Methods for Measuring Maternal Mortality

Presentation prepared for workshop on Improving National Capacity to Track Maternal Mortality towards the attainment of the MDG5
Nairobi, Kenya: December 2010

Kenneth Hill
Stanton-Hill Research, LLC
What Is a Maternal Death?

- A *maternal death* is the death of a woman
  - while pregnant (or within 42 days of termination of pregnancy)
  - irrespective of the duration and the site of the pregnancy,
  - from any cause related to or aggravated by the pregnancy or its management
  - but not from accidental causes

Source: WHO (1993), 10th revision of the ICD
What Is The Difference Between a Maternal Death and a Pregnancy-Related Death?

- Maternal death has two criteria:
  - Temporal relationship to the pregnant state
  - Causal relationship to the pregnant state

- Pregnancy-related death has only one criterion:
  - Temporal relationship to the pregnant state:
    - While pregnant or during the 42 days following the termination of the pregnancy
When Is Information Collected on Maternal versus Pregnancy-Related Deaths?

- The data collection method determines whether one measures maternal or pregnancy-related deaths
  - Identifying maternal deaths requires either death certification by an attending physician or a verbal autopsy
  - Household survey methods frequently used in low/middle income countries (LMICs) simply ask time of death relative to pregnancy and thus measure pregnancy-related death
Maternal Mortality Ratio (MMRatio)

By expressing maternal deaths per live birth, rather than per woman of reproductive age, the MM Ratio is designed to express direct or indirect obstetric risk:

\[ \text{MMRatio} = \left( \frac{MD}{Births} \right) \times 100000 \]

where \( MD \) is the number of maternal deaths in a period, and \( Births \) is the number of births in the same period.
Maternal Mortality Rate (MMRate)

- The MM Rate is a cause-specific death rate:

\[ \text{MMRate} = \left( \frac{MD}{PYL^f} \right) \times 1000 \]

where \( MD \) is the number of maternal deaths in a period, and \( PYL^f \) is the person years lived by women of reproductive age (normally 15 to 49) in the period.
How Are the MMRatio and the MMRate related?

Defining $MMRatio$ and $MMRate$ per unit (not per 100,000 births or 1,000 person-years):

$$MMRatio = \left( \frac{MD}{Births} \right) = \left( \frac{MD}{PYL^f} \right) \cdot \left( \frac{PYL^f}{Births} \right)$$

$$= \left( MMRate \right) \cdot \left( \frac{1}{GFR} \right) = \left( \frac{MMRate}{GFR} \right)$$

where $GFR$ is the General Fertility Rate, births per woman of reproductive age.
Reproductive Lifetime Risk of Maternal Death

- LTR reflects the risk that a woman who survives to age 15 will die of maternal causes at some point during her reproductive lifespan, given current rates of maternal mortality and fertility.
- Often used for advocacy purposes.
Measuring Lifetime Risk (LTR)

- The MM Technical Advisory Group suggests defining $LTR$ as the proportion of women reaching reproductive age who would die of maternal causes, taking into account competing causes.
- Calculation of $LTR$ then requires consideration of competing risks, and thus level of overall mortality.
- Wilmoth suggests the following approximation:

$$LTR = \frac{T_{15} - T_{50}}{\ell_{15}} \left( \frac{MMRate}{1000} \right)$$

where $T_{15}$, $T_{50}$ are life table person-years lived above ages 15 and 50 (taken as being the starting and ending ages of reproduction) respectively, and $\ell_{15}$ is survivors to age 15.
Proportion Maternal (PMDF)

- The proportion of all deaths of women of reproductive age due to maternal causes

\[
PMDF = \left( \frac{MD}{D^f} \right)
\]

where \( D^f \) is total deaths of women at ages 15 to 49

- Range: <1% in developed countries to ~45% in developing countries
Maternal and Pregnancy-Related Mortality

- All the indicators described can be calculated either for Maternal deaths or for Pregnancy-Related deaths
- However, it is important to specify which is being used, since interpretation may be different
Comparing Indicators: DHS Data

