

Evaluation of Pregnancy Mortality in Louisiana Using Enhanced Linkage and Different Indicators Defined by WHO and CDC/ACOG: Challenging and Practical Issues

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Abstract Differences in definitions and methods of data collection on deaths occurring during or shortly after pregnancy have created confusion and challenges in evaluating research findings. The study aimed to determine if the use of enhanced linkage procedures improve data collection of deaths occurring during or shortly after pregnancy, and how different definitions of those deaths changed the results of data analysis. The study used 2000–2005 Louisiana Pregnancy Mortality Surveillance System (LPMSS) and 2000–2005 death certificates linked with 1999–2005 live birth and fetal death certificates. Five indicators of deaths occurring during or shortly after pregnancy using WHO and CDC/ACOG definitions were estimated. One-sided Spearman rank test was used to analyze maternal mortality trends from 2000 to 2005. Of

345 women who died within 1 year of pregnancy, 187 were identified through linkage; 38 of those were missed by the LPMSS. Total mortality ratios of deaths occurring within 1 year of pregnancy ranged from 13.4 to 88.9 per 100,000 live births depending on the indicator used. CDC/ACOG pregnancy-related death and pregnancy-associated death statistically increased, whereas WHO pregnancy-related death decreased between 2000 and 2005. The most common causes of death differed by indicator. Universal adoption of linkage procedures could improve data on deaths occurring during or shortly after pregnancy. Estimates, trends, and most common causes of death were markedly different depending on which indicator was used. Additionally, the use of different mortality indicators during analysis provides a more detailed picture of potential target areas for future research and interventions.

Keywords Pregnancy mortality · Maternal mortality · Surveillance · Data linkage · Trend

Introduction

Inconsistencies in terms and definitions between the World Health Organization (WHO) and American College of Obstetricians and Gynecologists (ACOG) have led to challenges and confusion in evaluating mortality occurring during or shortly after pregnancy. While providing useful data for analysis, the new definitions WHO included in the Tenth Revision of its International Classification of Diseases manual (ICD-10) [1, 2] have, in some cases, added to the confusion in collecting and interpreting data on deaths occurring during or shortly after pregnancy. This is especially evident in the case of the term pregnancy-related death which, when used by the Centers for Disease Control

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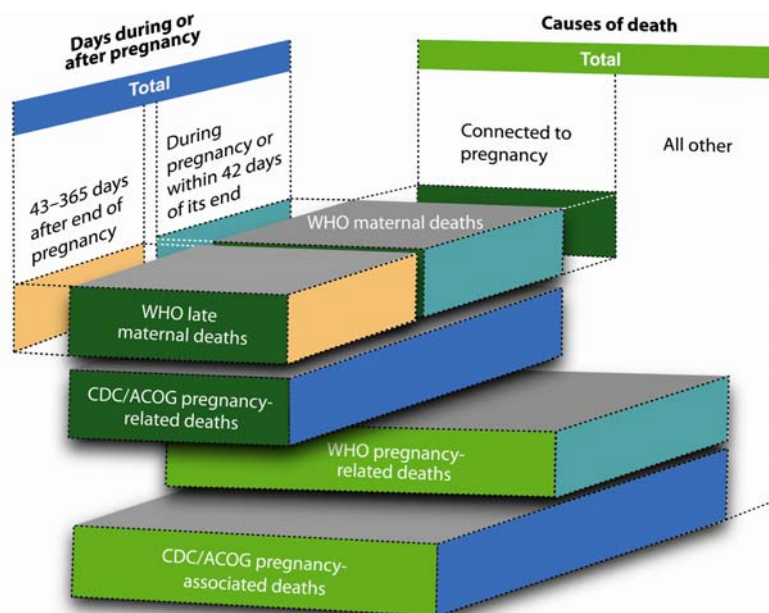
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Fig. 1 Indicators of a woman's death during or shortly after pregnancy



SOURCES: WHO, *International Statistical Classification of Diseases and Related Health Problems, Tenth Revision*; CDC, *Strategies to reduce pregnancy-related deaths: From identification and review to action*.

