Estimating Obstetric Mortality from Pregnancy-Related Deaths Recorded in Demographic Censuses and Surveys

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Demographic surveys and censuses often record pregnancy-related deaths, defined as those occurring during the maternal risk period (pregnancy, delivery, and six weeks postpartum), but do not include cause of death. This study presents a method for estimating obstetric mortality from pregnancy-related deaths data. Calculations are based on multiple-decrement life tables, and data needed are simply age-specific fertility and mortality rates that are commonly available in Demographic and Health Survey (DHS) or census data, and an estimate of the relative risk of death from nonobstetric causes during the maternal risk period. The method is tested on 59 DHS surveys from Africa. Results show that, on average, less than half of the pregnancy-related deaths are attributable to obstetric causes. This proportion varies with the level of mortality and fertility, and in particular with the prevalence of HIV in the population. (Studies in Family Planning 2011; 42[4]: 237–246)

For more than two decades, various agencies worldwide have focused on reducing maternal mortality, in large part in response to Millennium Development Goal 5 (MDG-5)—the UN's goal of reducing the maternal mortality ratio by three quarters between 1990 and 2005 (Rosenfield and Maine 1985; Shiffman 2000; United Nations 2000; Ronsmans and Graham 2006; Starrs 2006; Obaid 2009). Measurement of maternal mortality has been the source of numerous debates and controversies (Graham, Brass, and Snow 1989; Garenne and Friedberg 1997; Stanton et al. 2001; Graham and Hussein 2006; Hill et al. 2007; Yazbeck 2007; Graham et al. 2008; Cross, Bell, and Graham 2010; Jain 2011). In countries maintaining complete vital registration that includes medical causes of death, debates have focused on the "case definition"—or the precise definition of what constitutes a maternal death. Changes in case definition over time may imply a substantial rise in estimates of maternal mortality, as is the case in the US in recent years (Hoyert 2007). The issue is even more complex in countries lacking complete vital registration that includes causes of death. The vast majority of maternal deaths occur in such countries, and maternal mortality data from these countries come from censuses and demographic surveys. Several factors add to the difficulty: confusion about the case definition; diversity and heterogeneity of available demographic methods; large fluctuations resulting from small numbers of maternal deaths; and great diversity in antenatal and obstetric care around the world, which hampers the use of simple correction methods.

To estimate maternal mortality, several case definitions of maternal deaths have been applied:

(1) *A strict medical definition (obstetric death or direct causes)*: The underlying cause is one of the obstetric causes listed in the International Classification of Diseases (ICD) (O00–O97 in the ICD-10). The strict medical definition is the most common one used in vital registration systems; sometimes the list is restricted to the deaths occurring in the maternal risk period (which covers the pregnancy, delivery, and postpartum period—variously considered to be six weeks, two months, or even 90 days after pregnancy termination), excluding late deaths resulting from obstetric causes (listed under codes O96–O97 in the ICD-10).

(2) *A loose medical definition (direct and indirect causes)*: This category includes a number of infectious and noninfectious diseases (indirect causes) listed in the International Classification of Diseases (O98–O99 in the ICD-10), in addition to those causes listed above.

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(3) *A demographic definition (pregnancy-related death)*: The death occurred during the maternal risk period, irrespective of cause of death. This category includes external (fortuitous) causes and is the most common definition used in demographic censuses and surveys.

A recent United Nations statistical paper, "Principles and Recommendations for Population and Housing Censuses," recommends including in censuses two questions about death: one on external causes (Was the death caused by accident or violence?) and one for women of reproductive age (Did the death occur during the maternal risk period?) (United Nations 2008a and 2008b). The latter question corresponds to the third (demographic) definition of maternal death: pregnancy-related death. According to the ICD, only the second of the three definitions qualifies as "maternal mortality." The third definition commonly leads to twice as many deaths as the first, and the nonobstetric deaths are usually not related to the pregnancy (fortuitous causes). The first definition—consisting only of those deaths directly associated with pregnancy, delivery, and their consequences—is the best suited for monitoring safe motherhood.

Further confusion arose recently from the inclusion of HIV/AIDS deaths occurring during the maternal risk period (which is contrary to ICD-10 recommendations), and from adding other causes assumed to be consequences of the pregnancy (Hogan et al. 2010). This study proposes a simple method for estimating obstetric mortality from data concerning pregnancy-related mortality provided by demographic censuses and surveys. The method is applied to DHS data from Africa, where the emergence of HIV/AIDS has changed adult mortality profiles dramatically, and where these estimates are most needed. In numerous African countries, adult women's mortality and pregnancy-related mortality have risen considerably recently because of HIV/AIDS (and in some cases because of external causes) without any clear indication of a rise in obstetric mortality. Without a consistent and specific case definition, monitoring progress in safe motherhood will not be possible.

