Original Research

Underreporting of Pregnancy-Related Mortality in the United States and Europe

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OBJECTIVE: Available maternal mortality statistics do not allow valid international comparisons. Our objective was to uniformly measure underreporting of mortality from pregnancy in official statistics from selected regions within the U.S. and Europe, and to provide comparable revised profiles of pregnancy-related mortality.

METHODS: We developed a standardized enhanced method to uniformly identify and classify pregnancy-associated deaths from 2 U.S. states, Massachusetts and North Carolina, and 2 European countries, Finland and France, for the years 1999–2000. Identification method included the use of all data available from the death certificate as well as computerized linkage of births and deaths registers. All cases were reviewed and classified by an international panel of experts.

RESULTS: Four-hundred-and-four pregnancy-associated deaths were identified and reviewed. Underestimation of mortality causally related to pregnancy based on International Classification of Diseases cause-of-death codes alone varied from 22% in France to 93% in Massachusetts. Underreporting was greater in the regions with lower initial maternal mortality ratios. The distribution of causes of pregnancy-related mortality was specific to each region. The leading causes of death were cardiovascular conditions in Massachusetts; hemorrhage, pregnancy-induced hypertension, and peripartum cardiomyopathy in North Carolina; noncardiovascular medical conditions in Finland; and hemorrhage in France.

CONCLUSION: This study shows the limitations of maternal mortality statistics based on International Classification of Diseases cause-of-death codes alone. Linkage of births and deaths registers should routinely be used in the ascertainment of pregnancy-related deaths. In addition, extension of the definition of a maternal death should be considered. Beyond pregnancy-related mortality ratios, considering the specific distribution of causes-of-death is important to define prevention strategies.
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See related editorial on page 678.

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Maternal mortality is considered a major marker of the performance of health systems in a country.[1,2] It is a sentinel event, reflecting access to and quality of prenatal and obstetric care, as well as the health status of reproductive-aged women. In most developed countries, no important decrease in maternal mortality has been reported during the past 20 years.[2] However, a large proportion of maternal deaths are still considered preventable, indicating that further improvement is possible.[3–5] Between-country comparisons can help identify factors involved in the persistence of excess maternal mortality.

Comparisons of maternal mortality ratios that are based solely on International Classification of Dis-

eases (ICD) cause-of-death codes available from death certificates are hazardous, because these statistics have been shown repeatedly to underestimate maternal mortality.[3,6–12] In some settings, enhanced surveillance systems for maternal death ascertainment have been implemented.[7,8,13–16] However, because of substantial differences in the methods used for enhancing identification and classification of deaths, comparisons of the resulting statistics are still problematic. Observed contrasts in maternal mortality ratios and/or in causes-of-death distribution may reflect real differences in maternal mortality profiles or be the consequence of the identification methods and definitions used. To be able to conduct meaningful comparisons on maternal mortality, we need a uniform methodology for both identifying and classifying deaths.

We developed a standardized enhanced method to uniformly identify and classify deaths potentially related to pregnancy in 4 regions–2 U.S. states, Massachusetts and North Carolina, and 2 European countries, Finland and France–for the years 1999–2000.

The 4 regions were chosen so that they reflected the diversity in maternal mortality levels that is reported both within the U.S. and Europe.[17,18] In North Carolina and France, maternal mortality levels are classically reported to be high, as compared, respectively, with the level for the national U.S. [18] and other European countries.[17] In Massachusetts and Finland, low maternal mortality levels are reported.

Our objectives were 2-fold: 1) to measure underreporting of mortality causally related to pregnancy by using ICD cause-of-death codes alone compared with the use of a standardized enhanced method and 2) to compare the distribution of causes of pregnancy-related mortality in these regions using the standardized enhanced method.

MATERIALS AND METHODS

We used the definitions shown in the box. The definitions proposed by the American College of Obstetricians and Gynecologists and the Centers for Disease Control and Prevention Maternal Mortality Study Group[19] allow a clear distinction between deaths defined by a temporal link to pregnancy, ie, "pregnancy-associated" deaths, and deaths defined by a causal link to pregnancy, ie, "pregnancy-related" deaths. Pregnancy-related deaths are a subgroup of pregnancy-associated deaths, identified after review of the cause of death.

The study period was 1999–2000 in Massachusetts, North Carolina, and Finland, and 1999 in France. In France, data were restricted to mainland France. For both deaths and births, events were included based on place of occurrence and not residence.