and Prevention's Division of Reproductive Health (CDC) and American College of Obstetricians and Gynecologists (ACOG), has a different meaning from the term as used by WHO and those following the WHO definitions [3–5] (Fig. 1). There has also been an increased emphasis on data linkage as a way to compile a more accurate picture of deaths occurring during or shortly after pregnancy [5–7]. Research has suggested that data obtained from death certificates alone miss up to 50% of deaths occurring during or shortly after pregnancy due to errors in what is reported [6]. Linking death certificate data sets with live birth and fetal death data sets has been shown to identify more deaths occurring during or shortly after pregnancy [7, 8], sometimes capturing up to 150% more deaths than when using death certificates alone [9].

The purposes of this study were to (1) determine if an improvement occurred in the accuracy of data collection of deaths occurring during or shortly after pregnancy (deaths of pregnant women occurring within 1 year of pregnancy) through use of Louisiana death records linked with live birth and fetal death records, (2) estimate and clarify differences among five indicators: maternal death, late maternal death, and pregnancy-related death as defined by WHO; as well as pregnancy-related death and pregnancy-associated death as defined by CDC/ACOG, (3) determine the most common causes of deaths, and (4) evaluate time trends for deaths occurring during or shortly after pregnancy by each definition category. In addition to the above purposes, when data were available, racial disparity of deaths between black and white women was examined.

Methods

Data Sources

1. 2000–2005 Louisiana Pregnancy Mortality Surveillance System (LPMSS). LPMSS is Louisiana's program, initiated in 1992, to identify pregnant women who died within 90 days of pregnancy. Data collection is based on a check box on the death certificate in the following question item being marked as 'yes': "If deceased was female 10–49, was she pregnant in the last 90 days".
2. 2000–2005 death certificates for female Louisiana residents aged 10–55 years.
3. 1999–2005 live birth and fetal death certificates.

Procedures of Data Collection and Linkage

The LPMSS provided hardcopies of death records of pregnant women aged 10–49 identified as having died within 90 days of pregnancy (data set 1). This represents what normally is available in Louisiana about deaths occurring during or shortly after pregnancy. To identify additional deaths occurring after 90 days and up to 1 year of pregnancy, to women older than 49 years, or those missed by the LPMSS, a second data set was created using data linkage.

The electronic files from death certificates for female Louisiana residents were linked with birth and fetal death

certificates, independently of the LPMSS data, to identify deaths to women who had died within 1 year of a live birth or fetal death delivery. SAS 9.1 and LinkPro 3.0 were utilized in linking certificates by first and last name, soundex of first and last name, date of birth, race, and social security number. Matched records were manually reviewed to confirm that death records and live birth or fetal death records related to the same pregnant or recently pregnant woman. The 345 records (data set 2) were identified through the linkage, which comprised all records collected from LPMSS and records identified solely through matching. So the universe of data set 1 was a subset of the universe of data set 2.

Then data set 1 and data set 2 were compared. This provided an assessment of how well the LPMSS identified deaths of pregnant women aged 10–49 who had died within 90 days of pregnancy. Data set 2 was used further for analyses on mortality ratio calculations, trends, and causes of death using five indicators of pregnancy mortality.

Causes of death in the study reflected the ICD-10 codes assigned by the Louisiana Center for Health Statistics and Vital Records to the information reported on the death certificates. Obstetric-cause deaths were those for which causes of death reported solely on the death certificate were assigned to any O-code in ICD-10 chapter XV, meaning that there was a connection between the cause and the women having been pregnant at the time of death or in the recent past. In this study, no other protocol to review the original text on the death certificate or to examine all sources of clinical information on the cases was followed to potentially refine cause of death.

