Moving beyond essential interventions for reduction of maternal mortality (the WHO Multicountry Survey on Maternal and Newborn Health): a cross-sectional study

João Paulo Souza, Ahmet Metin Gülmezoglu, Joshua Vogel, Guillermo Carroli, Pisake Lumbiganon, Zahida Qureshi, Maria José Costa, Bukola Fawole, Yvonne Mugerwa, Idi Nafiou, Isilda Neves, Jean-José Wolomby-Molondo, Hoang Thi Bang, Kannitha Cheang, Kang Chuyun, Kapila Jayaratne, Chandani Anoma Jayathilaka, Syeda Batool Mazhar, Rintaro Mori, Mir Lais Mustafa, Laxmi Raj Pathak, Deepthi Perera, Tung Rathavy, Zenaida Recidoro, Malabika Roy, Pang Ruyan, Naveen Shrestha, Surasak Taneepanichsku, Nguyen Viet Tien, Togoobaatar Ganchimeg, Mira Wehbe, Buyanjargal Yadamsuren, Wang Yan, Khalid Yunis, Vicente Bataglia, José Guilherme Cecatti, Bernardo Hernandez-Prado, Juan Manuel Nardin, Alberto Narváez, Eduardo Ortiz-Panozo, Ricardo Pérez-Cuevas, Eliette Valladares, Nelly Zavaleta, Anthony Armson, Caroline Crowther, Carol Hogue, Gunilla Lindmark, Suneeta Mittal, Robert Pattinson, Mary Ellen Stanton, Liana Campodonico, Cristina Cuesta, Daniel Giordano, Nirun Intarut, Malinee Laopaiboon, Rajiv Bahl, Jose Martines, Matthews Mathai, Mario Merialdi, Lale Say

Summary

Background We report the main findings of the WHO Multicountry Survey on Maternal and Newborn Health (WHOMCS), which aimed to assess the burden of complications related to pregnancy, the coverage of key maternal health interventions, and use of the maternal severity index (MSI) in a global network of health facilities.

Methods In our cross-sectional study, we included women attending health facilities in Africa, Asia, Latin America, and the Middle East that dealt with at least 1000 childbirths per year and had the capacity to provide caesarean section. We obtained data from analysis of hospital records for all women giving birth and all women who had a severe maternal outcome (SMO; ie, maternal death or maternal near miss). We regarded coverage of key maternal health interventions as the proportion of the target population who received an indicated intervention (eg, the proportion of women with eclampsia who received magnesium sulphate). We used areas under the receiver operator characteristic curves (AUROC) with 95% CI to externally validate a previously reported MSI as an indicator of severity. We assessed the overall performance of care (ie, the ability to produce a positive effect on health outcomes) through standardised mortality ratios.

Results From May 1, 2010, to Dec 31, 2011, we included 314 623 women attending 357 health facilities in 29 countries (2538 had a maternal near miss and 486 maternal deaths occurred). The mean period of data collection in each health facility was 89 days (SD 21). 23 015 (7·3%) women had potentially life-threatening disorders and 3024 (1·0%) developed an SMO. 808 (26·7%) women with an SMO had post-partum haemorrhage and 784 (25·9%) had pre-eclampsia or eclampsia. Cardiovascular, respiratory, and coagulation dysfunctions were the most frequent organ dysfunctions in women who had an SMO. Reported mortality in countries with a high or very high maternal mortality ratio was two-to-three-times higher than that expected for the assessed severity despite a high coverage of essential interventions. The MSI had good accuracy for maternal death prediction in women with markers of organ dysfunction (AUROC 0·826 [95% CI 0·802–0·851]).

Interpretation High coverage of essential interventions did not imply reduced maternal mortality in the health-care facilities we studied. If substantial reductions in maternal mortality are to be achieved, universal coverage of life-saving interventions need to be matched with comprehensive emergency care and overall improvements in the quality of maternal health care. The MSI could be used to assess the performance of health facilities providing care to women with complications related to pregnancy.

Funding UNDP–UNFPA–UNICEF–WHO–World Bank Special Programme of Research, Development and Research Training in Human Reproduction (HRP); WHO; USAID; Ministry of Health, Labour and Welfare of Japan; Gynuity Health Projects.

