.96)
Certified nurse-midwives	9.06 (8.85-9.28)	11.82 (11.25-12.40)	9.14 (8.68-9.62)	7.38 (7.07-7.69)	9.63 (9.19-10.08)
Primary care physicians*	293.51 (292.29-294.72)	352.59 (349.44-355.77)	316.55 (313.79-319.33)	257.99 (256.14-259.85)	286.06 (283.61-288.52)
Internal medicine physicians	157.27 (156.38-158.16)	240.10 (237.5-242.73)	148.70 (146.81-150.61)	132.39 (131.07-133.72)	142.85 (141.12-144.59)
All women's health providers	361.33 (359.98-362.68)	437.88 (434.36-441.42)	383.09 (380.05-386.15)	321.27 (319.2-323.34)	349.29 (346.58-352.01)
Variable	Regional-National Rate Ratio (95% CI)				
	National	Northeast	Midwest	South	West
Maternal mortality	1.00 (reference)	0.86 (0.72-1.01)	0.99 (0.85-1.14)	1.28 (1.15-1.42)†	0.68 (0.58-0.79)†
Women's health provider availability					
Direct childbirth providers	1.00 (reference)	0.97 (0.96-0.98)†	1.15 (1.14-1.16)†	0.93 (0.92-0.93)†	1.01 (1.00-1.02)
Obstetrician-gynecologists	1.00 (reference)	1.25 (1.22-1.28)†	0.98 (0.95-1.00)	0.95 (0.93-0.97)†	0.91 (0.89-0.93)†
Family medicine physicians	1.00 (reference)	0.83 (0.81-0.84)†	1.23 (1.22-1.25)†	0.92 (0.91-0.93)†	1.05 (1.04-1.07)†
Certified nurse-midwives	1.00 (reference)	1.30 (1.23-1.38)†	1.01 (0.95-1.07)	0.81 (0.77-0.85)†	1.06 (1.01-1.12)
Primary care physicians*	1.00 (reference)	1.20 (1.19-1.21)†	1.08 (1.07-1.09)†	0.88 (0.87-0.89)†	0.97 (0.97-0.98)†
Internal medicine physicians	1.00 (reference)	1.53 (1.51-1.55)†	0.94 (0.93-0.96)†	0.84 (0.83-0.85)†	0.91 (0.90-0.92)†
All women's health providers	1.00 (reference)	1.21 (1.20-1.22)†	1.06 (1.05-1.07)†	0.89 (0.88-0.90)†	0.97 (0.96-0.98)†

* Includes family medicine physicians and internal medicine physicians.

† Denotes that regional differences occurred at a statistically significant level ($P < 0.001$). For the Northeast, the observed regional difference in maternal mortality fell outside a level of statistical significance by a small margin ($P = 0.062$).

Figure 3. Patterns of regional maternal mortality rates as they relate to women's health provider availability in 2017.

Region/provider pairings represent health provider availability rate ratios for the 4 health care occupations studied (OB-GYN, FM, CNM, and IM) within each of the 4 U.S. census regions (Northeast, Midwest, South, and West). CNM = certified nurse-midwives; FM = family medicine physicians; IM = internal medicine physicians; OB-GYN = obstetrician-gynecologists.

to women of reproductive age, often mitigating health care access gaps in communities facing physician shortages (20, 36, 39, 40).

A recent study identified a linkage between primary care physician supply and cause-specific population mortality in the United States, suggesting that directed efforts to bolster the health workforce where shortages exist are important for improving population health (41). A similar strategic approach might also apply to domestic maternal mortality policy and would be consistent with the United Nations global strategy of addressing mortality by expanding the midwifery and obstetric workforce (42). A health literature search in MEDLINE from 1965 to January 2020, using the terms *health workforce* and *mortality*, produced 2248 results that were then examined manually for topical relevance. A broad array of relevant international maternal mortality studies were identified, including qualitative or mixed-methods studies, correlations between workforce and neonatal outcomes, impact studies related to health worker deployment (most commonly for midwives and community health workers), analyses of facility and service availability, or workforce-mortality comparisons between 2 countries (16–22, 43–46). One report used a multivariate analysis approach and found a marginally significant association between per-

population maternal death rates and midwife density across Iranian provinces (47). Within the U.S.-based literature, 31 studies examined health workforce-mortality linkages for various specialty areas and conditions, 3 of which specifically examined neonatal/infant mortality and 2 of which examined maternal mortality outcomes (48–52). Sullivan and colleagues used a multivariate analysis of WONDER data to demonstrate that maternal-fetal medicine specialist density at the state level is significantly and inversely associated with maternal mortality ratios, even when socioeconomic factors are controlled for (52). Kozhimannil and colleagues examined rural-urban maternal mortality differences from 2007 to 2015 using hospital discharge data by U.S. census region, controlling for sociodemographic factors and clinical conditions, but not specifically examining or controlling for provider supply (48). On the basis of this literature review, our preliminary findings suggest that the current study is one of the few in the United States to examine the association between the availability of health care providers for women of reproductive age and maternal mortality rates within this population.