Maternal deaths were identified using ICD cause-of-death codes according to the definition in the box, as done by the National Center for Health Statistics in

DEFINITIONS USED IN THIS STUDY.

- **Maternal death:** death of a woman with a cause-of-death code from the death certificate selected by the country center for health statistics, within the obstetrical chapter of the International Classification of Diseases (ICD, 10th revision, O00-O99 range).[20]
- **Pregnancy-associated death** (from the American College of Obstetricians and Gynecologists and the Centers for Disease Control and Prevention Maternal Mortality Study Group[19]): death of a woman, from any cause, while she was pregnant or within 1 year of termination of pregnancy, regardless of duration and site of pregnancy.
- **Pregnancy-related death** (*see above*[19]): death of a woman while pregnant or within 1 year of termination of pregnancy, regardless of duration and site of pregnancy, from any cause related to or aggravated by her pregnancy or its management. This was determined after review by the panel of experts. Pregnancy-related deaths were further classified as direct or indirect.
  - **Direct death:** death resulting from obstetric complications of the pregnant state (pregnancy, labor, and puerperium), from interventions, omissions, incorrect treatment, or from a chain of events resulting from any of the above.
  - **Indirect death:** death resulting from previously existing disease or disease that developed during pregnancy and which was not due to direct obstetric causes, but which was aggravated by the physiologic effects of pregnancy.
- **Early death:** death that occurred during pregnancy or within 42 days of its end.
- **Late death:** death that occurred between 43 and 365 days after the end of pregnancy.
- **Pregnancy outcome:** result of conception and ensuing pregnancy, including undelivered ectopic pregnancy, induced abortion, spontaneous abortion, stillbirth, or live birth.

the U.S., CépiDC in France, and Statistics Finland in Finland, to provide official national maternal mortality statistics.

Pregnancy-associated deaths were identified through a standardized enhanced method in the 4 regions. In the standardized enhanced method used, death certificates were the first source of case identification. Deaths with any cause-of-death code within the ICD obstetric chapter (ICD-10 O00-O99 range)[20] were included. In addition, every death certificate of women in reproductive age was manually reviewed by the state or national office in charge of mortality statistics. Deaths with any mention of pregnancy, birth, or puerperium in the death certificate's content (ie, in the "causes of death" section or "contributing conditions" section or even in the margin) were selected, whether the code for underlying cause of death was in the obstetric chapter.

The second common source of case identification was a computer-based linkage of deaths register or certificates with births and fetal deaths register or certificates, identifying women who died within 1 year after the end of a pregnancy that resulted in a live birth or a fetal death. The linkage process was as similar as possible across regions, considering the constraints of the data. In Massachusetts, North Carolina, and Finland, death certificates of reproductive-age women for year X were matched with birth and fetal death certificates for years X and X–1. In France, live births and fetal death certificates for 1998 and 1999 were matched with the "national register for identification of persons" to identify mothers who died in 1999, and in a second stage, a second linkage with the cause-of-death register selected the corresponding death certificates. In all regions, a deterministic approach was used for the linkage. Matching variables were as follows: in Massachusetts, the woman's name, date of birth, and ZIP code of residence; in North Carolina, the woman's name, date of birth, and Social Security number; in Finland, the woman's unique Personal Identification Number; and in France, the woman's name, date and place of birth, and postal code of residence.

A form was developed and used to abstract information for each identified pregnancy-associated death. Information available from the birth and death certificates in the 4 regions included 1) the woman's age, race or ethnicity in North Carolina and Massachusetts (this variable is not collected in vital statistics from Finland or France); 2) information about the death: the date of death, the immediate and underlying causes of death, and contributing conditions specified by the certifying practitioner and whether an autopsy was performed; 3) information about the pregnancy and birth: number of previous live births, plurality, date of delivery, method of delivery; and from North Carolina, Massachusetts and Finland, number of prenatal visits, medical history for this pregnancy, obstetric procedures, events of labor and delivery, gestational age at birth, birth weight, and Apgar score. In addition to death and birth certificate content, more detailed medical information about the circumstances that led to death was collected from available hospital records and autopsy reports, through the certifying practitioner. The data abstraction form was in English and anonymous, without dates, names, or country names.