Indirect Causes of Maternal Death

Presented here is a brief literature review on indirect causes, which is necessary to understand the rationale of the statistical method proposed here. The review relies primarily on published reviews for selected diseases, as well as our own analysis of data from the Agincourt Demographic Surveillance System (DSS) for the 1992–2008 period, from South Africa censuses conducted in 2001 and 2007, and from Confidential Enquiries into maternal deaths conducted in the same country.

The ICD-10 defines "indirect causes" as those resulting from previously existing diseases or diseases developed during pregnancy that did not result from direct obstetric causes but were aggravated by the physiological effects of pregnancy. This definition is not based on epidemiological evidence (increased risk of death, compared with nonpregnant controls of the same age) but rather on a clinical judgment as to whether the pregnancy aggravated the nonobstetric disease, and sometimes on biological evidence—for example, severe anemia that develops during pregnancy or just after delivery (Williams and Wheby 1992).

Pregnancy is associated with major physiological changes that may increase susceptibility to infectious and noninfectious diseases. In particular, pregnancy induces transient depression of cell-mediated immunity and is often associated with anemia and hypertension, conditions that may have an effect on the pathogenicity of various diseases. Some of the immunological changes may be associated with increased susceptibility, whereas others may be associated with increased resistance.

Infectious Diseases and Pregnancy

The relationship between pregnancy and susceptibility to infectious diseases has been studied for a number of diseases that are key causes of morbidity and mortality in the 15–49-year age group—in particular, malaria, HIV/AIDS, tuberculosis, cholera and other diarrheal diseases, listeria, some sexually transmitted diseases (gonorrhea, syphilis), and selected viral infections (influenza, measles, mumps, rubella, viral hepatitis). With the exception of HIV/AIDS, these infectious diseases may be classified among indirect causes of maternal death, under the O98 code in the ICD-10.

The literature on malaria and pregnancy has been reviewed recently in several studies (Menendez 2006; Uneke 2007a, 2007b, and 2008). Women become more susceptible to *Plasmodium falciparum* malaria during pregnancy, which may lead to cerebral malaria or may induce severe anemia with numerous consequences (for example, heart failure, postpartum hemorrhage). The effect of malaria on maternal health depends on a variety of factors, including maternal age (adolescents are more vulnerable), gravidity (the first pregnancy has higher risk), nutritional status, host genetics, parasite genetics, prophylaxis and treatment, previous exposure and natural immunity, and co-infection with other diseases, including parasites (such as hookworm) and viruses (such as HIV). Beyond the effect on the mother, the malaria parasite may also infect the placenta and cause intrauterine growth retardation, low birth-weight, preterm delivery, stillbirth, and perinatal

death, as well as fetal anemia and congenital malaria for the newborn.

The demographic effect of malaria during pregnancy on maternal mortality remains poorly documented and controversial. For instance, in Burkina Faso, a country with seasonal malaria and high mortality, Hounton and colleagues (2008) found higher maternal mortality during the dry season (characterized by low malaria transmission) than during the rainy season (the peak of malaria transmission). In Senegal, also a country with seasonal malaria, Etard, Kodio, and Ronsmans (2003) found the opposite: higher mortality from obstetric causes during the rainy season, but not for maternal mortality from indirect causes. In Mozambique, a country with high malaria mortality, Granja and colleagues (1998) found that 16 percent of maternal deaths that occurred in a Maputo Central Hospital during a five-year period were associated with malaria, and the proportion was greater among adolescents and primigravidae women. The study did not, however, provide a comparison with nonpregnant women of the same age, and so was unable to measure the relative risk of death. In Agincourt, South Africa, according to the 1992–2008 Demographic Surveillance System (DSS), the relative risk of malaria mortality during pregnancy was not significantly different from that of nonpregnant women.

