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Improving Maternal Mortality: Comprehensive Reporting for All Pregnancy Outcomes

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Abstract

Objective: To demonstrate the impact of inadequate standardization and population coverage on the ability to measure and improve maternal mortality in the United States. **Data Sources:** The CDC Wonder system for the years 2000-2015 using the following definitions of maternal mortality and associated ICD-CM-10 codes: 1) Maternal deaths up to 42 days after delivery (A34, O00-O99, except O96-O97); 2) Maternal deaths within one year after delivery (A34, O00-O99, except O97); 3) All maternal deaths (A34, O00-O99). **Study Design:** For each year between 2000-2015, we provided maternal deaths, live births, and calculated maternal mortality ratios (MDR). For deaths within 42 days, we also calculated adjusted mortality ratios (ADR). **Principal Findings:** Maternal mortality comparisons which utilize inconsistent definitions and apply non-validated statistical adjustments produce specious results. **Conclusions:** Variation and inconsistency in definitions, coding, and other reporting anomalies render the current aggregated vital statistics on maternal mortality inadequate for accurate trending and service impact studies. The definition of maternal mortality must be expanded to all outcomes of pregnancy: births, induced abortions, and natural fetal losses.

Keywords

Maternal Mortality, Maternal Mortality/Trends, Pregnancy Complications/Mortality, Public Health Surveillance/Methods, United States/Epidemiology

1. Introduction

The World Health Organization (WHO) defines public health surveillance as the continuous systematic collection, analysis, and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice, including prevention. Surveillance may be used to monitor and clarify the epidemiology of a health problem, to document the impact of an intervention, or to track progress towards specific goals. Although one of the United Nations' Millennium Development goals was to reduce the maternal mortality ratio by 75% from 1990 to 2015, US maternal mortality appears to have increased and the US surveillance system has been unable to produce an official maternal mortality ratio in a decade [1] [2].

Two of the essential requirements for an effective surveillance system are: 1) standardization of reporting; and 2) complete coverage of the target or study population. The first requirement is met by common data definitions, common coding practices, frequent case definition validation, error collection loops, and universal reporting compliance. The coverage requirement is met by assuring that the entire population at risk for the adverse outcome is under surveillance. In the following paper, we demonstrate the impact of inadequate standardization and population coverage on the ability to measure and improve maternal mortality in the United States.

2. Background

Although it is a rare event, maternal mortality has attracted attention because it appears to be increasing in the US, but it is apparently declining in most of the rest of the industrialized world [3]. The World Health Organization (WHO) defines maternal death as "...the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes" [4]. WHO then uses a ratio of maternal deaths per 100,000 live births as a seminal indicator of public health, where live births is defined as "the complete expulsion or extraction from its mother of a product of conception, irrespective of the duration of the pregnancy, which, after such separation, breathes or shows any other evidence of life—e.g. beating of the heart, pulsation of the umbilical cord, or definite movement of voluntary muscles—whether or not the umbilical cord has been cut or the placenta is attached. Each product of such a birth is considered live born" [4]. This is the definition used by WHO in international comparisons of maternal mortality. WHO also defines a new measure, pregnancy-related death, as "...the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of death" [4]. Again, metrics derived from this measure generally employ live births as the denominator.

In contrast, the US Centers for Disease Control and Prevention (CDC) defines pregnancy-related death as "…the death of a woman during pregnancy or within one year of the end of pregnancy from a pregnancy complication, a chain of events initiated by pregnancy, or the aggravation of an unrelated condition by the physiologic effects of pregnancy" [5].

The distinctions between these two measures are not subtle ones: 1) WHO looks only at the 42 days after termination of pregnancy, whereas the CDC looks out to a full 365 days; and 2) WHO considers the pregnancy itself to be the sole criterion for a mortality relationship, whereas the CDC requires a proximate nexus of pregnancy to the death to deem it pregnancy-related. In both cases, however, the denominator employed to compute comparative metrics is the number of live births, not the number of pregnant women. That is, even though a woman bears all the risks of a pregnancy for nearly a full term, unless the pregnancy results in a live birth, it is not included in the denominator. This will naturally introduce wide distortions in the ratios computed where the proportion of pregnancies terminated before birth varies, particularly where terminations occur late in the pregnancy.