<table>
<thead>
<tr>
<th>Country</th>
<th>“MMRatio” (per 100,000 Live Births)</th>
<th>“MMRate” (per 1,000 Women 15-49)</th>
<th>% “Maternal”</th>
<th>Life Time Risk (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Democratic Republic of Congo 2007</td>
<td>553</td>
<td>1.107</td>
<td>19.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Malawi 2004</td>
<td>975</td>
<td>1.989</td>
<td>16.8</td>
<td>5.7</td>
</tr>
<tr>
<td>Mali 2006</td>
<td>439</td>
<td>1.026</td>
<td>27.1</td>
<td>3.4</td>
</tr>
<tr>
<td>Zambia 2007</td>
<td>584</td>
<td>1.169</td>
<td>8.7</td>
<td>3.3</td>
</tr>
</tbody>
</table>

*Source: DHS data*
Characteristics of the MM Ratio (1)

- Not age-standardized
  - Less comparable across countries than the infant mortality or total fertility rates
- Risk is per 100,000 events (implies misleading accuracy)
- Cause-specific death indicator
  - More demanding data-wise than other summary mortality indicators routinely used
Characteristics of the MM Ratio (2)

- Ignores the fact that women will face this risk per birth several times over lifespan
- Changes in the MMR are a result of changes in any or all of the following:
  - Risk of maternal deaths
  - Distribution of births by risk factors
  - Age distribution of women
- Interplay between maternal mortality and fertility is not intuitive
Sources of Data to Estimate Maternal Mortality
Sources of Data

- Vital registration
- Sample vital registration
- Reproductive Age Mortality Studies (RAMOS)
- Large population-based surveys
- National population censuses
- Facility-based studies
- Statistical models (UNICEF/UNFPA/WHO/World Bank estimates)
Vital Registration Systems

**Advantage**
- Some data exist in most countries (not all report to UN agencies)
- Continuous recording
- Relatively large numbers of events

**Disadvantage**
- Well documented under-reporting in both High Income (HIC) and Low or Middle Income (LMIC) countries
  - Reasons vary by setting
  - Provided MMRs for only 15% of global births in global estimates for 2008
Vital Registration Data

- WHO estimates that 72 (out of 193) member states have complete (≥ 90%) recording of deaths
  - But not all have adequate cause of death data
  - Only 1 (Mauritius) in sub-Saharan Africa
- Even in countries with complete VR, classification of deaths as maternal is problematic
  - Recent increase in MMR (47% 2002 to 2004) in US partly due to change in standard death certificate
- Issues:
  - 10 studies (confidential enquiry, record linkage) of countries with complete registration found on average (median) one-third of true maternal deaths were incorrectly recorded as non-maternal
Under-Reporting in Vital Registration Systems

High Income Countries
- Complete reporting of female deaths, imperfect classification of cause of death

Low or Middle Income Countries
- Frequently female deaths from all causes are under-recorded
- Lack of incentive to report vital events
- Differential under-reporting by sex
- Even with complete reporting of deaths, poor classification of cause of death
## Linking U.S. Vital Records to Identify Maternal Deaths

<table>
<thead>
<tr>
<th>Place/ Yr</th>
<th>Type of Records Linked</th>
<th>MM Ratio</th>
<th>Without Adjustment</th>
<th>Adjusted</th>
<th>Percent Underreporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. Carolina (1988-89)</td>
<td>Live Birth, Fetal Death</td>
<td>9.5</td>
<td>24.0</td>
<td></td>
<td>60%</td>
</tr>
<tr>
<td>Georgia (1990-92)</td>
<td>Live Birth</td>
<td>16.8</td>
<td>21.9</td>
<td></td>
<td>23%</td>
</tr>
<tr>
<td>Tennessee (1989-91)</td>
<td>Live Birth, Fetal Death</td>
<td>7.3</td>
<td>15.0</td>
<td></td>
<td>51%</td>
</tr>
<tr>
<td>S. Carolina (1992)</td>
<td>Civil Registration</td>
<td>16.0</td>
<td>38.0</td>
<td></td>
<td>58%</td>
</tr>
<tr>
<td>New York (1993-94)</td>
<td>Civil Registration</td>
<td>12.5</td>
<td>21.6</td>
<td></td>
<td>42%</td>
</tr>
<tr>
<td>France (1988-89)</td>
<td>Review</td>
<td>9.7</td>
<td>21.9</td>
<td></td>
<td>56%</td>
</tr>
</tbody>
</table>