The effect of HIV/AIDS on pregnancy has also been studied. McIntyre (2003) reviewed the numerous effects of HIV infection on pregnancy. Pregnancy was not found to accelerate the progression of HIV, which implies that HIV mortality during pregnancy is not likely to be higher than among nonpregnant women of the same age. HIV infection was found to reduce fertility, which leads to a selection effect, implying that pregnant women might be less likely to be infected than others of the same age. HIV might have an effect on direct causes by inducing changes in behavior, such as induced abortion and cesarean section (for preventing mother-to-child transmission), which may increase maternal mortality. HIV might also have an effect on indirect causes, particularly through favoring the emergence of opportunistic infections such as miliary tuberculosis, pneumonia, or severe diarrhea, and by exacerbating malaria. Numerous studies have documented the relatively high proportion of AIDS deaths among pregnant women, either in hospital studies or in confidential inquiries (Ujah et al. 2005; Oyieke, Obore, and Kigondu 2006; Kongnyuy, Mlava, and van den Broek 2009; van der Spuy 2009). This does not imply, however, that AIDS mortality is higher within the maternal risk period than outside it, after controlling for age. In fact, no evidence was found in published literature of increased risk of death from AIDS during pregnancy. The proportion of AIDS deaths among pregnant women, often found in descriptive studies to be between 5 percent and 15 percent, is not above the proportion found in the general population. In Agincourt, the 1992–2008 DSS reveals that the relative risk of death from AIDS or pulmonary tuberculosis during the maternal risk period, compared with periods outside pregnancy, is 0.39. HIV/AIDS no doubt has a large impact on pregnancy-related mortality, as shown in numerous studies throughout Africa (Congo, Kenya, Malawi, Nigeria, South Africa, Zambia, and Zimbabwe). HIV/AIDS may have differing effects on direct and indirect causes, however, yet these remain largely undocumented. An association with lower maternal mortality may exist because of the selection bias resulting from lower fertility, and possibly from changes in sexual behavior (women in the final stage of AIDS might have less intercourse.)

Pregnancy has often been viewed as a potential risk for tuberculosis (TB), because the associated immunosuppression might reactivate latent TB. A recent review of the literature on TB in pregnancy concluded, however, that "pregnancy on its own has not been found to be associated with an increased risk of TB" (Mnyani and McIntyre 2011: 227). Of course, deaths due to TB during pregnancy have increased in recent years because of the increasing incidence of TB and its close relationship with increasing HIV. This implies an increase in pregnancy-related deaths, but does not mean that the risk of dying from pulmonary tuberculosis or other forms of TB is higher among pregnant women than among nonpregnant women of the same age. Here again, selection bias might be in effect, wherein women in the final stages of dying of tuberculosis are less likely to become pregnant, leading to an apparent lower risk for mothers. Also, as with HIV/AIDS, maternal TB infection may lead to adverse pregnancy outcomes and transmission of the mycobacteria to the newborn.

The literature on cholera and other diarrheal diseases (for example, shigella) during pregnancy is limited and sometimes conflicting. A study in Nigeria compared cholera mortality among pregnant and nonpregnant women, and found lower mortality among pregnant women (Ayangade 1981). Other studies did not include nonpregnant controls and are therefore not relevant here. As with most of the other diseases investigated, cholera is often found to have an effect on pregnancy outcome, particularly on inducing frequent stillbirths. Listeria is clearly more lethal during pregnancy, but has less demographic impact because of its rarity (Silver 1998).

Literature on viral diseases such as measles, mumps, and rubella is also limited. All three of these diseases can cause adverse pregnancy outcomes, for example, fetal loss, prematurity, and child infection (if the disease occurs in the third trimester). Rubella can induce congenital defects (Enders, Biber, and Exler 2007). A recent review concluded that of these three viral diseases, only

measles was more severe during pregnancy than otherwise. The impact of such diseases on maternal mortality remains poorly documented, and probably small. On the contrary, the effect of influenza on maternal morbidity and mortality has been recognized at least since the influenza epidemic of 1918–19, and has been extensively documented in the recent influenza A (H1N1) epidemic (Laibl and Sheffield 2005; Creanga et al. 2010). Hepatitis E is also more virulent during pregnancy, and may even cause death (Kumar et al. 2004).

The effect of pregnancy on the susceptibility to infectious diseases is, in summary, complex and often controversial. Some acute infections occurring independently of pregnancy (such as malaria and influenza) seem more severe and could lead to death among pregnant women. Some chronic infections (such as HIV and tuberculosis) do not seem to be more severe during pregnancy, and seem associated with selection biases for biological and possibly behavioral reasons. Some diarrheal diseases (such as cholera and shigellosis) could be associated with lower mortality for biological reasons. For instance, antimicrobial peptides are expressed during pregnancy and seem to protect against infections in the genital tract (for example, syphilis) and possibly in the intestinal tract as well (Frew and Stock 2011).