This definitional disparity introduces a highly problematic variable into interpretation of "maternal mortality" statistics, particularly among sub-populations. For example, in the US, Non-Hispanic Blacks voluntarily terminate a far greater fraction of pregnancies than do other sub-populations, incurring the attendant risks of pregnancy [6]. However, none of these aborted pregnancies will be reflected in the denominators of the calculated mortality ratios, nor related deaths in the numerators.

Similarly, comparison of national maternal mortality ratios computed using the WHO ratio, whether measured using a 42-day or 365-day window, will be subject to significant distortion due to widely differing rates of natural fetal losses and induced abortions. The use of two distinctly different populations in the numerator—all pregnant women who have died—and the denominator—only pregnant women who give live birth—is a fundamental flaw in the metric definition.

A 2016 publication by MacDorman *et al.* sought to develop a method for trending mortality data by accounting for variation among the states in adopting a 2003 revision to the standard US death certification [7]. This certification added a question about pregnancy [8]. The question specified various possible time periods between the death of the woman and the termination of a pregnancy. Apparently, the addition of the question resulted in an increase in reported maternal mortality rates [5]. The study sought to provide a trend in US mortality ratios from 2000-2014 which accounted for variation in when each of the states adopted the 2003 revision and the different question formats that were utilized. The analysis organized the states into four groups based on these reporting differences and then aggregated the groups into a national picture. Two states, California and Texas, were analyzed separately because they had "trends that were markedly different from other US states" [7]. The authors used different methodologies and outcome definitions in analyzing the two states, but it is the observations made in the article about Texas which have caused an unintended controversy. In particular, the Texas data were said to show "a modest increase in maternal mortality between 2000-2010 followed by a doubling of the maternal mortality rate between 2010-2012… and this doubling was not found for other states" [7]. Although the authors observed that this doubling was unlikely to have actually occurred, this observation was also juxtaposed with another statement which implied (but did not explicitly state) a causal link between these Texas increases and the closing of several women's health clinics between 2011-2015. Advocates of legal abortion were quick to seize upon these statements as a means to oppose the efforts to defund Planned Parenthood. Popular media coverage has attributed the Texas maternal mortality increase to the closing of Planned Parenthood centers in the state even though Planned Parenthood provides little prenatal and no postnatal services, and there is not a single reputable study which relates Planned Parenthood services to improved maternal mortality [9] [10] [11].

In 2013, fully three years before the publication of the MacDorman *et al.* paper, by order of the Texas legislature, a 15-member panel of experts, stakeholders, and representatives of professional organizations was appointed to investigate a trend of increasing maternal mortality. Their charge was to study cases of pregnancy-related deaths in the state. The July 2016 biennial report published three months before MacDorman *et al.*, studied maternal deaths that occurred in calendar years 2011-2012 for any woman who died within 365 days of a birth or fetal death. Motor accidents and non-pregnancy related cancers were excluded per protocol. Using this definition, there were 189 maternal deaths in 2011-2012, versus the 262 found by MacDorman *et al.*, while the dramatic doubling of the mortality ratio found by MacDorman *et al.* was replaced by a much more gradual consistent upward trend [12].

3. Objectives and Methods

Our objectives were: 1) To demonstrate how the variation of the definition for determining a maternal death, and any methodological adjustments applied, can influence the trends and interpretation of group-specific comparisons; and 2) To establish the rationale for broadening the population considered under maternal mortality because of serious existing threats to the validity of the maternal mortality calculation caused by the current exclusion of a large proportion of pregnant women.