This study had important limitations. The presence of a provider in a census region does not directly translate to available and accessible obstetric care in a community or for an individual. The extent to which family

physicians provide obstetric care varies geographically, and the overall proportion doing so seems to be decreasing markedly over time (36, 53-56). Obstetrician-gynecologists may subspecialize or focus their clinical care on gynecology alone, although approximately 79% are estimated to practice obstetrics (56). Further, access to health care services is a complex, multifactorial concept that requires available health workers and sites of care, such as medical practices and hospitals, but it is also influenced by such variables as proximity and accessibility, affordability, cultural factors, and issues of health equity (57).

Caution should be used in interpreting these study findings because of the small number of observations used for analysis. Further, nationally representative data sources on maternal mortality and the health workforce have many well-known limitations (58-60). For example, maternal deaths may not always be captured accurately in national vital statistics data sets because of dependence on accurate pregnancy status reporting by death certificate certifiers (61). Maternal mortality rates reported here may differ from those in other studies depending on the denominators used, the ICD-10 codes included, approaches for age adjustment, and the population age range studied. An underlying assumption in this investigation was that birth and delivery patterns were uniform over time across regions. The population of women of child-bearing age in our analysis did seem to be proportional, nationally and regionally, as did the observed birthrate decline, the latter being consistent with trends reported elsewhere (31). Pregnancy rates may be a more accurate measure for study than births; however, available national vital statistics systems, such as the Pregnancy Risk Assessment Monitoring System, miss approximately 17% of the nation's pregnancy data (62). Nonetheless, an increase in maternal mortality in the setting of decreasing pregnancy and birthrates would be concerning, particularly because demand for primary care and women's health providers is anticipated to increasingly outpace their supply in coming years (20, 21).

This study is intended to be exploratory in nature, and further investigation into the apparent association between provider availability and maternal mortality is necessary. For instance, examining this relationship over a longer period and at a more granular geographic level may be beneficial. Evaluation at the relatively macro level of census region was selected for this study to have sufficient, geographically consistent data for analysis and because other studies have noted regional patterns when examining associations between physician supply and mortality (29). However, county-level or rural-urban assessments may yield important insights for the communities facing the greatest challenges in health care access and population health outcomes (63-66). More than half of all rural counties lack hospital-based obstetric services, predominantly lower-income counties with fewer obstetricians and family physicians; more restrictive Medicaid eligibility thresholds for pregnant women; and higher percentages of

non-Hispanic Black women, who disproportionately experience pregnancy complications and maternal mortality (3-6, 11, 66, 67). Cities with higher proportions of uninsured and Medicaid patients tend to have the most demanding obstetrician workloads and an older overall obstetric workforce that is closer to retirement age and thus affects workforce attrition rates (68). Future investigations may also consider using complex analyses that adjust for relevant socioeconomic variables, insurance status, and population racial/ethnic composition (3-6, 67).

Identification of a potential workforce-mortality relationship has policy relevance because the availability of health care providers serving women before, during, and after childbirth may play a role in maternal mortality. Access to skilled providers is essential for managing a woman's perinatal health and handling high-risk deliveries (12, 13). Policies to fortify the women's health workforce should prioritize alleviating the access disparities faced by the most vulnerable communities. The American College of Physicians advocates for correcting primary care workforce shortages; addressing social determinants of health; and addressing urgent public health threats, such as maternal mortality, to achieve a stronger overall U.S. health care system (69). Health workforce insufficiencies may not directly cause maternal mortality but are a barrier to the delivery of essential services, and health professional shortage areas may serve as a marker for communities with higher overall mortality risks (70). Improving access, choice, and quality of birthing facilities and health care providers in primary care and obstetrics-gynecology are all likely important steps for addressing the nation's rising rates of maternal mortality. This approach aligns with HRSA's programmatic health workforce investments, including through the National Health Service Corps and Teaching Health Center Graduate Medical Education Program (71). The recent passage of the Improving Access to Maternity Care Act (P.L. 115-320) requires HRSA to identify and publish collected data on "maternity care health professional target areas" (72). This information has the potential to facilitate targeting of federal, state, and other health workforce investments to the areas of greatest need. The preliminary results of this study, which found an association between regional maternal mortality rate variations and the availability of birth-attending and primary care providers, provide a starting point from which to further explore the concept of targeted health workforce investments that address maternal mortality disparities.