Anemia and Pregnancy

The literature on anemia and pregnancy is as complex and controversial as the literature on infectious diseases (for reviews, see Fleming 1989; van den Broek 1996). Anemia is often a consequence of pregnancy (not an independent risk) because of the increased need for iron and folate, and can be severe because of women's inadequate and insufficient diet in many developing countries, although anemia in pregnancy also occurs in developed countries. Anemia in pregnancy may result from causes other than nutritional factors: infections with parasites and viruses (malaria, hookworm, HIV), genetic factors, and various hemoglobinopathies. Severe anemia may cause hemorrhage, cardiac failure, and other adverse health conditions during pregnancy, but whether anemia is a risk factor for maternal mortality at the demographic level remains doubtful. Values such as 40 percent of maternal deaths associated with anemia often quoted in the literature are not above the 42 percent prevalence of anemia in the general population quoted by WHO or found in DHS surveys, which implies that anemia is not a risk factor overall (Sanghvi, Harvey, and Wainwright 2010). Furthermore, various attempts at giving pregnant women iron and folic acid supplements have had mixed results and sometimes adverse effects (Peña-Rosas and Viteri 2006). Classifying anemia *per se* as an indirect cause of maternal death (that is, as an underlying cause) is difficult without understanding the precise pathology and its etiology in a particular case.

External Causes (Accidents and Violence)

The literature on accidents and violence during pregnancy is limited. In South Africa, a country where the rates of external causes of maternal mortality are high, our analysis of the 2001 census reveals an elevated risk of mortality from accidents and violence during pregnancy (relative risk = 1.32). In Agincourt, however, mortality resulting from external causes was lower during the maternal risk period than for other women aged 15–49, although the relative risk (0.61) was not significant. In Bangladesh, mortality from injuries was higher during pregnancy (Khlat and Ronsmans 2000). Most likely the relationship between pregnancy and external causes is complex and context-specific, and the attributable risk probably small, even when the relative risk is greater than one.

Selection for Healthy Pregnant Women

The "healthy pregnant women" effect has been popularized in the demographic literature by comparing the risk of death from nonobstetric causes during and outside the maternal risk period. In most cases, the relative risk of death is found to be less than one, both in developing countries (Bangladesh and Senegal) and in developed countries (Finland and the US) (Khlat and Ronsmans 2000; Ronsmans et al. 2001). Pregnant women may be selected for a variety of reasons, biological and behavioral. Women with severe diseases, severe malnutrition, or under severe stress are often temporarily sterile, or at least less fertile. They may have less frequent intercourse or may use contraceptives to avoid a pregnancy while sick. Women may change their lifestyle during pregnancy, rest more, eat more, or take fewer risks, so that susceptibility to a variety of diseases or accidents may be reduced. All of these effects seem complex and context-specific, and deserve further research.

Taken together, these factors may yield a scenario in which a strong selection bias for pregnancy (for biological and behavioral reasons) implies a reduced risk of death but, simultaneously, an increased susceptibility to selected diseases (for biological reasons), so that the mortality of pregnant women is still somewhat lower than that of nonpregnant women of the same age, but no attributable risk can be defined.

In any case and through whatever mechanisms, the inclusion of all nonobstetric diseases or conditions that could

potentially be associated with pregnancy does not seem warranted for studying maternal mortality. For monitoring safe motherhood, focusing on obstetric causes—and studying separately other causes of deaths occurring during the maternal risk period (whether infectious, noninfectious, or external)—seems more appropriate.

Proportion of Obstetric Causes among Pregnancy-Related Deaths

Several studies conducted in developing countries recorded both obstetric deaths (usually assessed by verbal autopsies) and pregnancy-related deaths. This is the case in the RAMOS surveys (Reproductive Age Mortality Survey). In RAMOS surveys conducted in Argentina, Egypt, Ghana, and Turkey, the proportion of obstetric deaths among pregnancy-related deaths varied from 59 percent to 81 percent.

In a detailed hospital study conducted in Mozambique using medical autopsies, the proportion of obstetric deaths was found to be only 38 percent (Menendez et al. 2008). Incidence of HIV / AIDS (58 percent of the women were infected with HIV), malaria, meningitis, and pneumonia was high, and the study did not include external causes. In South Africa, the most recent Confidential Enquiry (2005–07) revealed that 46 percent of maternal deaths were obstetric deaths, excluding external causes, which are important. In Agincourt, obstetric deaths accounted for only 35 percent of all pregnancy-related deaths. In Matlab, Bangladesh, obstetric deaths accounted for about 76 percent of maternal deaths between 1976 and 2005, excluding fortuitous cases (Shahidullah 1995; Chowdhury et al. 2009).

The proportion of obstetric deaths among pregnancy-related deaths varies widely depending on the level of mortality from other causes—in particular, infectious diseases (HIV / AIDS and pulmonary tuberculosis), noncommunicable diseases, and external causes (accidents and violence).

A Method for Estimating Obstetric Mortality from Demographic Surveys

Presented here is an empirical method for converting pregnancy-related mortality ratios into obstetric mortality ratios using demographic survey data. An earlier study (Stecklov 1995) attempted to estimate the mortality risk attributable to pregnancy by taking into account mortality from nonobstetric causes. Stecklov examined the 1992 Bolivia Demographic and Health Survey (DHS) and concluded that 69 percent of deaths classified as pregnancy-related probably resulted from obstetric causes, assuming the same death rate from nonobstetric causes during and outside the maternal risk period. The approach presented here is similar, but the relative risk of death during the maternal risk period is taken into account.