Statistical Analyses

Deaths were classified into five groups by using both WHO and CDC/ACOG definitions. Table 1 shows details of

definitions and codes of causes of death for each indicator used in this study. The definitions differ according to two dimensions: cause (i.e., just obstetric causes vs. all causes) and time between pregnancy and death (i.e., within 42 days, within 43 days–1 year, anytime within 1 year). Results will start with the shortest time frame and restricted cause and end with the indicator for the broadest definition. Mortality ratios of deaths occurring during or shortly after pregnancy per 100,000 live births (called mortality ratios from here forward in the paper) were calculated for each indicator by race (white and black) from 2000 to 2005. The number of live births used in the denominator is considered an approximation of the population of women who are at risk of death once they have become pregnant [2]. Methods to estimate confidence intervals of mortality ratios were based on number of deaths [2, 10]. When the number of deaths, which follows a Poisson distribution, was equal to or greater than 100, a normal distribution approximation was used in the calculation of confidence intervals. When the number of deaths was fewer than 100, a gamma method was used to estimate confidence intervals of mortality ratios due to the fact that the Poisson distribution is not approximated by the normal distribution. Mortality ratios based on number of deaths fewer than 20, which is equivalent of a relative standard error of 23% or more, were not shown or were marked by an asterisk (*) in the results. These ratios were considered statistically unreliable for presentation.

Analysis of time trend of mortality ratios from 2000 to 2005 was conducted using 3-year average mortality ratios. Since number of deaths occurring during or shortly after pregnancy in each year was small when stratified by definition of death, particularly when stratified by both definition of death and race, the trend analysis of mortality ratio for each death definition by using individual year data was not feasible in perspective of statistical analysis. One-

Table 1 Definitions of indicators of a woman's death during or shortly after pregnancy and ICD-10 codes used in the study

Indicator	Definitions	ICD-10 for codes of causes of death
WHO maternal death	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 [1, 2]	O00–O95, O98–O99, and A34
WHO late maternal death	Death of a woman from direct or indirect obstetric causes more than 42 days but less than 1 year after termination of pregnancy [1, 2]	O96
WHO pregnancy-related death	Death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of death [1, 2]	All codes
CDC/ACOG pregnancy-related death	Death of a woman while pregnant or within 1 year 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 [3, 5]	O00–O96, O98–O99, or A34
CDC/ACOG pregnancy-associated death	Death of a woman while pregnant or within 1 year of termination of pregnancy, irrespective of cause of death [3, 5]	All codes

sided Spearman rank test [11] was used to analyze the trend and alpha level was set at .05 for a statistical significance of trend analysis.

The study was conducted by Epidemiology, Assessment, and Evaluation Unit, Maternal and Child Health program, Office of Public Health, Louisiana Department of Health and Hospital. Louisiana is one of the states where pregnancy mortality is still high in the United States.

Results

Number of Deaths Within 90 Days Found Through LPMSS and Data Linkage

For the years 2000–2005, conventional LPMSS reported 158 deaths to Louisiana female residents occurring within 90 days of pregnancy based on positive responses to the question on Louisiana's death certificate: If deceased was female 10–49, was she pregnant in the last 90 days? Of those 158 records, a review of death certificates and their related birth and fetal death certificates confirmed that 156 deaths occurred within 90 days of pregnancy and two deaths occurred after 90 days of pregnancy. An additional 38 deaths occurring within 90 days of pregnancy were found through linkage: four with positive response to the pregnancy-check box on the death certificates which were not included when LPMSS submitted such records, 33 through linkage with the live birth certificates, and one through linkage with the fetal death certificates. This increased the total number of pregnancy deaths occurring within 90 days to 194 deaths (156 from LPMSS and 38 through data linkage).