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Appendix Table. ICD-10 Codes Used for Assessments of Maternal Deaths*

ICD-10 Code	Description
O00-O08: Pregnancy with abortive outcome	
O00	Ectopic pregnancy
O00.0	Abdominal pregnancy
O00.1	Tubal pregnancy
O00.2	Ovarian pregnancy
O00.8	Other ectopic pregnancy
O00.9	Ectopic pregnancy, unspecified
O01	Hydatidiform mole
O01.0	Classical hydatidiform mole
O01.1	Incomplete and partial hydatidiform mole
O01.9	Hydatidiform mole, unspecified
O02	Other abnormal products of conception
O02.0	Blighted ovum and nonhydatidiform mole
O02.1	Missed abortion
O02.8	Other specified abnormal products of conception
O02.9	Abnormal product of conception, unspecified
O03	Spontaneous abortion
O03.0	Spontaneous abortion, incomplete, complicated by genital tract and pelvic infection
O03.1	Spontaneous abortion, incomplete, complicated by delayed or excessive hemorrhage
O03.2	Spontaneous abortion, incomplete, complicated by embolism
O03.3	Spontaneous abortion, incomplete, with other and unspecified complications
O03.4	Spontaneous abortion, incomplete, without complication
O03.5	Spontaneous abortion, incomplete, without complication
O03.6	Spontaneous abortion, complete or unspecified, complicated by delayed or excessive hemorrhage
O03.7	Spontaneous abortion, complete or unspecified, complicated by embolism
O03.8	Spontaneous abortion, complete or unspecified, with other and unspecified complications
O03.9	Spontaneous abortion, complete or unspecified, without complication
O04.0	Medical abortion
O04.1	Medical abortion, incomplete, complicated by delayed or excessive hemorrhage
O04.2	Medical abortion, incomplete, complicated by embolism
O04.3	Medical abortion, incomplete, with other and unspecified complications
O04.4	Medical abortion, incomplete, without complication
O04.5	Medical abortion, complete or unspecified, complicated by genital tract and pelvic infection
O04.6	Medical abortion, complete or unspecified, complicated by delayed or excessive hemorrhage
O04.7	Medical abortion, complete or unspecified, complicated by embolism
O04.8	Medical abortion, complete or unspecified, with other and unspecified complications
O04.9	Medical abortion, complete or unspecified, without complication
O05	Other abortion
O05.0	Other abortion, incomplete, complicated by genital tract and pelvic infection
O05.1	Other abortion, incomplete, complicated by delayed or excessive hemorrhage
O05.2	Other abortion, incomplete, complicated by embolism
O05.3	Other abortion, incomplete, with other and unspecified complications
O05.4	Other abortion, incomplete, without complication
O05.5	Other abortion, complete or unspecified, complicated by genital tract and pelvic infection
O05.6	Other abortion, complete or unspecified, complicated by delayed or excessive hemorrhage
O05.7	Other abortion, complete or unspecified, complicated by embolism
O05.8	Other abortion, complete or unspecified, with other and unspecified complications
O05.9	Other abortion, complete or unspecified, without complication
O06	Unspecified abortion
O06.0	Unspecified abortion, incomplete, complicated by genital tract and pelvic infection
O06.1	Unspecified abortion, incomplete, complicated by delayed or excessive hemorrhage
O06.2	Unspecified abortion, incomplete, complicated by embolism
O06.3	Unspecified abortion, incomplete, with other and unspecified complications
O06.4	Unspecified abortion, incomplete, without complication
O06.5	Unspecified abortion, complete or unspecified, complicated by genital tract and pelvic infection
O06.6	Unspecified abortion, complete or unspecified, complicated by delayed or excessive hemorrhage
O06.7	Unspecified abortion, complete or unspecified, complicated by embolism
O06.8	Unspecified abortion, complete or unspecified, with other and unspecified complications
O06.9	Unspecified abortion, complete or unspecified, without complication
O07	Failed attempted abortion
O07.0	Failed medical abortion, complicated by genital tract and pelvic infection
O07.1	Failed medical abortion, complicated by delayed or excessive hemorrhage
O07.2	Failed medical abortion, complicated by embolism
O07.3	Failed medical abortion, with other and unspecified complications
O07.4	Failed medical abortion, without complication
O07.5	Other and unspecified failed attempted abortion, complicated by genital tract and pelvic infection