We queried the CDC Wonder system for the years 2000-2015 using the following definitions of maternal mortality and associated ICD-CM-10 codes [13]: 1) Maternal deaths up to 42 days after delivery (A34, O00-O99, except O96-O97); 2) Maternal deaths within one year after delivery (A34, O00-O99, except O97); 3) All maternal deaths (A34, O00-O99).

For each year, 2000-2015, we provided maternal deaths, live births, and calculated maternal mortality ratios (MDR). For deaths within 42 days, we also calculated adjusted mortality ratios (ADR) re MacDorman *et al.* Mortality rates are expressed as maternal deaths per 100,000 live births. We used the term ratio rather than rate since the numerator is derived from a different population than the denominator.

4. Results

4.1. Deaths within 42 Days of Delivery

Table 1 shows births, deaths, and maternal mortality ratios for the years 2000-2015. For Texas both adjusted (ADR) and unadjusted (MDR) ratios are shown. The Texas adjustment is from MacDorman *et al*. and is derived by multiplying the unadjusted deaths by the factor of 2.067. As per MacDorman *et al*., we did the adjustment only for the years 2000-2005, so that the ADR and MDR are identical from 2006-2015.

Figure 1 is the unadjusted data from Table 1, with trend lines for the 2000-2015 period for Texas, California and the United States (US). Note that in the period 2010-2011, the Texas ratios increased 61.9% (18.65 - 30.20) and that in the following year (2011-2012), the ratio increased another 28.0% (30.20 - 38.67). This is the two-year period which has been the focus of so much attention. However, note that with the unadjusted data, the year-to-year period with the largest percentage increase in Texas was 2005-2006, 73.3% (10.11 - 17.52). The largest year-to-year ratio increase overall, however, was in California, 2007-2008, 142% (7.42 - 17.94). California also had an increase of 66.2% (10.01 - 16.64) from 2002-2003. Note the sharp decline in California's reported deaths between 2008-2015, with only 11 maternal deaths reported in 2014 and 2015, and 502,879 and 491,748 births, respectively, a ratio so low as to suggest some reporting

Table 1. Maternal deaths, births, and unadjusted and adjusted mortality ratios within 42 days of delivery.

	California				Texas				US			
Year	Births	Deaths	MDR	ADR	Births	Deaths	MDR	ADR	Births	Deaths	MDR	ADR
2000	531,959	54	10.15		363,414	28	7.70	15.96	4,058,814	396	9.76	
2001	527,759	43	8.15		365,410	36	9.85	20.25	4,025,933	399	9.91	
2002	529,357	53	10.01		372,450	31	8.32	17.18	4,021,726	357	8.88	
2003	540,997	90	16.64		377,476	36	9.54	19.60	4,089,950	495	12.10	
2004	544,843	81	14.87		381,293	28	7.34	15.21	4,112,052	540	13.13	
2005	548,882	77	14.03		385,915	39	10.11	20.99	4,138,349	623	15.05	
2006	562,440	63	11.20		399,603	70	17.52	17.52	4,265,555	569	13.34	
2007	566,414	42	7.42		407,625	69	16.93	16.93	4,316,233	548	12.70	
2008	551,779	99	17.94		405,554	82	20.22	20.22	4,247,694	660	15.54	
2009	527,020	<10	supp		401,977	73	18.16	18.16	4,130,665	685	16.58	
2010	510,198	47	9.21		386,118	72	18.65	18.65	3,999,386	674	16.85	
2011	502,120	35	6.97		377,445	114	30.20	30.20	3,953,590	765	19.35	
2012	503,755	31	6.15		382,727	148	38.67	38.67	3,952,841	787	19.91	
2013	494,705	24	4.85		387,340	140	36.14	36.14	3,932,181	864	21.97	
2014	502,879	11	2.19		399,766	135	33.77	33.77	3,988,076	856	21.46	
2015	491,748	11	2.24		403,618	131	32.46	32.46	3,978,497	832	20.91	