Introduction

In recent years, two important changes in maternal health have taken place worldwide: first, a substantial reduction in global maternal mortality and second an increase in the proportion of childbirths occurring in health facilities.[1] Although substantial progress has been made, not enough has been done to meet the fifth Millennium Development Goal. An estimated 287 000 women died in 2010 of causes related to pregnancy and childbirth and a substantial proportion of childbirths still occur in communities without skilled birth assistance.[1] In this context, improving quality of care has become increasingly important to accelerate reduction in maternal mortality, to reduce maternal deaths in health facilities, and stimulate demand for institutional births.[2–5] In many settings, women prefer to deliver in the

Lancet 2013; 381: 1747–55

See **Comment** page 1695

UNDP/UNFPA/UNICEF/WHO/Word Bank Special Programme of Research, Development and Research Training in Human Reproduction, WHO, Geneva, Switzerland (J P Souza MD, A M Gülmezoglu MD, J Vogel MBBS, M Merialdi MD, L Say MD); **Centro Rosarino de Estudios Perinatales, Rosario, Argentina** (G Carroli MD, J M Nardin MD, L Campodonico BSc, C Cuesta MSc, D Giordano BSc); **Khon Kaen University, Khon Kaen, Thailand** (Prof P Lumbiganon MD, Prof M Laopaiboon PhD); **University of Nairobi, Nairobi, Kenya** (Z Qureshi MD); **WHO Angola, Luanda, Angola** (M J Costa MD); **University of Ibadan, Ibadan, Nigeria** (B Fawole MD); **Makerere University, Makerere, Uganda** (Y Mugerwa MD); **Université Abdou Moumouni de Niamey, Niamey, Niger** (I Nafiou MD); **Delegação Provincial de Saúde de Luanda, Luanda, Angola** (I Neves MD); **Cliniques Universitaires de Kinshasa, Kinshasa, DR Congo** (J-J Wolomby-Molondo MD); **WHO, Hanoi, Vietnam** (H T Bang MD); **WHO, Phnom Penh, Cambodia** (K Cheang MD); **Peking University, Beijing, China** (K Chuyun MD, P Ruyan MD, Prof W Yan DrPH); **Ministry of Health, Government of Sri Lanka, Colombo, Sri Lanka** (K Jayaratne MD, D Perera MD); **WHO, Colombo, Sri Lanka** (C A Jayathilaka MD); **Pakistan Institute of Medical Sciences, Islamabad, Pakistan**

(Prof S B Mazhar MD); **Department of Health Policy,National Center for Child Health and Development, Tokyo, Japan** (R Mori MD); **Afghan Public Health Institute, Kabul, Afghanistan** (M L Mustafa MD); **Ministry of Health and Population, Government of Nepal, Kathmandu, Nepal** (L R Pathak MBBS); **National Maternal and Child Health Center, Phnom Penh, Cambodia** (T Rathavy MD); **National Center for Disease Prevention and Control, Manila, Philippines** (Z Recidoro MPH); **Indian Council of Medical Research, New Delhi, India** (M Roy MD); **Central Institute of Science and Technology (CIST) College, Pokhara University, Kathmandu, Nepal** (Prof N Shrestha MScPH); **Chulalongkorn University, Bangkok, Thailand** (Prof S Taneepanichsku MD, N Intarut MPH); **National Obstetrics and Gynaecology Hospital, Hanoi, Vietnam** (N V Tien MD); **The University of Tokyo, Tokyo, Japan** (T Ganchimeg PhD); **American University of Beirut, Beirut, Lebanon** (M Wehbe MPH, Prof K Yunis MD); **Ministry of Health, Government of Mongolia, Ulaanbaatar, Mongolia** (B Yadamsuren MD); **Hospital Nacional de Itauguá, Itauguá, Paraguay** (V Bataglia MD); **University of Campinas, Campinas, SP, Brazil** (J G Cecatti MD); **Institute for Health Metrics and Evaluation, University of Washington, Seattle, WA, USA** (B Hernandez-Prado DSc); **Colegio Medico de Pichincha and Fundación Salud, Ambiente y Desarollo, Pichincha, Ecuador** (A Narvaez MD); **Instituto Nacional de Salud Pública, Cuernavaca, Mexico** (E Ortiz-Panozo MSc); **Social Protection and Health Division, Inter American Development Bank, Mexico City, Mexico** (R Pérez-Cuevas DrSc); **Universidad Nacional Autónoma de Nicaragua, León, Nicaragua** (E Valladares PhD); **Instituto de Investigación Nutricional, Lima, Peru** (N Zavaleta MD); **Dalhousie University, Halifax, Canada** (Prof A Armson MD); **University of Adelaide, Adelaide, Australia**

community because of concerns about perceived quality of care in health facilities.[5]

Good quality of care is a multidimensional notion that includes, among other factors, appropriate use of effective clinical and non-clinical interventions and strengthened health infrastructure and attitude of health providers, resulting in satisfaction of patients and providers and improved health outcomes.[5–7] As part of strategies to improve maternal health care, great emphasis has been placed on maximising coverage of life-saving maternal health interventions (eg, uterotonics for prevention and treatment of post-partum haemorrhage or magnesium sulphate for prevention and treatment of eclampsia).[8] Although coverage can be objectively monitored and assessed, other dimensions of quality are hard to measure.