Using the following process, abstraction forms for all pregnancy-associated deaths were reviewed by a panel of experts. The panel was composed of 8 scientists distributed in 4 teams, each with an obstetrician and an epidemiologist or public health expert, 1 from the United States and 1 from Europe. Cases were randomly allocated to teams, using a table of random numbers. Each team member independently reviewed each assigned case and assessed 1) the underlying cause of death, 2) whether the death was pregnancy-related, and 3) if pregnancy-related, whether it was a direct or indirect pregnancy-related death. Then, the 2 team members compared their independent assessments. Cases that remained undecided at the end of this team review were reviewed by the entire panel to arrive at a final conclusion.

The experts developed the following classification rules that were applied to all cases. 1) Deaths due to the following causes were classified as direct pregnancy-related: obstetric hemorrhage, amniotic fluid embolism, pregnancy-induced hypertension, genital infection, peripartum cardiomyopathy, and complication of anesthesia or obstetric intervention. 2) Cardiovascular deaths (other than peripartum cardiomyopathy) were classified as pregnancy-related if they occurred during pregnancy or within 42 days of its end and then further classified as direct for pulmonary embolism except if preexisting prothrombotic condition, direct for cerebrovascular accident, except in the presence of arteriovenous malformation or arterial aneurysm, and indirect for myocardial infarction, aortic dissection, and other cardiovascular condition. 3) Deaths due to cancer were classified as non–pregnancy-related except for choriocarcinoma (related, direct) and melanoma (related, indirect). 4) Deaths from extragenital infection were classified as pregnancy-related (indirect) if infection onset was within 14 days of the end of pregnancy, and non–pregnancy-related after 14 days. 5) Suicides were classified as non–pregnancy-related, unless they occurred in a specified context of

postpartum depression, in which case they were considered direct deaths. 6) Other injury deaths were classified as non–pregnancy-related except when there was an explicit relation to pregnancy. 7) Cases for which the cause of death was undetermined because of a lack of information were classified as possibly pregnancy-related if they occurred during pregnancy or within 42 days of its end and non–pregnancy-related after 42 days.

Initial and revised levels of mortality causally related to pregnancy were compared in each region. Initial maternal mortality ratios were calculated as the number of maternal deaths (identified using ICD cause-of-death codes only) per 100,000 live births. Then, revised pregnancy-related mortality ratios were calculated as the number of deaths classified as pregnancy-related (identified using the standardized enhanced method and judged by the study panel to be pregnancy-related) per 100,000 live births. Ratios were used rather than rates, because there is no accurate way to assess the true denominator (all clinically recognized pregnancies) from vital records. Underestimation of mortality was calculated as the difference between initial and revised ratios divided by the revised ratio.

The distribution of pregnancy-related deaths was further examined by timing of death (early or late), direct or indirect relation to pregnancy, outcome of pregnancy, and cause of death. Causes of pregnancy-related deaths were grouped in 12 categories.

RESULTS

A total of 404 pregnancy-associated deaths were identified in the 4 regions (Table 1). In all regions, around one third of pregnancy-associated deaths were classified as pregnancy-related. However, this proportion varied according to timing of death (Table 1). About two thirds of early pregnancy-associated deaths were pregnancy-related, a proportion similar in all regions. The percent of late pregnancy-associated deaths that were pregnancy-related was notably smaller in all regions, although varying from 6% in France to 23% in Finland.

In all regions, the use of the standardized enhanced method resulted in the identification of an increased number of deaths causally related to pregnancy (Table 2). The revised pregnancy-related mortality ratios were higher than the initial maternal mortality ratios, and this was true for early deaths as well as for all deaths up to 1 year after pregnancy end. Case ascertainment based solely on ICD cause-of-death codes was associated with an underestimation of mortality causally related to pregnancy, ranging from 22% in France to 93% in Massachusetts, from 19% to 90% when restricted to the 42-day time window (Table 2). Assuming that all "possibly pregnancy-related" deaths were actually pregnancy-related led to a further increase in the extent of underestimation in all regions.