Sample Vital Registration Systems

- Special procedures in random sample of areas (7,600 in India 2004, 160 in China)
- Continuous monitoring of vital events plus 6-monthly household survey (India)
- Cause of death identified by verbal autopsy (VA) (India) or case records plus VA (China)

Issues:
- Requires considerable administrative sophistication
- Cannot be implemented rapidly
- Needs periodic evaluation
Reproductive Age Mortality Studies (RAMOS)

- Has previously been considered gold standard (without validation), recently questioned as a “method” at all
- Relies on multiple sources of data to identify adult female deaths:
  - Vital registration, medical records, undertaker, TBA, mother’s groups, market, newspaper, verbal autopsy (“triangulation”)
  - Almost impossible without reasonable VR base
- Once adult female deaths have been identified, a verbal autopsy or medical records or a combination of both are used to determine cause of death

Continued
Reproductive Age Mortality Studies (RAMOS)

- Advantages
  - More complete reporting of maternal deaths
  - Allows for important data collection on avoidable causes of death both in facilities and at home (care-seeking behavior)
Reproductive Age Mortality Studies (RAMOS)

- Disadvantages
  - Expensive and labor-intensive
  - Should be considered generally in settings with 60%+ completeness of reporting for adult female deaths in vital registration
  - Rarely carried out at a national level (exceptions: Egypt, Honduras, Guatemala)
  - Approach to data collection varies by country
  - Does not provide number of births (for MM Ratio)
RAMOS: An Example from Egypt 1992/3

- Random sample of Health Bureaus (HB)
  - Covering > 25% of women aged 14-50 (WRA)
- Selected HBs to report all deaths of (WRA) weekly
- Maternal deaths initially identified by screening at HBs, confirmed by in-depth home interview
  - Interviewed TBAs
  - Interviewed medical practitioners and reviewed medical records
- Cause of death determined by consensus of reviewing physicians
- 7,487 deaths of WRAs, 825 pregnancy-related, 772 maternal
Example: Egypt RAMOS (1992/3 and 2000)

<table>
<thead>
<tr>
<th>Region</th>
<th>MMR 1992/93</th>
<th>95% CI 1992/93</th>
<th>MMR 2000</th>
<th>95% CI 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metropolitan</td>
<td>233</td>
<td>(197-276)</td>
<td>48</td>
<td>(40-56)</td>
</tr>
<tr>
<td>Lower Egypt</td>
<td>132</td>
<td>(118-148)</td>
<td>93</td>
<td>(86-100)</td>
</tr>
<tr>
<td>Upper Egypt</td>
<td>217</td>
<td>(195-244)</td>
<td>89</td>
<td>(82-96)</td>
</tr>
<tr>
<td>Frontier</td>
<td>*</td>
<td>*</td>
<td>120</td>
<td>(78-161)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>174</td>
<td>(162-187)</td>
<td>84</td>
<td>(80-89)</td>
</tr>
</tbody>
</table>

Mortality dropped the most in Metropolitan area (bias?)
Major efforts in Upper Egypt seemed to have been successful

Source: Campbell et al. 2005. WHO Bulletin 83(6)
### Egypt RAMOS: Avoidable Factors*

<table>
<thead>
<tr>
<th>Avoidable Factor(s)</th>
<th>% of Maternal Deaths 1992/93</th>
<th>% of Maternal Deaths 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substandard care</td>
<td>71</td>
<td>66</td>
</tr>
<tr>
<td>No or poor antenatal care</td>
<td>33</td>
<td>34</td>
</tr>
<tr>
<td>Lack of supplies/personnel</td>
<td>8</td>
<td>26</td>
</tr>
<tr>
<td>Delay in recognizing problem</td>
<td>42</td>
<td>30</td>
</tr>
<tr>
<td>Lack of transportation/distance</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Unwanted pregnancy</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>None</td>
<td>8</td>
<td>19</td>
</tr>
</tbody>
</table>

* %’s add to more than 100 because of multiple avoidable factors
Large Population-Based Surveys
Three Survey Methods of Data Collection, Estimation

1. The original sisterhood method
   - Indirect estimation (not discussed)
   - Graham et al., 1989

2. Sibling history-based method
   - Direct estimation (DHS adaptation)

3. Identification of all female deaths in the household in some reference period
   - Can be used in census or large survey
Sibling-based Direct Method