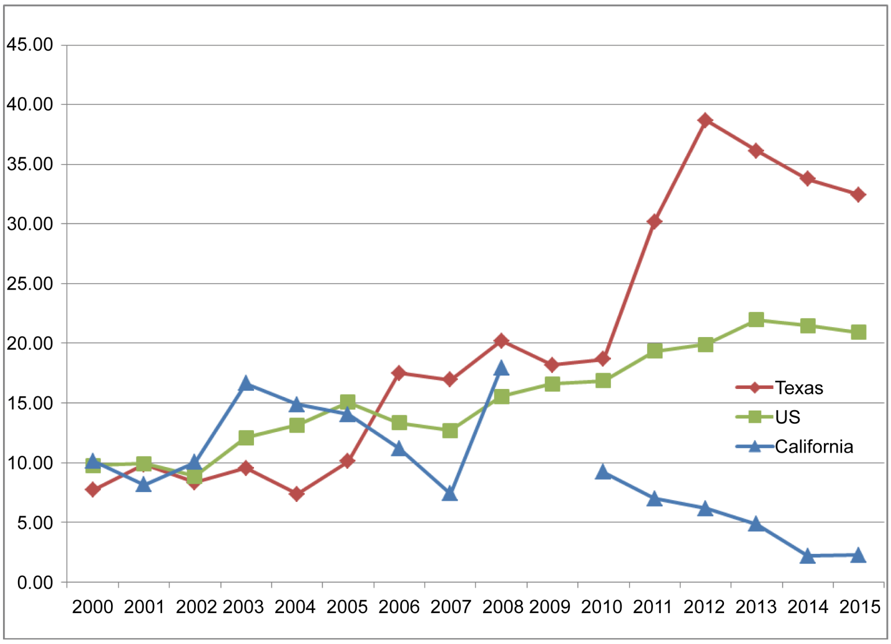

Figure 1. Unadjusted maternal mortality ratios within 42 days of delivery.

anomaly.

Figure 2 is a composite of the adjusted (MacDorman *et al.*) trend line and the unadjusted trend line for Texas. Note that the adjusted trend line shows a relatively flat ratio, varying between 15 - 20 from 2000-2010, while the unadjusted ratio shows a more gradual and consistently upward climb. The MacDorman *et al.* adjusted data represent the 2010-2011 increase as a sudden departure from the previous decade's relative stability. The unadjusted data, by contrast, represent 2010-2011 as an acceleration in a relatively consistent upward trend beginning in 2004.

4.2. Deaths within One Year of Delivery

Table 2 and **Figure 3** show births, deaths, and the mortality ratios (MDR) for maternal deaths within one year of delivery. Note that the Texas increase in mortality ratio is now 32.6% (26.16 - 34.71) between 2010-2011. Between 2011 and 2012, the Texas rate increase was 18.1% (34.71 - 41.02). The two year rate of increase between 2010 and 2012 ratios is 43.6% lower than the 42 day time frame (89.9% versus 50.7%). Further, year-to-year percentage increases in Texas between 2002 until 2006 were 78.9%, 58.5%, and 24.5%. While the Texas ratio has been increasing consistently between 2000 and 2014, there is no suggestion that 2010 represents some dramatic acceleration in the ratio trend.

California death ratios are higher than Texas in 2000, 2002, 2003, 2004, and 2005. In 2006, the California rates drop below Texas, and the rate difference between the two states widens to the maximum difference in 2013.