Analyses of the Five Indicators

WHO Maternal Death

There were 57 deaths reported as WHO maternal deaths through LPMSS. Through data linkage five of those 57 death records were found to have occurred more than 42 days after live birth deliveries. This resulted in a total of only 52 deaths defined as WHO maternal deaths from 2000 to 2005 in Louisiana (Table 2). Of those, 67.3% (35) were black women and 30.8% (16) were white women. The maternal mortality ratio¹ for all races between 2000 and 2005 was 13.4 per 100,000 live births (95% CI: 10.0, 17.6). The maternal mortality ratio for black women was 3 times that of white women (22.1 vs. 7.3^{*}) (Table 3). The most

Table 2 Number of deaths received from LPMSS and through the linkage by indicator, Louisiana 2000–2005

Indicator	Data sources	Total deaths
WHO maternal death	LPMSS	57
	Data linkage	–5 ^a
	Total	52
WHO late maternal death	LPMSS	0
	Data linkage	5 ^a
	Total	5
WHO pregnancy-related death	LPMSS	139
	Data linkage	24
	Total	163
CDC/ACOG pregnancy-related death	LPMSS	57
	Data linkage	0
	Total	57
CDC/ACOG pregnancy-associated death	LPMSS	158
	Data linkage	187
	Total	345

^a Five death records defined as WHO maternal death were re-classified as WHO late maternal death through data linkage

common causes of maternal death were eclampsia and pre-eclampsia (11, 21.2%), obstetrical embolism (7, 13.5%), and hemorrhage of pregnancy, childbirth, or placenta previa (5, 9.6%) (Table 4). Because of the small number of deaths, it was not possible to analyze common causes of death by race for this death category.

WHO Late Maternal Death

Five WHO maternal deaths reported by LPMSS were re-classified as late maternal deaths between 2000 and 2005 through data linkage. Causes of death for those death records had been assigned to O26.8, O75.1, O88.2, O88.3, and O98.8. Those codes were recoded as WHO late maternal death (O96) because death occurred after 42 days but less than 1 year after live birth deliveries (Table 2). Due to the very small number of deaths, no statistical data analysis was conducted for common causes of late maternal death and the mortality ratio estimate was not calculated in this study.

WHO Pregnancy-Related Death

Through LPMSS, 156 deaths to Louisiana residents occurring within 90 days of pregnancy and from any cause were identified. Of those, 139 occurred within 42 days of pregnancy; these were classified as WHO pregnancy-related deaths. There were an additional 24 deaths classified as WHO pregnancy-related deaths solely through the linkage. This increased the total number of deaths occurring within

¹ This ratio is also reported as maternal mortality rate in some vital statistics publications [2].

Table 3 Number of deaths and mortality ratio (per 100,000 live births) by indicator and race, Louisiana 2000–2005

Indicator	Race	Number of deaths	Mortality ratio	95% CI mortality ratio
WHO maternal death	All races	52	13.4	10.0, 17.6
	White	16	7.3*	4.2, 11.8
	Black	35	22.1	15.4, 30.7
WHO late maternal death ^a	All races	5	–	–
WHO pregnancy-related death	All races	163	42.0	35.6, 48.5
	White	60	27.2	20.8, 35.1
	Black	101	63.8	51.3, 76.2
CDC/ACOG pregnancy-related death	All races	57	14.7	11.1, 19.0
	White	16	7.3*	4.2, 11.8
	Black	39	24.6	17.5, 33.7
CDC/ACOG pregnancy-associated death	All races	345	88.9	79.5, 98.3
	White	141	64.0	53.5, 74.6
	Black	199	125.7	108.2, 143.1

CI Confidence interval

* Mortality ratio with number of deaths less than 20 may be statistically unreliable

^a Because of very small number of death, racial distribution, mortality ratios, and common causes of death are not presented for this death category

ICD-10 codes applied for Table 3:

Eclampsia and pre-eclampsia: O11, O13–O16

Obstetrical embolism: O88

Hemorrhage of pregnancy and childbirth and placenta previa: O20, O44–O46, O67, O72

Motor vehicle accidents: V02–V04, V09.0, V09.2, V12–V14, V19.0–V19.2, V19.4–V19.6, V20–V79, V80.3–V80.5, V81.0, V81.1, V82.0, V82.1, V83–V86, V87.0–V87.8, V88.0–V88.8, V89.0–V89.2

Homicide (all modes): X91, X93–X95, Y06, Y07, X85–X90, X92, X96–X99, Y00–Y04, Y05.0, Y08, Y09