Revised pregnancy-related mortality ratios varied from 7.9 in Finland to 15.5 in North Carolina, per 100,000 live births (Table 3). Two thirds or more of

Table 1. Pregnancy-Associated Deaths Identified Through Standardized Enhanced Methods and Distribution by Causal Relation to Pregnancy and Timing of Death*

≤ 1 y After the End of Pregnancy	Finland	France	Massachusetts	North Carolina
All pregnancy-associated deaths	23 (100)	222 (100)	52 (100)	107 (100)
Pregnancy-related	9 (39)	68 (31)	15 (29)	37 (35)
Possibly pregnancy-related	2 (9)	14 (6)	3 (6)	3 (3)
Not pregnancy-related	12 (52)	140 (63)	34 (65)	67 (63)
Early*				
All early pregnancy-associated deaths	10 (100)	84 (100)	14 (100)	44 (100)
Pregnancy-related	6 (60)	58 (69)	10 (71)	30 (68)
Possibly pregnancy-related	1 (10)	10 (12)	0 (0)	3 (7)
Not pregnancy-related	3 (30)	16 (19)	4 (29)	11 (25)
Late*				
All late pregnancy-associated deaths	13 (100)	134 (100)	37 (100)	62 (100)
Pregnancy-related	3 (23)	8 (6)	5 (14)	6 (10)
Possibly pregnancy-related	1 (8)	3 (2)	2 (5)	– (–)
Not pregnancy-related	9 (69)	123 (92)	30 (81)	56 (90)
Live births	113 (988)	744 (791)	162 (448)	238 (623)

Values are n (%).

* Timing of death: Early is within 42 days of pregnancy end, and late is 43–365 days after the end of pregnancy. Timing unknown for 6 pregnancy-associated deaths: 4 in France, 1 in Massachusetts, and 1 in North Carolina.

Table 2. Initial and Revised Mortality (Numbers and Ratios) and Extent of Underestimation

≤ 1 y After the End of Pregnancy	Finland			France			Massachusetts			North Carolina		
	n	Ratio*	Underestimation†	n	Ratio	Underestimation	n	Ratio	Underestimation	n	Ratio	Underestimation
Initial maternal mortality‡	3	2.6	–	53	7.1	–	1	0.6	–	27	11.3	–
Revised pregnancy-related mortality I§	9	7.9	67	68	9.1	22	15	9.2	93	37	15.5	27
Revised pregnancy-related mortality II‖	11	9.6	73	82	11.0	35	18	11.1	94	40	16.8	32
Early¶												
Initial maternal mortality	3	2.6	–	47	6.3	–	1	0.6	–	24	10.1	–
Revised pregnancy-related mortality I	6	5.3	50	58	7.8	19	10	6.2	90	30	12.6	20
Revised pregnancy-related mortality II	7	6.1	57	68	9.1	31	10	6.2	90	33	13.8	27

* Deaths per 100,000 live births
† Underestimation (%) of mortality causally related to pregnancy, using case ascertainment based on International Classification of Diseases cause-of-death codes only.
‡ Maternal deaths identified using only International Classification of Diseases cause-of-death codes, as defined in box in text.
§ Revised pregnancy-related deaths identified through standardized enhanced method, as defined in box in text.
‖ Revised pregnancy-related and possibly pregnancy-related deaths, identified through standardized enhanced method.
¶ Early timing of death is within 42 days of pregnancy end.

Table 3. Revised Pregnancy-Related Mortality (Numbers and Ratios)* and Distribution by Timing of Death, Direct or Indirect Link to Pregnancy, Pregnancy Outcome, Woman's Age, and Race or Ethnicity

	Finland			France			Massachusetts			North Carolina		
	n	%	Ratio†	n	%	Ratio	n	%	Ratio	n	%	Ratio
All pregnancy-related deaths	9	100	7.9	68	100	9.1	15	100	9.2	37	100	15.5
Timing of death‡												
Early deaths	6	67	5.3	58	88	7.8	10	67	6.2	30	83	12.6
Late deaths	3	33	2.6	8	12	1.1	5	33	3.1	6	17	2.5
Direct or indirect link to pregnancy												
Direct	5	56	4.4	54	79	7.2	7	47	4.3	32	87	13.4
Indirect	3	33	2.6	12	18	1.6	7	47	4.3	3	8	1.3
Unclear	1	11	–	2	3	–	1	7	–	2	5	–
Pregnancy outcome												
Birth (live or still)	7	78		57	88		14	93		27	73	
Undelivered	2	22		6	9		1	7		4	11	
Abortion (induced or spontaneous)	–	–		–	–		–	–		2	5	
Ectopic	–	–		2	3		–	–		4	11	
Unknown	–	–		3	–		–	–		–	–	
Age (y)												
≤ 19	–	–	–	1	1	6.8	–	–	–	6	16	19.1
20–29	3	33	5.5	24	36	6.5	4	27	6.3	15	41	11.4
≥ 30	6	66	10.6	43	63	11.8	11	73	12.6	16	43	21.2
Race or ethnicity§												
African American non-Hispanic	N/A	N/A	N/A	N/A	N/A	N/A	3	20	25.9	19	51	32.6
White non-Hispanic	N/A	N/A	N/A	N/A	N/A	N/A	10	67	8.3	16	43	10.7
Other	N/A	N/A	N/A	N/A	N/A	N/A	2	13	6.7	2	6	7.3