In countries with complete or near-complete vital registration systems, counting obstetric deaths is straightforward and defined by the underlying cause. The main difficulty is the imputation of "unknown / ill-defined causes." The imputation of these unknown causes to maternal causes is rarely done in surveys. Several statistical methods for imputation are available such as the "hot-deck" method or the "maximum likelihood" method. They can be applied using standard statistical software.

In countries lacking a reliable vital registration system, demographic censuses and surveys are relied upon to estimate pregnancy-related deaths. Deaths of women aged 15–49 are recorded, and those occurring during the maternal risk period are singled out. From age-specific death rates of women aged 15–49 and the total fertility rate (TFR), the maternal mortality ratio can be derived, expressed per 100,000 live births. Another method is to use the death rate of women aged 15–49 and the general fertility rate (GFR) to obtain the same ratio. These are the two methods used in the DHS (Stanton, Abderrahim, and Hill 1997 and 2000). Censuses and some DHS surveys also record deaths from external causes (accidents and violence), which can be discounted.

Two approaches have been followed for recording deaths of women aged 15–49. The first is a simple direct method in which interviewers ask about deaths that occurred in a household in the recent past (usually in the past 12 months, sometimes in the past 24 or 36 months)—the most common approach in censuses. The second is an indirect method in which interviewers ask about the survival of sisters of the adult respondent—the method of choice in DHS surveys. Both strategies produce a death rate and a proportion of pregnancy-related deaths among deaths of women aged 15–49. These "pregnancy-related deaths" may be quite different from "obstetric deaths," however, especially in places where deaths from other causes (such as AIDS and external causes) are significant.

A multiple-decrement life table framework is proposed here to estimate obstetric deaths from pregnancy-related deaths. The rationale for the method is straightforward: the nonobstetric causes occurring during the maternal risk period can be derived from the mortality occurring outside the maternal risk period, given the percentage of time spent in the maternal risk period. This calculation takes into account the level of fertility and mortality in the population, and requires knowledge of the relative risk of mortality during the maternal risk period

for causes other than obstetric causes. The data needed for these calculations are the age-specific death rates, the proportion of pregnancy-related deaths among the total number of deaths of women aged 15–49, and the fertility rate, all available in DHSs.

Let:

D = number of deaths from all causes combined (women aged 15–49)

P = number of pregnancy-related deaths

D – P = nonpregnancy-related deaths

O = obstetric deaths

P – O = nonobstetric deaths occurring in the maternal risk period

K = relative risk of mortality during the maternal risk period for nonobstetric causes, compared with the risk of mortality outside the maternal risk period

F = percentage of time spent in the maternal risk period

F can be calculated from fertility rates, because the proportion of time spent in the maternal risk period is proportional to fertility, in proportion of 46 weeks out of 52 weeks per year exposed.

The basic relation is:

$$(P - O) / F = K \times (D - P) / (1 - F)$$

This leads to:

$$(1 - O / P) = K \times [(1 - P / D) / (P / D)] \times F / (1 - F) \quad (1)$$

which can be written as simple functions of fertility and mortality. The formula can also be computed in a log scale, with:

$P_{ob} = O / P$

= the proportion of obstetric deaths among pregnancy-related deaths

$P_{pr} = P / D$

= the proportion of pregnancy-related deaths among all deaths

Formula (1) becomes:

$$\text{Log}(1 - P_{ob}) = \text{Log}(K) - \text{Logit}(P_{pr}) + \text{Logit}(F) \quad (2)$$

This formula applies for all ages combined (15–49) as well as for any age group. The proportion of obstetric deaths among pregnancy-related deaths can therefore be derived from the fertility rate, the proportion of pregnancy-related deaths, and the relative risk of death from nonobstetric causes during the maternal risk period (K). The proportion of obstetric deaths is very sensitive to changes in fertility and mortality. When fertility declines, the proportion tends to increase; when mortality declines, it usually decreases. When an emerging disease such as AIDS appears, however, mortality rises but the proportion of pregnancy-related deaths and the relative risk tend to decrease.