Accident poisoning and exposure to noxious substances: X40–X49

Disease of the circulatory system: I00–I99

Infectious and parasitic diseases: A00–A33, A35–B99

Neoplasm: C00–D48

42 days of pregnancy to 163 WHO pregnancy-related deaths (Table 2). Of those, 62% (101) were black and 36.8% (60) were white. The pregnancy-related mortality ratio for all races was 42.0 deaths per 100,000 live births (95% CI: 35.6, 48.5). When stratified by race, the mortality ratio was over twice as high in black women as in white women (63.8 vs. 27.2) (Table 3). Almost one-third of deaths were due to obstetric causes of death occurring during pregnancy or within 42 days after delivery (52, 31.9%), with eclampsia and pre-eclampsia being the most common (11, 6.7%). The next most common causes of death were motor vehicle accidents (22, 13.5%), homicide (20, 12.3%), and disease of the circulatory system (17, 10.4%) (Table 4). The most common causes of WHO pregnancy-related death differed between white and black women. Over one-third (35, 34.7%) of deaths in black women were due to obstetric causes of death occurring during pregnancy or within 42 days after delivery, making it by far the most common cause of death in this group, followed by homicide (15, 14.9%) and disease of the circulatory system (12, 11.9%). For white women, the top

two most common causes of death were obstetric causes of death occurring during pregnancy or within 42 days after delivery (16, 26.7%), and motor vehicle accidents (12, 20%).

CDC/ACOG Pregnancy-Related Death

When using the CDC/ACOG definition of pregnancy-related death, 57 deaths were identified by ICD-10 maternal death codes on death certificates and within 1 year of pregnancy. Data linkage did not identify any additional records because the current study was constrained by assigned codes and time of death (Table 2). Of the 57 deaths, 68.4% (39) were black and 28% (16) were white. The mortality ratio for all races was 14.7 deaths per 100,000 live births (95% CI: 11.1, 19.0). When stratified by race, the mortality ratio was 3.4 times higher in black women than in white women (24.6 vs. 7.3*) (Table 3). The most common causes of death for all women were eclampsia and pre-eclampsia (11, 19.3%), obstetrical embolism (9, 15.8%), and hemorrhage of pregnancy,

Table 4 Causes of death by indicator, all races, Louisiana 2000–2005

Indicator	Causes of death	Number	Percent
WHO maternal death	Eclampsia and pre-eclampsia	11	21.2
	Obstetrical embolism	7	13.5
	Hemorrhage of pregnancy and childbirth and placenta previa	5	9.6
	Other maternal causes	29	55.8
	Total	52	100.0
WHO pregnancy-related death	External causes of mortality:	62	38.0
	Motor vehicle accidents	22	13.5
	Homicide (all modes)	20	12.3
	Accident poisoning and exposure to noxious substances	9	5.5
	Other external causes	11	6.7
	Maternal causes of death occurring <42 days after delivery:	52	31.9
	Eclampsia and pre-eclampsia	11	6.7
	Other obstetric causes	41	25.2
	Disease of the circulatory system	17	10.4
	Infectious and parasitic diseases	7	4.3
	Neoplasm	6	3.7
	All other causes	19	11.7
	Total	163	100.0
	CDC/ACOG pregnancy-related death	Eclampsia and pre-eclampsia	11
Obstetrical embolism		9	15.8
Hemorrhage of pregnancy and childbirth and placenta previa		5	8.8
Other maternal or pregnancy-related causes		32	56.1
Total		57	100.0
CDC/ACOG pregnancy-associated death	External causes of mortality:	165	47.8
	Motor vehicle accidents	60	17.4
	Homicide (all modes)	57	16.5
	Accident poisoning and exposure to noxious substances	23	6.7
	Other external causes	25	7.2
	Maternal causes of death occurring <42 days after delivery	52	15.1
	Eclampsia and pre-eclampsia	11	3.2
	Obstetrical embolism	9	2.6
	Other obstetric causes	32	9.3
	Disease of the circulatory system	42	12.2
	Neoplasm	19	5.5
	Disease of the respiratory system	11	3.2
	All other causes	56	16.2
	Total	345	100.0

childbirth, or placenta previa (5, 8.8%) (Table 4). Because of the small numbers of deaths, common causes of death by race were not analyzed for this death category.