N/A, not applicable.
* Not including possibly pregnancy-related deaths.
† Deaths per 100,000 live births.
‡ Timing of death: Early is within 42 days of pregnancy end, and late is 43–365 days after the end of pregnancy. Timing unknown for 3 pregnancy-related deaths: 2 in France and 1 in North Carolina.
§ Race or ethnicity was available only for Massachusetts and North Carolina, not collected in Finnish and French vital statistics.

pregnancy-related deaths occurred within 42 days of pregnancy end in all regions (Table 3). The proportion of direct deaths among pregnancy-related deaths was greater in North Carolina and France than in Massachusetts and Finland. In all regions, over three quarters of pregnancy-related deaths occurred after a birth.

The distribution of cause of death varied between regions (Table 4). In Massachusetts, cardiovascular conditions other than peripartum cardiomyopathy constituted the leading cause of pregnancy-related mortality. In North Carolina, the leading causes were hemorrhage, pregnancy-induced hypertension, and peripartum cardiomyopathy. The cause-specific mortality ratio for peripartum cardiomyopathy was 4–6 times higher in North Carolina than in other regions. In France, obstetric hemorrhage was the leading cause of death, and the classical triad of hemorrhage, pregnancy-induced hypertension, and pulmonary embolism were the greatest contributors to pregnancy-related mortality. In Finland, noncardiovascular medical conditions were the leading cause of pregnancy-related deaths (Table 4). When cardiovascular, cardiomyopathy, and cerebrovascular deaths were pooled (Table 4, categories 6 to 8), the mortality ratio associated with this cause-of-death grouping was higher in Massachusetts and North Carolina than in France (3.3- and 2.5-fold, respectively) and Finland (5.6- and 4.3-fold, respectively).

DISCUSSION

Using a standard-enhanced method for case identification and classification, we found significant underreporting of mortality causally related to pregnancy in 4 U.S. and European regions. The extent of this underreporting varied, being greater in regions with lower initial maternal mortality ratios, leading to a smaller difference of revised pregnancy-related mortality ratios. The distribution of causes of revised pregnancy-related mortality was specific to each region and could not be inferred from the pregnancy-related mortality ratio.

This study shows that initial maternal mortality ratios obtained through case ascertainment method based only on ICD cause-of-death codes–ie, similar to the method used internationally by the World Health Organization (WHO) to measure maternal mortality–are associated with an underreporting of mortality causally related to pregnancy varying from 22% in France to 93% in Massachusetts. Such underreporting has been described previously in developed countries.[6,9–12] However, inconsistency in definitions and methods used to identify cases made comparison of the degree of underestimation found in these studies difficult. In this study, the extent of underestimation varied considerably across regions, indicating that part of the heterogeneity in initial maternal mortality

Table 4. Cause-Specific Revised Pregnancy-Related Mortality*

	Finland			France			Massachusetts			North Carolina		
Cause-of-Death Category	n	%	Ratio†	n	%	Ratio	n	%	Ratio	n	%	Ratio
1. Obstetric hemorrhage	1	11	0.9	14	21	1.9	2	13	1.2	6	16	2.5
2. Amniotic fluid embolism	–	–	–	3	4	0.4	2	13	1.2	3	8	1.3
3. Pulmonary embolism	1	11	0.9	9	13	1.2	1	7	0.6	3	8	1.3
4. Pregnancy-induced hypertension	–	–	–	9	13	1.2	1	7	0.6	6	16	2.5
5. Infection	1	11	0.9	5	7	0.7	–	–	–	5	13	2.1
6. Cerebrovascular accident (excluding pregnancy-induced hypertension)	–	–	–	4	6	0.5	2	13	1.2	2	5	0.8
7. Peripartum cardiomyopathy	–	–	–	3	4	0.4	1	7	0.6	6	16	2.5
8. Cardiovascular condition, other than peripartum cardiomyopathy	1	11	0.9	4	6	0.5	5	33	3.1	1	3	0.4
9. Complication of anesthesia or of obstetric intervention	1	11	0.9	2	3	0.3	–	–	–	–	–	–
10. Noncardiovascular medical condition‡	3	34	2.6	6	9	0.8	–	–	–	4	11	1.7
11. Suicide and other injury§	1	11	0.9	7	10	0.9	1	7	0.6	1	3	0.4
12. Unknown	–	–	–	2	3	0.3	–	–	–	–	–	–
All	9	100	7.9	68	100	9.1	15	100	9.2	37	100	15.5