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Appendix Table—Continued

ICD-10 Code	Description
O07.6	Other and unspecified failed attempted abortion, complicated by delayed or excessive hemorrhage
O07.7	Other and unspecified failed attempted abortion, complicated by embolism
O07.8	Other and unspecified failed attempted abortion, with other and unspecified complications
O07.9	Other and unspecified failed attempted abortion, without complication
O10–O16: Edema, proteinuria, and hypertensive disorders in pregnancy, childbirth, and the puerperium	
O10	Preexisting hypertension complicating pregnancy, childbirth, and the puerperium
O10.0	Preexisting essential hypertension complicating pregnancy, childbirth, and the puerperium
O10.1	Preexisting hypertensive heart disease complicating pregnancy, childbirth, and the puerperium
O10.2	Preexisting hypertensive renal disease complicating pregnancy, childbirth, and the puerperium
O10.3	Preexisting hypertensive heart and renal disease complicating pregnancy, childbirth, and the puerperium
O10.4	Preexisting secondary hypertension complicating pregnancy, childbirth, and the puerperium
O10.9	Unspecified preexisting hypertension complicating pregnancy, childbirth, and the puerperium
O11	Preexisting hypertensive disorder with superimposed proteinuria
O12	Gestational pregnancy-induced edema and proteinuria without hypertension
O12.0	Gestational edema
O12.1	Gestational proteinuria
O12.2	Gestational edema with proteinuria
O13	Gestational pregnancy-induced hypertension without significant proteinuria
O14	Gestational pregnancy-induced hypertension with significant proteinuria
O14.0	Moderate preeclampsia
O14.1	Severe preeclampsia
O14.2	HELLP syndrome
O14.9	Preeclampsia, unspecified
O15	Eclampsia
O15.0	Eclampsia in pregnancy
O15.1	Eclampsia in labor
O15.2	Eclampsia in the puerperium
O15.9	Eclampsia, unspecified as to time period
O16	Unspecified maternal hypertension
O20–O29: Other maternal disorders predominantly related to pregnancy	
O20	Hemorrhage in early pregnancy
O20.0	Threatened abortion
O20.8	Other hemorrhage in early pregnancy
O20.9	Hemorrhage in early pregnancy, unspecified
O21	Excessive vomiting in pregnancy
O21.0	Mild hyperemesis gravidarum
O21.1	Hyperemesis gravidarum with metabolic disturbance
O21.2	Late vomiting of pregnancy
O21.8	Other vomiting complicating pregnancy
O21.9	Vomiting of pregnancy, unspecified
O22	Venous complications in pregnancy
O22.0	Varicose veins of lower extremity in pregnancy
O22.1	Genital varices in pregnancy
O22.2	Superficial thrombophlebitis in pregnancy
O22.3	Deep phlebothrombosis in pregnancy
O22.4	Hemorrhoids in pregnancy
O22.5	Cerebral venous thrombosis in pregnancy
O22.8	Other venous complications in pregnancy
O22.9	Venous complication in pregnancy, unspecified; Gestational phlebitis NOS; Gestational phleboopathy NOS; Gestational thrombosis NOS
O23	Infections of genitourinary tract in pregnancy
O23.0	Infections of kidney in pregnancy
O23.1	Infections of bladder in pregnancy
O23.2	Infections of urethra in pregnancy
O23.3	Infections of other parts of urinary tract in pregnancy
O23.4	Unspecified infection of urinary tract in pregnancy
O23.5	Infections of the genital tract in pregnancy
O23.9	Other and unspecified genitourinary tract infection in pregnancy
O24	Diabetes mellitus in pregnancy
O24.0	Preexisting diabetes mellitus, insulin-dependent
O24.1	Preexisting diabetes mellitus, non-insulin-dependent
O24.2	Preexisting malnutrition-related diabetes mellitus
O24.3	Preexisting diabetes mellitus, unspecified
O24.4	Diabetes mellitus arising in pregnancy
O24.9	Diabetes mellitus in pregnancy, unspecified