CDC/ACOG Pregnancy-Associated Death

A total of 345 pregnancy-associated deaths as defined by CDC/ACOG were identified for the years 2000–2005. Of these, 158 were reported by LPMSS and 187 additional

deaths were identified through the linkage. The deaths identified through linkage included: four through positive response to the pregnancy-check box in the death certificates which were missed when LPMSS submitted such records, 181 through linkage with the live birth certificates, and two through linkage with the fetal death certificates. This increased the total number of deaths from any cause occurring within 1 year of pregnancy to 345 CDC/ACOG pregnancy-associated deaths (Table 2). Of the 345 deaths

identified, 57.7% (199) were black and 40.9% (141) were white. The overall pregnancy-associated mortality ratio for the period from 2000 to 2005 was 88.9 per 100,000 live births (95% CI: 79.5, 98.3). When stratified by race, the mortality ratio for black women was almost double that of white women (125.7 vs. 64.0) (Table 3). The most common cause of death for all races was motor vehicle accidents (60, 17.4%), followed by homicide (57, 16.5%), and obstetric causes of death occurring while pregnant or within 42 days after delivery (52, 15.1%). Of the obstetric causes of death, eclampsia and pre-eclampsia was the most common (11, 3.2%) (Table 4). When stratified by race, the most common causes of death among white women were motor vehicle accidents (38, 27.0%), accidental poisoning/exposure to noxious substances (18, 12.8%), obstetric causes of death occurring while pregnant or within 42 days after delivery (16, 11.3%), and homicide (14, 9.9%). The most common cause of pregnancy-associated death among black women was homicide (43, 21.6%), followed by obstetric causes of death occurring during pregnancy or within 42 days after delivery (39, 19.6%), disease of the circulatory system (31, 15.6%), and motor vehicle accidents (21, 10.6%).

Time Trend Analysis of Mortality Ratios From 2000 to 2005

Mortality ratios for obstetric causes of death as measured by either WHO maternal death or CDC/ACOG pregnancy-related death both showed a statistically significant increase between 2000 and 2005 in Louisiana (Spearman's rank correlation coefficients for trend tests of both mortality ratios (Rho): 1.000, one-sided test *P*-value (*P*) < .0001). In terms of all-cause definitions for all races,

WHO pregnancy-related death decreased (Rho: -0.800, *P*: 0.025) and CDC/ACOG pregnancy-associated death increased (Rho: 0.800, *P*: 0.025) in Louisiana between 2000 and 2005. However, the results of trend analysis changed when stratified by race. Both WHO pregnancy-related and CDC/ACOG pregnancy-associated mortality ratios statistically decreased only among black women between 2000 and 2005 (Rho for trend tests of both mortality ratios: -1.000, *P*: < .0001). Among white women, the mortality ratio as defined by ACOG/CDC pregnancy-associated death increased (Rho: 0.800, *P*: 0.025) but there was no statistically significant trend for WHO pregnancy-related mortality ratio (Rho: 0.40, *P*: 0.30) between 2000 and 2005 in Louisiana (Table 5; Fig. 2).

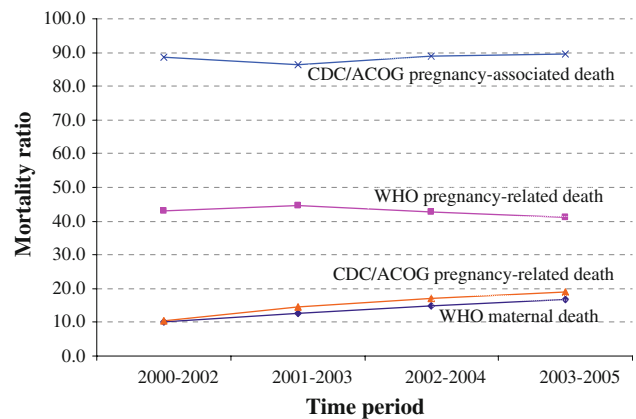


Fig. 2 Trend of 3-year average mortality ratios (per 100,000 live births) by indicator, Louisiana 2000–2005