Comparing California ratios for maternal deaths within 42 days versus one year, between 2010 and 2015, we see an increasing ratio differential: 2010 (9.21 -

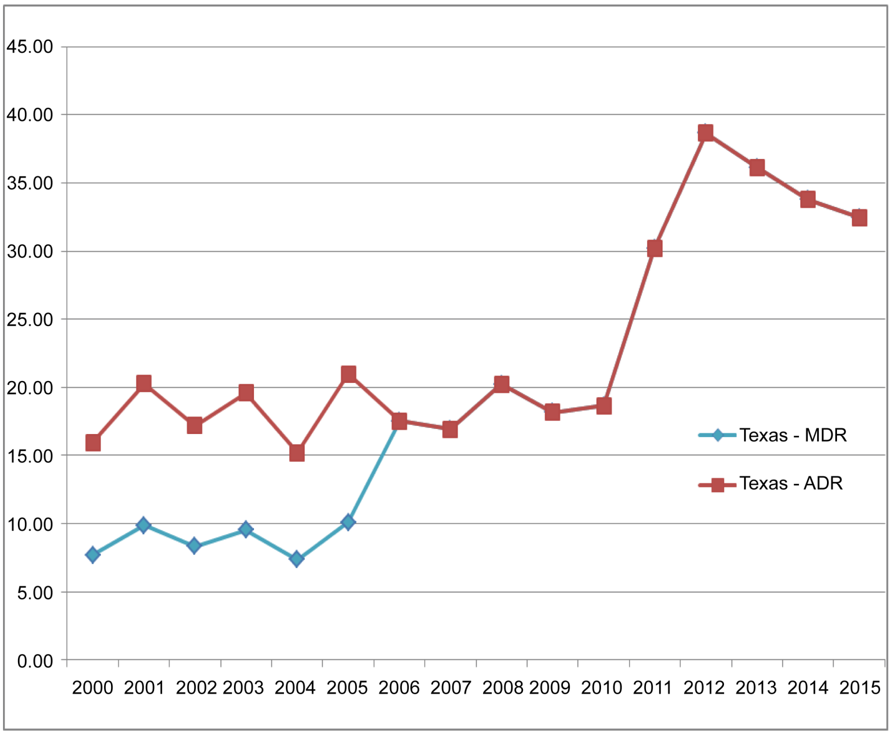

Figure 2. Texas unadjusted and adjusted mortality ratios within 42 days of delivery.

Table 2. Maternal deaths, births, and unadjusted mortality ratios within one year of delivery.

	California			Texas			US		
Year	Births	Deaths	MDR	Births	Deaths	MDR	Births	Deaths	MDR
2000	531,959	54	10.15	363,414	29	7.98	4,058,814	398	9.81
2001	527,759	44	8.34	365,410	38	10.40	4,025,933	408	10.13
2002	529,357	54	10.20	372,450	32	8.59	4,021,726	366	9.10
2003	540,997	93	17.19	377,476	58	15.37	4,089,950	541	13.23
2004	544,843	148	27.16	381,293	43	11.28	4,112,052	685	16.66
2005	548,882	118	21.50	385,915	69	17.88	4,138,349	753	18.20
2006	562,440	121	21.51	399,603	89	22.27	4,265,555	749	17.56
2007	566,414	96	16.95	407,625	80	19.63	4,316,233	763	17.68
2008	551,779	99	17.94	405,554	96	23.67	4,247,694	788	18.55
2009	527,020	107	20.30	401,977	115	28.61	4,130,665	942	22.81
2010	510,198	82	16.07	386,118	101	26.16	3,999,386	822	20.55
2011	502,120	70	13.94	377,445	131	34.71	3,953,590	923	23.35
2012	503,755	79	15.68	382,727	157	41.02	3,952,841	973	24.62
2013	494,705	73	14.76	387,340	167	43.11	3,932,181	1121	28.51
2014	502,879	88	17.50	399,766	146	36.52	3,988,076	1111	27.86
2015	491,748	84	17.08	403,618	155	38.40	3,978,497	1128	28.35