Continued on following page

Appendix Table—Continued

ICD-10 Code	Description
O25	Malnutrition in pregnancy
O26	Maternal care for other conditions predominantly related to pregnancy
O26.0	Excessive weight gain in pregnancy
O26.1	Low weight gain in pregnancy
O26.2	Pregnancy care of habitual aborter
O26.3	Retained intrauterine contraceptive device in pregnancy
O26.4	Herpes gestationis
O26.5	Maternal hypotension syndrome
O26.6	Liver disorders in pregnancy, childbirth, and the puerperium
O26.7	Subluxation of symphysis pubis in pregnancy, childbirth, and the puerperium
O26.8	Other specified pregnancy-related conditions
O26.9	Pregnancy-related condition, unspecified
O28	Abnormal findings on antenatal screening of mother
O28.0	Abnormal hematological finding on antenatal screening of mother
O28.1	Abnormal biochemical finding on antenatal screening of mother
O28.2	Abnormal cytological finding on antenatal screening of mother
O28.3	Abnormal ultrasonic finding on antenatal screening of mother
O28.4	Abnormal radiological finding on antenatal screening of mother
O28.5	Abnormal chromosomal and genetic finding on antenatal screening of mother
O28.8	Other abnormal findings on antenatal screening of mother
O28.9	Abnormal finding on antenatal screening of mother, unspecified
O29	Complications of anesthesia during pregnancy
O29.0	Pulmonary complications of anesthesia during pregnancy
O29.1	Cardiac complications of anesthesia during pregnancy
O29.2	Central nervous system complications of anesthesia during pregnancy
O29.3	Toxic reaction to local anesthesia during pregnancy
O29.4	Spinal and epidural anesthesia-induced headache during pregnancy
O29.5	Other complications of spinal and epidural anesthesia during pregnancy
O29.6	Failed or difficult intubation during pregnancy
O29.8	Other complications of anesthesia during pregnancy
O29.9	Complication of anesthesia during pregnancy, unspecified
O30–O48: Maternal care related to the fetus and amniotic cavity and possible delivery problems	
O30	Multiple gestation
O30.0	Twin pregnancy
O30.1	Triplet pregnancy
O30.2	Quadruplet pregnancy
O30.8	Other multiple gestation
O30.9	Multiple gestation, unspecified; Multiple pregnancy NOS
O31	Complications specific to multiple gestation
O31.0	Papyraceous fetus
O31.1	Continuing pregnancy after abortion of one fetus or more
O31.2	Continuing pregnancy after intrauterine death of one fetus or more
O31.8	Other complications specific to multiple gestation
O32	Maternal care for known or suspected malpresentation of fetus
O32.0	Maternal care for unstable lie
O32.1	Maternal care for breech presentation
O32.2	Maternal care for transverse and oblique lie
O32.3	Maternal care for face, brow, and chin presentation
O32.4	Maternal care for high head at term
O32.5	Maternal care for multiple gestation with malpresentation of one fetus or more
O32.6	Maternal care for compound presentation
O32.8	Maternal care for other malpresentation of fetus
O32.9	Maternal care for malpresentation of fetus, unspecified
O33	Maternal care for known or suspected disproportion
O33.0	Maternal care for disproportion due to deformity of maternal pelvic bones
O33.1	Maternal care for disproportion due to generally contracted pelvis
O33.2	Maternal care for disproportion due to inlet contraction of pelvis
O33.3	Maternal care for disproportion due to outlet contraction of pelvis
O33.4	Maternal care for disproportion of mixed maternal and fetal origin
O33.5	Maternal care for disproportion due to unusually large fetus
O33.6	Maternal care for disproportion due to hydrocephalic fetus
O33.7	Maternal care for disproportion due to other fetal deformities; Conjoined twins
O33.8	Maternal care for disproportion of other origin
O33.9	Maternal care for disproportion, unspecified; Cephalopelvic disproportion NOS; Fetopelvic disproportion NOS
O34	Maternal care for known or suspected abnormality of pelvic organs
O34.0	Maternal care for congenital malformation of uterus
O34.1	Maternal care for tumor of corpus uteri