Table 5 Results of trend analysis of 3-year average mortality ratios by indicator, Louisiana 2000–2005

Indicator	Race	2000–2002		2001–2003		2002–2004		2003–2005		Coef. ^a	P value ^b
		<i>n</i>	Ratio	<i>n</i>	Ratio	<i>n</i>	Ratio	<i>n</i>	Ratio		
WHO maternal death ^c	All races	20	10.1	25	12.8	29	14.9	32	16.8	1.000	<.0001
WHO pregnancy-related death	All races	85	43.0	87	44.7	83	42.7	78	41.0	-0.800	0.025
	White	29	26.1	34	30.8	31	28.0	31	28.5	0.400	0.300
	Black	56	68.4	53	66.6	50	63.2	45	58.9	-1.000	<.0001
CDC/ACOG pregnancy-related death ^c	All races	21	10.6	28	14.4	33	17.0	36	18.9	1.000	<.0001
CDC/ACOG pregnancy-associated death	All races	175	88.5	168	86.3	173	89.0	170	89.4	0.800	0.025
	White	67	60.2	66	59.8	72	65.1	74	68.0	0.800	0.025
	Black	108	131.8	101	126.9	97	122.6	91	119.1	-1.000	<.0001

n Number of deaths

^a Coef. Spearman correlation coefficient

^b One-sided test *P*-value

^c Because of small number of death, trends by race are not presented

Discussion

Without the use of enhanced linkage, an accurate assessment of the number of deaths occurring during or shortly after pregnancy would not have been possible. Using linkage of death certificates with live birth and fetal death certificates identified an additional 24 deaths defined as WHO pregnancy-related death and 187 deaths defined as CDC/ACOG pregnancy-associated death beyond those routinely identified in the state of Louisiana using a question on the death certificate about pregnancy within 90 days. With respect to the definition used in LPMSS, an additional 38 deaths occurring within 90 days of pregnancy were found through the data linkage. Five deaths identified as WHO maternal deaths through LPMSS were re-classified as WHO late maternal deaths through the data linkage. By using enhanced linkage with birth and fetal death certificates, the linked data included additional deaths occurring after 90 days and up to 1 year of pregnancy, deaths to women older than 49 years, or those missed by the LPMSS. The findings from this study were consistent with results of previous studies, which indicated that linking death certificate data sets with live birth and fetal death data sets has been shown to identify more deaths occurring during or shortly after pregnancy [6–9]. However, data linkage did not identify any additional records of CDC/ACOG pregnancy-related deaths in this study, possibly because the study used assigned codes and did not seek or use any other clinical information that may have existed.

During the period between 2000 and 2005 in the state of Louisiana, mortality ratios markedly varied by indicator, ranging from 13.4 for WHO maternal death to 88.9 per 100,000 live births for CDC/ACOG pregnancy-associated death. Although the CDC/ACOG definition of pregnancy-related death gives a more complete picture of death from obstetric causes than did the WHO maternal death definition because of the longer time frame, our findings did not show significant differences in the number of deaths between the two indicators for those definitions. Only five obstetric-cause deaths were identified as occurring after 42 days post-pregnancy. Both WHO's pregnancy-related death and CDC/ACOG's pregnancy-associated death definitions were useful for determining all-cause deaths. This revealed that there were significant differences between the most common causes of death during these two time periods, within 42 days and within 1 year after termination of pregnancy, with obstetric causes as the most common cause of WHO pregnancy-related death and external causes of death as the most common for CDC/ACOG pregnancy-associated deaths. The findings from this study were consistent with results of the study conducted by Chang et al. [14, 15], in which homicide and motor vehicle accidents were the most common causes of CDC/ACOG's

pregnancy-associated death in the United States in the period 1991–1999. As a result, the use of both indicators during analysis provided important data allowing researchers to more accurately pinpoint the areas that could be most useful for future interventions.