* Not including possibly pregnancy-related deaths.
† Deaths per 100,000 live births.
‡ Including hyperemesis gravidarum, sickle cell disease, acute hepatitis, respiratory complications, lymphocytic hypophysitis, thrombotic thrombocytopenic purpura, choriocarcinoma, and melanoma.
§ Including 9 deaths due to suicide and 1 death due to intoxication with chloroquine that had been self-administered for inducing abortion at 3 months of pregnancy.

ratios was explained by differences in the initial ascertainment of maternal deaths.

The presence of significant underreporting in these 4 regions indicates that improvement in the identification and classification of maternal deaths is needed. The first step consists in the identification, as complete as possible, of pregnancy-associated deaths, defined by a temporal link to pregnancy. This implies educating practitioners about the importance of indicating any context of pregnancy, delivery, or puerperium when completing a death certificate. In addition, the use of live birth and fetal death and death certificates linkage should be part of routine identification of deaths related to pregnancy. In this study, 75% to 94% of pregnancy-related deaths that were unrecognized in the statistics based only on ICD cause-of-death codes were identified through the use of linkage. In Massachusetts,[15] North Carolina[7] and Finland,[14] enhanced case-finding methods, such as linkage of birth and death certificates and systematic review of hospital discharge databases, have been implemented at the state and country level and have demonstrated efficacy at improving assessment of mortality related to pregnancy. However, in the United States, national maternal mortality statistics are still based on ICD cause-of-death codes only and do not include any deaths identified through enhanced methods at the state level.

The WHO definition of maternal death is still limited to a death of a woman while pregnant or within 42 days of termination of pregnancy.[20] The adequacy of this definition has been questioned.[21] In this study, the inclusion of late deaths added 17% to 49% to the pregnancy-related mortality ratio. Suicide in a context of postpartum depression and deaths due to peripartum cardiomyopathy occurred preferentially after 42 days postpartum and were the main causes of late pregnancy-related deaths in the 4 regions in our study. The extension of the definition of maternal mortality to 1 year after the end of pregnancy would increase the awareness of and the knowledge about pregnancy-related morbidities that occur more frequently in the late postpartum period.

Underestimation was greater in Massachusetts and Finland, the 2 regions with lower official maternal mortality ratios and with the highest percent of indirect pregnancy-related deaths. For these cases, certifying practitioners may have failed to recognize or indicate on the death certificate the link between death and pregnancy. The fact that underreporting was differential across regions indicates that the WHO proposal[22,23] to apply a uniform correction factor to maternal mortality statistics based on ICD codes, to account for underreporting, may be misleading.

Pregnancy-related mortality ratios found here are far from national objectives,[24,25] indicating that efforts to prevent deaths caused by pregnancy are still needed. However, the different distributions of causes of pregnancy-related death suggest that region-specific issues are involved.

Pregnancy-related mortality due to peripartum cardiomyopathy was markedly higher in North Carolina than in the other regions. It is possible that peripartum cardiomyopathy is diagnosed more often in North Carolina because of the local focus on this entity. Some deaths attributed to other types of cardiomyopathy in other regions might have been actual peripartum cardiomyopathy. The contrast in peripartum cardiomyopathy contribution to pregnancy-related mortality between regions found in this study may hold insights into the cause of this disease.