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Appendix Table—Continued

ICD-10 Code	Description
O34.2	Maternal care due to uterine scar from previous surgery
O34.3	Maternal care for cervical incompetence
O34.4	Maternal care for other abnormalities of cervix
O34.5	Maternal care for other abnormalities of gravid uterus
O34.6	Maternal care for abnormality of vagina
O34.7	Maternal care for abnormality of vulva and perineum
O34.8	Maternal care for other abnormalities of pelvic organs
O34.9	Maternal care for abnormality of pelvic organ, unspecified
O35	Maternal care for known or suspected fetal abnormality and damage
O35.0	Maternal care for (suspected) central nervous system malformation in fetus
O35.1	Maternal care for (suspected) chromosomal abnormality in fetus
O35.2	Maternal care for (suspected) hereditary disease in fetus
O35.3	Maternal care for (suspected) damage to fetus from viral disease in mother
O35.4	Maternal care for (suspected) damage to fetus from alcohol
O35.5	Maternal care for (suspected) damage to fetus by drugs
O35.6	Maternal care for (suspected) damage to fetus by radiation
O35.7	Maternal care for (suspected) damage to fetus by other medical procedures
O35.8	Maternal care for other (suspected) fetal abnormality and damage
O35.9	Maternal care for (suspected) fetal abnormality and damage, unspecified
O36	Maternal care for other known or suspected fetal problems
O36.0	Maternal care for rhesus isoimmunization
O36.1	Maternal care for other isoimmunization
O36.2	Maternal care for hydrops fetalis
O36.3	Maternal care for signs of fetal hypoxia
O36.4	Maternal care for intrauterine death
O36.5	Maternal care for poor fetal growth
O36.6	Maternal care for excessive fetal growth
O36.7	Maternal care for viable fetus in abdominal pregnancy
O36.8	Maternal care for other specified fetal problems
O36.9	Maternal care for fetal problem, unspecified
O40	Polyhydramnios
O41	Other disorders of amniotic fluid and membranes
O41.0	Oligohydramnios; Oligohydramnios without mention of rupture of membranes
O41.1	Infection of amniotic sac and membranes; Chorioamnionitis
O41.8	Other specified disorders of amniotic fluid and membranes
O41.9	Disorder of amniotic fluid and membranes, unspecified
O42	Premature rupture of membranes
O42.0	Premature rupture of membranes, onset of labor within
O42.1	Premature rupture of membranes, onset of labor after
O42.2	Premature rupture of membranes, labor delayed by therapy
O42.9	Premature rupture of membranes, unspecified
O43	Placental disorders
O43.0	Placental transfusion syndromes
O43.1	Malformation of placenta; Abnormal placenta NOS; Circumvallate placenta
O43.2	Morbidly adherent placenta
O43.8	Other placental disorders
O43.9	Placental disorder, unspecified
O44	Placenta previa
O44.0	Placenta previa specified as without hemorrhage
O44.1	Placenta previa with hemorrhage
O45	Premature separation of placenta abruptio placentae
O45.0	Premature separation of placenta with coagulation defect
O45.8	Other premature separation of placenta
O45.9	Premature separation of placenta, unspecified
O46	Antepartum hemorrhage, not elsewhere classified
O46.0	Antepartum hemorrhage with coagulation defect
O46.8	Other antepartum hemorrhage
O46.9	Antepartum hemorrhage, unspecified
O47	False labor
O47.0	False labor before 37 completed weeks of gestation
O47.1	False labor at or after 37 completed weeks of gestation
O47.9	False labor, unspecified
O48	Prolonged pregnancy
O60-O75: Complications of labor and delivery	
O60	Preterm delivery
O61	Failed induction of labor
O61.0	Failed medical induction of labor
O61.1	Failed instrumental induction of labor

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Appendix Table—Continued

ICD-10 Code	Description
O61.8	Other failed induction of labor
O61.9	Failed induction of labor, unspecified
O62	Abnormalities of forces of labor
O62.0	Primary inadequate contractions
O62.1	Secondary uterine inertia
O62.2	Other uterine inertia
O62.3	Precipitate labor
O62.4	Hypertonic, incoordinate, and prolonged uterine contractions
O62.8	Other abnormalities of forces of labor
O62.9	Abnormality of forces of labor, unspecified
O63	Long labor
O63.0	Prolonged first stage (of labor)
O63.1	Prolonged second stage (of labor)
O63.2	Delayed delivery of second twin, triplet, etc.
O63.9	Long labor, unspecified
O64	Obstructed labor due to malposition and malpresentation of fetus
O64.0	Obstructed labor due to incomplete rotation of fetal head
O64.1	Obstructed labor due to breech presentation
O64.2	Obstructed labor due to face presentation
O64.3	Obstructed labor due to brow presentation
O64.4	Obstructed labor due to shoulder presentation
O64.5	Obstructed labor due to compound presentation
O64.8	Obstructed labor due to other malposition and malpresentation
O64.9	Obstructed labor due to malposition and malpresentation, unspecified
O65	Obstructed labor due to maternal pelvic abnormality
O66	Other obstructed labor
O66.0	Obstructed labor due to shoulder dystocia
O66.1	Obstructed labor due to locked twins
O66.2	Obstructed labor due to unusually large fetus
O66.3	Obstructed labor due to other abnormalities of fetus
O66.4	Failed trial of labor, unspecified
O66.5	Failed application of vacuum extractor and forceps, unspecified
O66.8	Other specified obstructed labor
O66.9	Obstructed labor, unspecified
O67	Labor and delivery complicated by intrapartum hemorrhage, not elsewhere classified
O67.0	Intrapartum hemorrhage with coagulation defect
O67.8	Other intrapartum hemorrhage
O67.9	Intrapartum hemorrhage, unspecified
O68	Labor and delivery complicated by fetal stress distress
O68.0	Labor and delivery complicated by fetal heart rate anomaly
O68.1	Labor and delivery complicated by meconium in amniotic fluid
O68.2	Labor and delivery complicated by fetal heart rate anomaly with meconium in amniotic fluid
O68.3	Labor and delivery complicated by biochemical evidence of fetal stress
O68.8	Labor and delivery complicated by other evidence of fetal stress
O68.9	Labor and delivery complicated by fetal stress, unspecified
O69	Labor and delivery complicated by umbilical cord complications
O69.0	Labor and delivery complicated by prolapse of cord
O69.1	Labor and delivery complicated by cord around neck, with compression
O69.2	Labor and delivery complicated by other cord entanglement
O69.3	Labor and delivery complicated by short cord
O69.4	Labor and delivery complicated by vasa previa
O69.5	Labor and delivery complicated by vascular lesion of cord
O69.8	Labor and delivery complicated by other cord complications
O69.9	Labor and delivery complicated by cord complication, unspecified
O70	Perineal laceration during delivery
O70.0	First-degree perineal laceration during delivery
O70.1	Second-degree perineal laceration during delivery
O70.2	Third-degree perineal laceration during delivery
O70.3	Fourth-degree perineal laceration during delivery
O70.9	Perineal laceration during delivery, unspecified
O71	Other obstetric trauma
O71.0	Rupture of uterus before onset of labor
O71.1	Rupture of uterus during labor
O71.2	Postpartum inversion of uterus
O71.3	Obstetric laceration of cervix
O71.4	Obstetric high vaginal laceration alone
O71.5	Other obstetric injury to pelvic organs
O71.6	Obstetric damage to pelvic joints and ligaments
O71.7	Obstetric hematoma of pelvis