Application of Method

Relative Risk of Death during Maternal Risk Period

The main difficulty in applying this method to African countries is the estimation of K. In a first try, one could arbitrarily let K = 1.0, but this leads to inconsistent results in countries with high levels of HIV. We did not find estimates of K in the demographic literature. A brief survey of the data at hand indicates that K is usually less than 1.0, and that it tends to decrease markedly as HIV increases. Table 1 summarizes a few studies. In Matlab, Bangladesh, 1976–93, K was estimated at 0.87. In Agincourt, South Africa, K declined from 0.68 in 1992–97 to 0.57 in 1998–2002 and to 0.53 in 2003–08, whereas mortality (not shown) and prevalence of HIV increased. In the vital registration for South Africa in 2006, K was estimated at 0.41. K is also age-specific, because the pattern of deaths by cause varies between ages 15 and 49.

For this application, K is set at 0.9 for countries with high mortality and no HIV, and to follow a log linear relationship with the prevalence of HIV, K = 0.5 is set as the endpoint when HIV prevalence is 25 percent. These values are rough and can be further refined when additional empirical studies become available.

Multiple-Decrement Life Table Framework: Application to Ethiopia

The procedure follows a straightforward multiple-decrement life table. From death rates and proportion of pregnancy-related deaths, a life table by five-year age groups,

Table 1 Estimates of the relative risk of death from nonobstetric causes during the maternal risk period, Bangladesh and South Africa

Country, study	Period	HIV prevalence (percent)	Relative risk of death
Bangladesh, Matlab	1976–93	0.0	0.87
South Africa, Agincourt	1992–97	9.2	0.68
	1998–2002	24.2	0.57
	2003–08	29.2	0.53
South Africa, vital registration	2006	29.1	0.41

Sources: Author's calculations from Khlat and Ronsmans (2000), 1992–2008 Agincourt DSS, and 2006 vital registration in South Africa.

from 15–19 to 45–49, is computed. The expected number of nonobstetric deaths in the maternal risk period is calculated from formula 1 above, and the number of obstetric deaths is derived from the difference. Table 2 displays such calculations using the 2000 Ethiopia DHS data. All data were taken from the DHS final report as published; no new calculations were made from individual data. The total fertility rate (TFR) provided during the past three years was corrected to account for fertility decline in the seven years prior to the survey, the period for calculating mortality (TFR = 6.47). The mortality quotient ($_{35}q_{15}$) in Ethiopia was equal to 222 per 1,000 (22,163/100,000); the lifetime risk of dying of pregnancy-related deaths was 50 per 1,000 ([3017 + 1949] / 100,000 = 0.04966); the pregnancy-related mortality ratio was 785 per 100,000 live births ($1 - [1 - 0.04966]^{[1/6.47]}$); the lifetime risk of obstetric death was 20 per 1,000 (1949 / 100,000 = 0.01949); and the obstetric mortality ratio was 304 per 100,000 live births ($1 - [1 - 0.01949]^{[1/6.47]}$), which is 39 percent of the pregnancy-related value.

Application to African DHS Data

The same calculations are repeated for all African countries for which DHS datasets are available (see Table 3). Most are based on retrospective data in the past 7 to 10 years, with a range of 5 to 14 years. The fertility rates published in the survey reports, which are usually based on the past 3 years, were corrected to match the TFR in the retrospective period (7 to 10 years before the survey). For death rates, values were taken as published (deaths and person-years), sometimes given with one decimal only, which might occasionally introduce a small bias.

Results show that the proportion of obstetric deaths among pregnancy-related deaths vary from 16 percent to

Table 2 Multiple-decrement life table of obstetric and pregnancy-related mortality, Ethiopia, 2000

Age group (years)	Percent of time in MRP (F)	Deaths per person-year (D/Y)	Pregnancy-related mortality (%) (P/D)	Life table estimates (deaths per 100,000)			
				Total (D)	Non-pregnancy-related (D–P)	Non-obstetric (P–O)	Obstetric (O)
15–19	0.107	0.00490	19.0	2,421	1,962	212	247
20–24	0.238	0.00601	30.7	2,891	2,005	564	322
25–29	0.258	0.00615	31.8	2,865	1,956	611	299
30–34	0.242	0.00817	31.4	3,674	2,524	725	426
35–39	0.179	0.00848	23.0	3,662	2,824	552	285
40–44	0.098	0.00830	13.2	3,434	2,983	290	160
45–49	0.023	0.00810	8.6	3,216	2,942	63	210
Total	0.188	0.00665	25.3	22,163	17,197[a]	3,017	1,949

MRP = Maternal risk period. Y = Person-years lived.
[a]Difference from sum of 17,196 is a result of rounding.
Source: 2000 Ethiopia Demographic and Health Survey.