In the present study, hemorrhage was the leading cause of pregnancy-related mortality in France. This is in accordance with previous research that reported higher maternal mortality ratio due to hemorrhage in France compared with other European countries.[26] Studies conducted in this country have provided support to the hypothesis that factors related to health care services are involved in this particular importance of obstetric hemorrhage.[27,28] One study found that nearly 40% of reported cases of severe maternal hemorrhage in 3 regions of France received substandard care.[28] In the same study, organizational factors, such as the lack of a 24-hour on-site anesthetist and a low volume of deliveries, were associated with substandard care. Among the 14 pregnancy-related deaths due to hemorrhage found in France in the present study, the majority (8 of 14) were related to uterine atony, a pathology that requires quick responsiveness in the immediate postpartum period to avoid the evolution toward severe hemorrhage and death. Hemorrhage was also found to be 1 of the leading causes of pregnancy-related mortality in North Carolina. However, in this region, one half of the 6 deaths due to hemorrhage were related to ectopic pregnancy (3 of 6), suggesting that specific issues are involved. Among all causes of maternal deaths, mortality due to hemorrhage has been proposed as an indicator of health services quality because it would reflect the appropriateness of obstetric care for emergency.[29]

Cardiovascular deaths contributed significantly to pregnancy-related mortality in all regions. Because of increasing maternal age and increased survival and fertility of patients with chronic conditions, it is likely that more women with diagnosed or undiagnosed

cardiovascular conditions are becoming pregnant. The overall cardiovascular pregnancy-related mortality ratio was greater in the 2 U.S. states than in the 2 European countries. This finding possibly reflects the health status of U.S. women of reproductive age, who are more exposed to cardiovascular risk factors than their European counterparts,[30] or the differential willingness of physicians to discourage pregnancy among women with such conditions. Screening for signs of cardiovascular disease should be part of preconception care as well as routine prenatal care.

In several developed countries, a decrease in the relative importance of direct obstetric mortality, together with a growing importance of indirect deaths, has been described during past decades.[31–34] However, our results suggest that different regions among developed countries may be at various steps of this process. A predominance of direct obstetric deaths may indicate that emphasis is needed on improvement of obstetric care. In areas where a large proportion of pregnancy-related deaths are indirect, pregnancy-related mortality may be more of an indicator of the health status of reproductive-aged women, and more attention to preconception care and medical care of pregnant women with chronic conditions may be necessary.

One to 2 years of pregnancy-associated deaths per region were included in this study. This resulted in small numbers of pregnancy-related deaths, especially in Massachusetts and Finland, where the annual number of births is relatively small. However, the expected increase in pregnancy-related mortality in older women, as well as the reported disparity between African-American and white women in the United States, were found here (Table 3), suggesting that our data accurately reflect pregnancy-related mortality profiles.

Although enhanced methods for case ascertainment were used in this study, the resulting revised statistics still probably underestimate pregnancy-related mortality for the following reasons: 1) The linkage may have missed women who died after a birth that occurred outside the country or state, or women with mistakes on matching variables. 2) Identification of women who died during or after a pregnancy that did not result in a live birth or stillbirth was not enhanced through the linkage conducted. The feasibility of using other enhanced identification methods, more particularly focused on deaths during pregnancy and after abortion or ectopic pregnancy, needs to be carefully examined in the context of each region's resources. Among the 4 areas of this study, only Finland has a register of induced abortions that allows a systematic identification of women who died during the year after an induced abortion, through a linkage with death register.[35] Because the authors wanted the enhanced method to be as similar as possible across regions to allow valid comparisons, this linkage was not used in the present study. 3) Some deaths classified as "possibly pregnancy-related," or "not pregnancy-related," might possibly have been identified as pregnancy-related deaths if more information had been available. For some health issues, such as suicides or cardiovascular deaths, detailed information on the woman's health status before and during pregnancy and the circumstances at death, is needed to accurately characterize the causal link to pregnancy. Information from death certificates is often too reduced. Although in this study more detailed medical information about the circumstances that led to death was collected from available hospital records and autopsy reports, it is still possible that some actual pregnancy-related deaths were considered non–pregnancy-related because some piece of information was missing. Collecting all available medical information from various sources, at best through specific forms, is essential for accurate case classification. From this perspective, confidential inquiry on maternal deaths, first developed in the United Kingdom,[5] may be considered as a model.

Using standardized enhanced methods to allow a valid comparison of mortality causally related to pregnancy between regions, this study showed that statistics based on death certificate codes were associated with a differential underreporting of these deaths across the participating regions. It suggests that enhanced identification of pregnancy-related deaths should include a linkage of birth and death registers and be extended up to 1 year after the end of pregnancy. Beyond pregnancy-related mortality ratios, the distribution of causes of pregnancy-related deaths seemed to be specific to each region in this study and therefore seems important to examine to inform specific prevention strategies.

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