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Appendix Table—Continued

ICD-10 Code	Description
O71.8	Other specified obstetric trauma
O71.9	Obstetric trauma, unspecified
O72	Postpartum hemorrhage
O72.0	Third-stage hemorrhage
O72.1	Other immediate postpartum hemorrhage
O72.2	Delayed and secondary postpartum hemorrhage
O72.3	Postpartum coagulation defects
O73	Retained placenta and membranes, without hemorrhage
O73.0	Retained placenta without hemorrhage; Placenta accreta without hemorrhage
O73.1	Retained portions of placenta and membranes, without hemorrhage; Retained products of conception following delivery, without hemorrhage
O74	Complications of anesthesia during labor and delivery
O74.0	Aspiration pneumonitis due to anesthesia during labor and delivery
O74.1	Other pulmonary complications of anesthesia during labor and delivery
O74.2	Cardiac complications of anesthesia during labor and delivery
O74.3	Central nervous system complications of anesthesia during labor and delivery
O74.4	Toxic reaction to local anesthesia during labor and delivery
O74.5	Spinal and epidural anesthesia-induced headache during labor and delivery
O74.6	Other complications of spinal and epidural anesthesia during labor and delivery
O74.7	Failed or difficult intubation during labor and delivery
O74.8	Other complications of anesthesia during labor and delivery
O74.9	Complication of anesthesia during labor and delivery, unspecified
O75	Other complications of labor and delivery, not elsewhere classified
O75.0	Maternal distress during labor and delivery
O75.1	Shock during or following labor and delivery
O75.2	Pyrexia during labor, not elsewhere classified
O75.3	Other infection during labor
O75.4	Other complications of obstetric surgery and procedures
O75.5	Delayed delivery after artificial rupture of membranes
O75.6	Delayed delivery after spontaneous or unspecified rupture of membranes
O75.7	Vaginal delivery following previous caesarean section
O75.8	Other specified complications of labor and delivery
O75.9	Complication of labor and delivery, unspecified
O85–O92: Complications predominantly related to the puerperium	
O85	Puerperal sepsis
O86	Other puerperal infections
O86.0	Infection of obstetric surgical wound
O86.1	Other infection of genital tract following delivery
O86.2	Urinary tract infection following delivery
O86.3	Other genitourinary tract infections following delivery
O86.4	Pyrexia of unknown origin following delivery
O86.8	Other specified puerperal infections
O87	Venous complications in the puerperium
O87.0	Superficial thrombophlebitis in the puerperium
O87.1	Deep phlebothrombosis in the puerperium
O87.2	Hemorrhoids in the puerperium
O87.3	Cerebral venous thrombosis in the puerperium
O87.8	Other venous complications in the puerperium
O87.9	Venous complication in the puerperium, unspecified
O88	Obstetric embolism
O88.0	Obstetric air embolism
O88.1	Amniotic fluid embolism
O88.2	Obstetric blood-clot embolism
O88.3	Obstetric pyemic and septic embolism
O88.8	Other obstetric embolism; Obstetric fat embolism
O89	Complications of anesthesia during the puerperium
O89.0	Pulmonary complications of anesthesia during the puerperium
O89.1	Pulmonary complications of anesthesia during the puerperium
O89.2	Central nervous system complications of anesthesia during the puerperium
O89.3	Toxic reaction to local anesthesia during the puerperium
O89.4	Spinal and epidural anesthesia-induced headache during the puerperium
O89.5	Other complications of spinal and epidural anesthesia during the puerperium
O89.6	Failed or difficult intubation during the puerperium
O89.8	Other complications of anesthesia during the puerperium
O89.9	Complication of anesthesia during the puerperium, unspecified
O90	Complications of the puerperium, not elsewhere classified
O90.0	Disruption of caesarean section wound