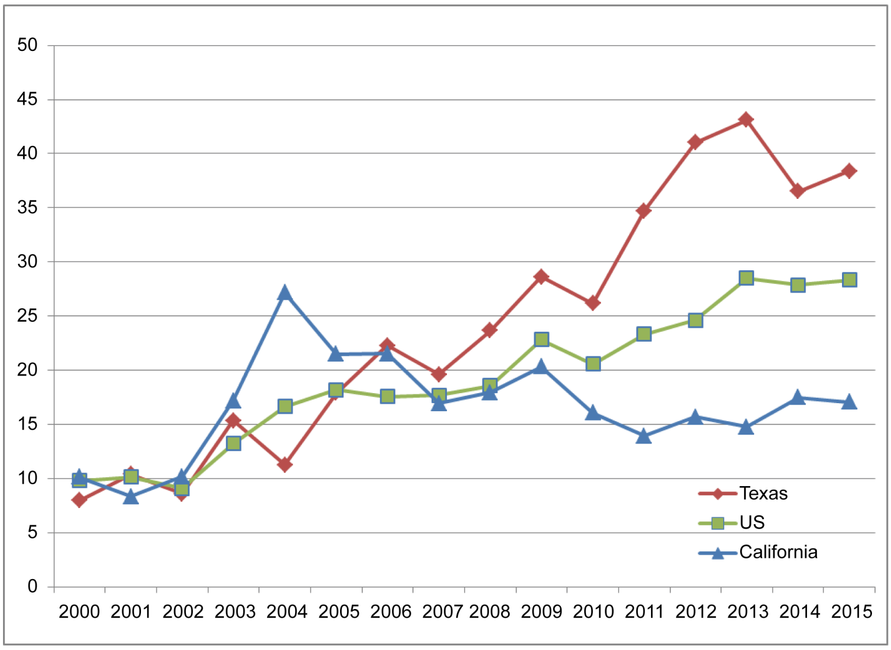

Figure 3. Unadjusted maternal mortality ratios within one year of delivery.

16.07), 2011 (6.97 - 13.94), 2012 (6.15 - 15.68), 2013 (4.85 - 14.76), 2014 (2.19 - 17.50), and 2015 (2.24 - 17.08). While we expect to see higher ratios for the one-year definition, the California ratio differentials increase to 700%, suggesting some serious reporting anomaly. Note that in the MacDorman *et al.* article unadjusted combined maternal and late maternal deaths occurring within one year of pregnancy are used for California. For Texas, however, MacDorman *et al.* used a very different methodology, one that included a combination of adjusted and unadjusted years in the same trend line. While the paper describes Texas "adjusted maternal mortality rates from 2000-2010" only the years 2000-2005 were adjusted. As previously indicated, this methodological inconsistency emphasizes increases after 2010 but deemphasizes the increases between 2000-2010 especially the increase occurring from 2005 to 2006.

4.3. All Maternal Deaths Regardless of Date of Delivery

These ratios and numbers track very closely with the one-year termination definition. The actual total count differences for the entire US between these two methods ranges between five and 15 maternal deaths per year.

5. Discussion

5.1. Full Disclosure of All Pregnancy Outcomes

The "end of pregnancy" occurs in one of three ways: 1) live birth; 2) natural fetal loss; and 3) induced abortion. Identification of true maternal mortality requires accurate identification of the women who become pregnant regardless of which of these outcomes occurs, and inclusion of these women in the denominator of any derived rates.

There are two essential elements in identifying maternal mortality (pregnancy-related death) as defined by the CDC: 1) identifying the universe of deaths of women who were pregnant within one year of death; and 2) identifying whether the proximate cause of death was pregnancy related.

The national standard of identifying women's deaths (element a.) is through selecting specific cause-of-death ICD-10 codes, commonly A34 (obstetric tetanus) and O00-O99 (obstetric causes). This approach appears grossly simplistic, as evidenced by the results of the Texas Maternal Mortality and Morbidity Task Force biennial report. A detailed review of death records for all women who had given birth within one year, as identified by matching birth records, found:

> "…this method to be unreliable because it results in too many non-obstetric deaths being miscoded as 'obstetric' and too few maternal deaths being coded as 'obstetric' despite occurring within 365 days of pregnancy termination. For 2011-2012, there were 189 maternal deaths identified, of which only 79 had 'obstetric' coded as cause of death. Conversely, 181 total deaths in 2011-2012 were coded as 'obstetric' when the narrative on the death certificate did not indicate pregnancy" [12].