Trend analysis revealed discrepancies among different indicators. Deaths from obstetric causes (WHO maternal death and CDC/ACOG pregnancy-related death) showed a strong increasing trend for all races. In contrast, the two all-cause definitions showed trends in different directions, with WHO pregnancy-related deaths decreasing and CDC/ACOG pregnancy-associated deaths increasing across the 6 year period. The decrease in WHO pregnancy-related deaths could be explained by the decrease in non-obstetrical-cause deaths, which contributed 68% (111/163) of total all-cause deaths while pregnant or within 42 days of termination of pregnancy. The discrepancy became even more significant when stratified by race. Both WHO pregnancy-related death and CDC/ACOG pregnancy-associated death ratios strongly decreased among black women between 2000 and 2005, but increased slightly among white women. In this way, the all-cause ratios showed a trend towards convergence, albeit with a still high level of disparity between black and white women.

Limitations of the Study

Because the study used assigned codes on death certificates when defining CDC/ACOG pregnancy-related deaths, data linkage was of limited value for this death category. Application of procedures advocated by the CDC Pregnancy Mortality Surveillance System where all clinical information available for each death has improved the identification of CDC/ACOG pregnancy-related deaths in other studies because this type of review allows for the assignment of causes of deaths using information regarding temporal and causal relationships between the pregnancy and death, instead of assigned by ICD codes [12]. Based on timing information available from data linkage, five records were reclassified from WHO maternal to late maternal deaths. Other studies have asserted that the rules governing the coding of causes of death on death certificates in the 1990s contributed to under identification of maternal deaths [12, 13]. Although data linkage improved data collection for WHO pregnancy-related and CDC/ACOG pregnancy-associated deaths, underreporting remains a concern. Data linkage could not identify pregnancy deaths if the events were not captured by reporting systems [3, 12]. For example, abortions and undelivered pregnancies would not have a live birth or fetal death certificate, so linking death, live birth, and fetal death certificates would not result in a match for these cases. The results of this study cannot be compared to previous publications regarding maternal mortality of

Louisiana Center for Health Statistics and Vital Records due to differences in the time frame used for ratios and definition of deaths.

Implications

Data linkage improves data collection quality for deaths occurring during or shortly after pregnancy. Using enhanced linkage combined with the reevaluation of cause procedure advocated by the CDC Pregnancy Mortality Surveillance System, instead of a procedure only using assigned codes on death certificates, may also improve identification of deaths. The indicator used may depend upon purpose. For clinical perspective, indicators restricted to obstetric causes, either WHO maternal death combined with late maternal death or CDC/ACOG pregnancy-related death can be used. However, CDC/ACOG pregnancy-related death indicator has an advantage of capturing a longer time frame. For public health perspective, the indicators that are not restricted by cause are recommended. However, the CDC/ACOG pregnancy-associated death measure has the advantage of capturing both obstetric-cause and non-obstetric-cause deaths after 42 days and up to 1 year of pregnancy. This is of interest because of advanced life-prolonging medical technologies.

Since motor vehicle accidents and homicide are common causes of all mortality and external mortality by the CDC/ACOG pregnancy associated death definition, these areas could especially be targeted. The proper use of safety belts by pregnant women could be a possible public health campaign. Homicides in pregnancy are often the result of domestic violence, and activities to assure women access to safe havens and protection against domestic violence may improve outcomes. Understanding of the racial differences in these outcomes may help target specific groups for intervention.

Additionally, further research needs to be done to help explain the remaining disparity between maternal mortality for black and white women regardless of death definitions. Black women in Louisiana currently have a maternal mortality well above that of women in any developed country in the world [4]. In-depth research into the causes of death, health behaviors, social-economical status, and other risk factors behind these disparities is needed.

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