Table 3 Estimation of the percentage of obstetric deaths among pregnancy-related deaths, Africa, 1992–2007

Country (year)	Fertility (TFR)	Mortality quotient per 1,000 ($_{35}q_{15}$)	Mortality ratio per 100,000		Obstetric/ pregnancy-related mortality (percent)
			Pregnancy-related	Obstetric	
Benin (1996)	6.66	115	505	327	65
Benin (2006)	5.78	126	432	193	45
Burkina Faso (1999)	7.07	161	454	162	36
Cameroon (1998)	5.95	132	435	214	49
Cameroon (2004)	5.30	222	706	277	39
Central African Republic (1994)	5.85	260	1,020	549	54
Chad (1997)	6.94	164	866	586	68
Chad (2004)	6.65	197	1,136	811	71
Congo-Brazza (2005)	4.73	228	783	347	44
Congo-Kinshasa (2007)	6.52	204	546	171	31
Cote d'Ivoire (1994)	5.93	183	765	452	59
Cote d'Ivoire (2005)	4.91	224	625	237	38
Eritrea (1995)	6.10	189	992	649	65
Ethiopia (2000)	6.47	222	785	304	39
Ethiopia (2005)	5.79	217	673	219	33
Gabon (2000)	4.31	184	586	309	53
Ghana (2007)	4.37	148	512	231	45
Guinea (1999)	6.87	130	489	263	54
Guinea (2005)	6.31	186	975	670	69
Kenya (1998)	5.17	172	731	458	63
Kenya (2003)	4.97	231	498	110	22
Lesotho (2004)	3.75	336	800	273	34
Liberia (2007)	5.25	163	1,114	835	75
Madagascar (1992)	6.46	197	648	268	41
Madagascar (1997)	6.14	152	534	236	44
Madagascar (2003)	5.29	116	497	300	60
Malawi (1992)	7.12	223	697	299	43
Malawi (2000)	6.27	372	1235	562	46
Malawi (2004)	6.08	387	1067	410	38
Mali (1995)	7.79	138	579	330	57
Mali (2001)	7.44	172	582	246	42
Mali (2006)	6.75	147	486	213	44
Mauritania (2000)	4.68	108	818	643	79
Mozambique (2003)	5.92	144	436	161	37
Namibia (1992)	5.27	115	328	145	44
Namibia (2000)	4.46	156	276	48	17
Namibia (2007)	3.82	294	478	177	37
Niger 1992)	8.12	178	688	394	57
Niger (2006)	7.88	142	712	455	64
Nigeria (2008)	5.90	160	552	232	42
Rwanda (2000)	6.08	328	1,026	285	28
Rwanda (2005)	6.01	239	765	230	30
Senegal (1993)	6.94	117	560	354	63
Senegal (2005)	5.36	114	424	221	52
Sierra Leone (2008)	5.51	186	816	437	54
South Africa (1998)	3.01	103	150	38	25
Swaziland (2006)	3.83	447	658	174	26
Tanzania (1996)	6.27	146	587	340	58
Tanzania (2004)	5.79	236	611	154	25
Togo (1998)	5.37	137	552	290	53
Uganda (1995)	7.43	276	535	186	35
Uganda (2001)	7.34	294	518	139	27
Uganda (2006)	7.07	288	451	90	20
Zambia (1996)	6.45	352	628	125	20
Zambia (2001)	6.04	457	713	164	23
Zambia (2007)	5.95	420	627	153	24
Zimbabwe (1994)	5.13	125	303	103	34
Zimbabwe (1999)	4.49	318	632	100	16
Zimbabwe (2005)	4.06	442	641	124	19
Average	5.85	214	648	296	44

Sources: Fifty-nine African Demographic and Health Surveys.

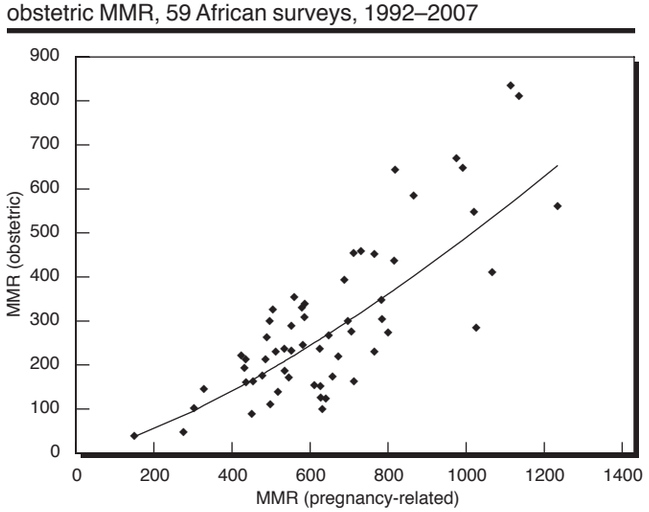
79 percent, and average 44 percent. This proportion tends to increase with higher mortality and with lower fertility, as expected. Each of these estimates has a wide confidence interval (not shown) because of the small sample size in some age groups.