The Texas task force approach of linking birth records to death records does not capture a significant fraction of pregnancies as it requires a record of live birth and ignores pregnancies terminated by either natural fetal loss or induced abortion. For some racial/ethnic groups, this oversight fails to identify over 50% of all pregnancies [14].

The use of O-codes to identify a death as pregnancy-related (element b.) also fails to capture "chain(s) of events initiated by pregnancy" [5]. Again, the Texas task force found nearly 25% of all maternal deaths were due to drug overdose, homicide, and suicide, all non-O codes of death.

A wide body of research has strongly correlated a significant rate of negative emotional outcomes stemming from the loss of the fetus, either through natural fetal loss or induced abortion (see **Appendix**). Given the relative rarity of maternal mortality and comparatively high incidence of natural fetal loss and induced abortion, natural miscarriage and abortion could be major unidentified contributors to the true rate of maternal mortality. Moreover, these causes of death are likely amenable to effective behavioral interventions once vulnerable sub-populations are identified.

While some jurisdictions may generate death certificates for miscarriages (natural fetal loss prior to 20 weeks) upon request of the parents, in general there is no requirement to generate a certificate of death unless there has first been a certificate of live birth, regardless of the fetal age at the time of loss. Neither any state nor the national vital statistics capture natural fetal losses, and no state tracks data on induced abortions except by raw numbers.

5.2. Implications for Research and Policy

Variation and inconsistency in definitions, coding, and other reporting anomalies render the current aggregated vital statistics on maternal mortality inadequate for accurate trending and service impact studies. As we have demonstrated in the Texas analysis, the inconsistent application of different definitions and adjustments for subgroup comparisons (*i.e.* Texas versus California) may further distort the findings and invalidate their interpretation. Indeed, the very conflation of "maternal mortality" and "pregnancy-related deaths" employing live births as a denominator renders the metric meaningless. The association of rates in any time period with similarly aggregated "explanatory" variables (e.g. "funding cuts") lacks methodological and conceptual validity. That is, data used in this way can neither confirm an impact nor explain how that impact is achieved.

Studies to measure the impact of preventive services on maternal mortality must utilize event-level (*i.e.* individual decedents) records with rich, multiple dimensions in order to analyze variable outcomes in the context of proximate medical causes, predisposing behaviors, demographic characteristic correlates, and chains of events initiated by pregnancy.

The ramifications of failing to account for pregnancies that do not result in live births may be crudely estimated. In 2009 in the United States, more pregnancies to Non-Hispanic Black women ended in induced abortions (445,000) and natural fetal losses (192,000) than in a live birth (615,000). Conversely, Non-Hispanic White women carried 69.6% of all pregnancies to term [15]. Using all pregnancies as a denominator for maternal mortality would reduce the computed rate by half (615,000/1,252,000) for Non-Hispanic Black women, but only 30.4% for Non-Hispanic White women, given the same number of deaths. But, of course, adding these additional pregnancies in the denominator mandates that the associated deaths also be included. Identifying these pregnancy-related deaths unassociated with live births presents significant challenges, although studies by Gissler [16] [17] and Reardon [18] provide working examples. Consistency argues strongly that all pregnancy outcomes (abortion, natural fetal loss, and live birth) must be included in maternal mortality statistics. Failure to include this large segment of pregnancy outcomes will seriously hamper efforts to improve women's health.

We can manage only what we measure. A comprehensive maternal mortality monitoring system must collect comprehensive data in a completely consistent fashion. Definitions and coding conventions must be standardized. Reporting compliance must be mandated and monitored. Birth, abortion, and fetal loss registries must be developed, deployed, and integrated. Finally, event-level data must be made available to researchers and providers so that these efforts can result in evidence-based strategies and services focused on improving maternal health.

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Appendix

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