- Method generally used by DHS
  - Also now by MICS
- Relies on direct estimation—demographic techniques in which all required data to produce an estimate are available
- Consists of an additional module added to women’s individual survey
- More demanding data requirements

Continued
Household Surveys With Sibling Histories

- Widely used in DHS program (60 surveys in 40 sub-Saharan African countries)

- Issues:
  - Measures pregnancy-related mortality (PRMR)
    - No realistic possibility for verbal autopsy
  - Even in surveys of 30,000 households, estimates are generally made for 7 years before survey (small numbers)
  - May under-estimate overall mortality (and hence PR mortality also): under-records high mortality sibships
Statistical Uncertainty in PRMRatio Estimates from Sibling Histories

- Pregnancy-related deaths are relatively rare events
- Despite “sample expansion” of sisterhood method, statistical uncertainty (sampling error) around PRMRatio is large
- For recent DHS’s, estimates of standard errors and 95% confidence intervals are (generally) given in an Appendix to Report
  - Number of years covered by estimate is not consistent (0 to 4, 0 to 6, 0 to 9) across countries
  - Can be compared to uncertainty around U5MR estimates (also given for varying time periods)
- 5 country reports (!) give sampling errors for U5MR for 0 to 4 years, for PRMR for 0 to 6 years, prior to survey
  - Coefficient of variation (SE divided by mean) ranges from 2 to 3 times larger for PRMR than U5MR despite longer period
  - The smallest c of v for PRMRatio is 6.4% (Nigeria 2008), translating into 95% confidence intervals of approximately ± 12%
Coefficients of variation for U5MR estimates are for the 5 years before the survey, for PRMR for 7 years before the survey; even so, PRMR is 2 to 3 times more uncertain than U5MR
Sibling-Based Method
(Direct Estimation)

Advantages

- Provides all information required to estimate pregnancy-related mortality, including fertility
  - Also provides estimates of male and female all-cause mortality between ages 15 and 50
- Relatively inexpensive if DHS or MICS is being carried out anyway

Continued
Sibling-Based Method
(Direct Estimation)

- Disadvantages
  - Risk that results will be interpreted as having similar precision to other DHS estimates
  - Given “standard” sample sizes, generates large sampling errors
  - Only produces national level estimate
  - May preclude use of other modules (“crowding out”)
  - Requires complex data processing
  - Evidence of under-reporting of adult deaths in recent period—unclear how to adjust
  - The module is usually the last DHS module used: risk of respondent fatigue
Censuses with Questions on Deaths

- Population censuses can include questions on deaths in households in defined recent reference period
  - Recommended in 2010 *Principles and Recommendations for Pop and Housing Censuses* for countries lacking complete VR

- Reported deaths of women of reproductive age trigger additional questions about the timing of death relative to pregnancy
  - Noted in 2010 *PRPHC*

- Issues:
  - Pregnancy-related mortality (unless combined with Verbal Autopsy)
  - Census misses deaths in single-person households
  - Death of leading household figure may result in breakup of household
  - Experience suggests there is almost always some under-reporting
  - Need to evaluate carefully
Facility-Based Studies

- Useful for identifying areas for improved care (confidential enquiries)
- Potential for gold standard case identification (case notes)
- Facility deaths (and births) are selected on characteristics that may not be known
- Not readily generalizable to a national MMR estimate (unless selection probabilities are known)
General Problems with MM Measurement

- Rare events (only ~ 5% of child deaths)
  - National trends unstable over short periods
  - For household surveys requires very large samples
- Certain types of maternal death hard to identify (especially abortion-related)
- Non-VR methods generally measure pregnancy-related mortality PRMR
  - PRMR should in theory be > MMR, but because of failure to report pregnancy status (especially for abortions) may approximate true MMR
  - Study from Matlab, Bangladesh in 1990s suggests the two “errors” trade off approximately ( but no consensus)
Summary

- Maternal mortality is difficult to measure accurately, even in countries with complete VR.
- In countries lacking complete VR, no approach is guaranteed to give accurate estimates.
  - Data need careful evaluation.
  - Periodic measurement by multiple methods is recommended.
  - Estimation of short-term trends not feasible.
  - In absence of verbal autopsy, estimates are of pregnancy-related mortality.
- In the long run, essential to improve VR.