The relationship between the pregnancy-related mortality ratio and the obstetric mortality ratio appears as monotonic, and was fitted empirically with a logit-linear regression (see Figure 1). At high levels of mortality, an obstetric mortality ratio of 628 for a pregnancy-related mortality ratio of 1,200 (52 percent) is predicted. At intermediate levels, an obstetric mortality ratio of 244 for a pregnancy-related mortality ratio of 600 (41 percent) is predicted. At low levels, an obstetric mortality ratio of 55 for a pregnancy-related mortality ratio of 200 (27 percent) is predicted. This relationship could be used for estimating the obstetric maternal mortality ratio from pregnancy-related deaths when data are missing or inconsistent. Large variations may occur, however, in specific situations depending on the underlying pattern of other causes of death.

African data should be thoroughly examined before final estimates are prepared, for several reasons. The pregnancy-related deaths may be biased because of a poor application of the case definition, especially for external causes, as seems to be the case in the 2007 Ghana DHS. They may also be biased because of lack of information from the respondent, especially in cases of early pregnancy or induced abortion. Missing values may exist in some of the variables defining the case. This was true for the 1998 South Africa DHS: information on age at death of sisters was missing in 20 percent of cases, and information on timing of death was missing in 13 percent of cases, so the final estimate might be 44 percent higher than estimates based on known cases. Finally, the sample size of pregnancy-related deaths occurring in the past seven years is often small (17 cases in the 1998 South Africa DHS), which leads to wide confidence intervals.

Some of the African DHS surveys included a question about whether, according to the family, the death was due to complications of pregnancy and childbirth. For instance, the 1998 South Africa DHS reported 26 deaths considered to be due to complications of pregnancy out of 51 pregnancy-related deaths (about half), which is consistent with the average for Africa, although higher than what our method predicts for South Africa.

Figure 1 Relationship between pregnancy-related MMR and obstetric MMR, 59 African surveys, 1992–2007



MMR = Maternal mortality ratio.
Sources: Fifty-nine African Demographic and Health Surveys.

Discussion

The method presented here for estimating obstetric deaths from pregnancy-related deaths seems to be an improvement upon a uniform correction, such as the one proposed by Stecklov (1995). The method takes into account the levels of mortality and fertility in the population (which affect the ratio of obstetric deaths to pregnancy-related deaths), and HIV prevalence (which has great impact on adult mortality). The ratio of obstetric deaths to pregnancy-related deaths may vary from 20 percent to 80 percent. Making this correction is necessary for focusing on safe motherhood. Estimates of the maternal mortality ratio based only on pregnancy-related mortality could be misleading for evaluating Millennium Development Goal 5, especially in the case of fast-changing mortality from HIV / AIDS.

The method, which was applied here only to African countries, led to realistic values in most cases. The method should be applied to other settings and be validated more extensively. The method also needs to be tested in extreme situations: potential combinations of parameters—such as the absence of obstetric deaths—could lead to unrealistic estimates. Unrealistic estimates using this method could also arise as a result of erratic data, small sample size, or an erroneous value for K.

The value of K used here is a rough estimate but could be further refined when additional data become available and are made age-specific. The relative risk of dying during the maternal risk period from causes other than obstetric deaths deserves more research. The risk is obviously cause-specific, is likely to vary in different epidemiological environments, and seems to vary rapidly over time with rates of HIV. Why K is less than 1.0 remains to be investigated further. Likely it reflects a combination of selection factors (healthier women have higher fertility), changes in behavior (pregnant women take fewer risks), and possibly biological factors (pregnancy may be protec-

tive against certain diseases). Greater knowledge of these complex relationships could lead to better estimates of the relative risk of death from nonobstetric causes, and better estimates of obstetric mortality.

The present study focused on only one aspect of the case definition of maternal deaths. Another aspect is the proper recording of obstetric deaths, and in particular of deaths following induced abortions in places where abortion is illegal. Underreporting of these cases is probably frequent, as indicated by other studies (Shahidullah 1995), and is another crucial issue in monitoring the progress of safe motherhood.

Ideally, demographic censuses and surveys would include questions concerning basic causes of death. Identifying at least four categories (obstetric deaths, infectious and parasitic deaths, deaths from noncommunicable diseases, and external deaths) among pregnancy-related deaths could lead to more precise estimates, and could be accomplished by including basic questions regarding the signs, symptoms, and circumstances of the death. This information could be further refined with verbal autopsies, and cross-tabulated with the timing of the case—during pregnancy (if possible by trimester), delivery, postpartum, or outside the maternal risk period. Without proper information on causes of deaths, expecting precision on maternal mortality levels and trends will continue to be illusory.

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