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Appendix Table–Continued

ICD-10 Code	Description
O90.1	Disruption of perineal obstetric wound
O90.2	Hematoma of obstetric wound
O90.3	Cardiomyopathy in the puerperium
O90.4	Postpartum acute renal failure
O90.5	Postpartum thyroiditis
O90.8	Other complications of the puerperium, not elsewhere classified
O90.9	Complication of the puerperium, unspecified
O91	Infections of breast associated with childbirth
O91.0	Infection of nipple associated with childbirth
O91.1	Abscess of breast associated with childbirth
O91.2	Nonpurulent mastitis associated with childbirth
O92	Other disorders of breast and lactation associated with childbirth
O92.0	Retracted nipple associated with childbirth
O92.1	Cracked nipple
O92.2	Other and unspecified disorders of breast associated with childbirth
O92.3	Agalactia
O92.4	Hypogalactia
O92.5	Suppressed lactation
O92.6	Galactorrhea
O92.7	Other and unspecified disorders of lactation
O95–O99: Other obstetric conditions, not elsewhere classified	
O95	Obstetric death of unspecified cause
O96	Death from any obstetric cause occurring more than 42 days but less than 1 year after delivery
O96.0	Death from direct obstetric cause occurring more than 42 days but less than 1 year after delivery
O96.1	Death from indirect obstetric cause occurring more than 42 days but less than 1 year after delivery
O96.9	Death from unspecified obstetric cause occurring more than 42 days but less than 1 year after delivery
O97	Death from sequelae of direct obstetric causes
O97.0	Death from sequelae of direct obstetric cause
O97.1	Death from sequelae of indirect obstetric cause
O97.9	Death from sequelae of obstetric cause, unspecified
O98	Maternal infectious and parasitic diseases classifiable elsewhere but complicating pregnancy, childbirth, and the puerperium
O98.0	Tuberculosis complicating pregnancy, childbirth, and the puerperium
O98.1	Syphilis complicating pregnancy, childbirth, and the puerperium
O98.2	Gonorrhea complicating pregnancy, childbirth, and the puerperium
O98.3	Other infections with a predominantly sexual mode of transmission complicating pregnancy, childbirth, and the puerperium
O98.4	Viral hepatitis complicating pregnancy, childbirth, and the puerperium
O98.5	Other viral diseases complicating pregnancy, childbirth, and the puerperium
O98.6	Protozoal diseases complicating pregnancy, childbirth, and the puerperium
O98.7	Human immunodeficiency (HIV) disease complicating pregnancy, childbirth, and the puerperium
O98.8	Other maternal infectious and parasitic diseases complicating pregnancy, childbirth, and the puerperium
O98.9	Unspecified maternal infectious or parasitic disease complicating pregnancy, childbirth, and the puerperium
O99	Other maternal diseases classifiable elsewhere but complicating pregnancy, childbirth, and the puerperium
O99.0	Anemia complicating pregnancy, childbirth, and the puerperium
O99.1	Other diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism
O99.2	Endocrine, nutritional, and metabolic diseases complicating pregnancy, childbirth, and the puerperium
O99.3	Mental disorders and diseases of the nervous system complicating pregnancy, childbirth, and the puerperium
O99.4	Diseases of the circulatory system complicating pregnancy, childbirth, and the puerperium
O99.5	Diseases of the respiratory system complicating pregnancy, childbirth, and the puerperium
O99.6	Diseases of the digestive system complicating pregnancy, childbirth, and the puerperium
O99.7	Diseases of the skin and subcutaneous tissue complicating pregnancy, childbirth, and the puerperium
O99.8	Other specified diseases and conditions complicating pregnancy, childbirth, and the puerperium

HELLP = hemolysis, elevated liver enzymes, low platelet count; ICD-10 = International Classification of Diseases, 10th Revision; NOS = not otherwise specified.

* From references 18 and 21.