Despite the global nature of the issue, maternal deaths are relatively rare events in individual facilities, complicating the assessment of effects of care on mortality. To overcome this epidemiological challenge, the notion of a near-miss event was introduced in maternal health, which is potentially able to complement the information obtained with reviews of maternal deaths.[9] In 2004, the WHO published a systematic review[10] about the prevalence of severe maternal morbidity and maternal near miss. In that review, the absence of standard definitions for both severe maternal morbidities and near-miss cases was a major constraint for obtaining an overall prevalence of these conditions. This difficulty led WHO to develop a standard definition of maternal near miss, based on markers of organ dysfunction (ie, survivors of organ dysfunction during pregnancy, childbirth, or after birth are classified as maternal near-miss cases).[11] The WHO criteria for maternal near miss were developed through an international consultative process, which also included systematic reviews,[10,12] pilot studies,[13,14] and a multicentre validation study.[15] Through coupling of maternal deaths and near-miss cases (both regarded as severe maternal outcomes [SMO]) and assessing their similarities and differences, a more robust analysis of the quality of maternal health care and its determinants can be made.[11,15] This collaborative effort allowed the development of the maternal severity index (MSI) model, which estimates the death probability of women with complications related to pregnancy.[15] Comparison of observed mortality to the model-estimated mortality allows investigators to make an overall assessment of performance.[15–17]

The main goal of this study, the WHO Multicountry Survey on Maternal and Newborn Health (WHOMCS), was to characterise the severe maternal, perinatal, and neonatal morbidity that occurs in a worldwide network of health facilities. Our analysis specifically aimed to describe maternal characteristics and perinatal outcomes, assesses the prevalence and severity of complications related to pregnancy, determines the coverage of key maternal health interventions, tests and externally validates the MSI model, and assesses the overall performance of care in participating facilities.

Methods

Study design and participants

The study protocol and other methodological details of the WHOMCS have been published previously.[18] Briefly, the study was a cross-sectional analysis implemented in health facilities in 29 countries from Africa, Asia, Latin America, and the Middle East. Figure 1 shows countries included in this study, stratified by level of maternal mortality ratio (MMR).[1] Most participating health facilities had also taken part in the previous WHO Global Survey on Maternal and Perinatal Health (2004–08).[19] Countries, provinces (or other equivalent political divisions within countries), and health facilities were randomly selected through a stratified, multistage cluster sampling strategy. Health facilities were only eligible if they dealt with at least 1000 deliveries per year and had the capacity to provide caesarean section. All women who gave birth at participating facilities (and their newborn babies) and all women with SMO made up the study population. In this analysis, we excluded second or higher order infants, but first-born babies and mothers were included. We defined women with SMO as having had a maternal death or maternal near miss up to 7 days after giving birth or having an abortion, irrespective of gestational age or delivery status. We defined maternal near-miss cases as women who survived a life-threatening condition (as identified by any marker of organ dysfunction and listed in the appendix). Women admitted to participating facilities after 7 days of termination of pregnancy (delivery or abortion) were not eligible for inclusion.

The HRP specialist panel (WHO scientific staff and external, independent researchers) on epidemiological research reviewed and approved the study protocol for technical content. This study was approved by the WHO ethical review committee and the relevant ethical clearance mechanisms in all countries. Written consent from individual participants was not required. Hospitals obtained the relevant clearances to participate.

Procedures

During the period of data collection, data collectors (trained by study country coordinators) undertook daily visits to obstetrical or post-partum wards, gynaecological or abortion care units, delivery rooms, emergency or intensive-care units to identify eligible women. We used paper forms to obtain data related to demographic and reproductive characteristics, pregnancy and childbirth status, pregnancy complications and their management, and morbidity and mortality of mothers and newborn babies in hospitals. We obtained data for all eligible study participants from hospital records at hospital discharge, transfer, or death up to 7 days post partum for both mother and baby. Data collectors consulted facility medical staff about missing or unclear information

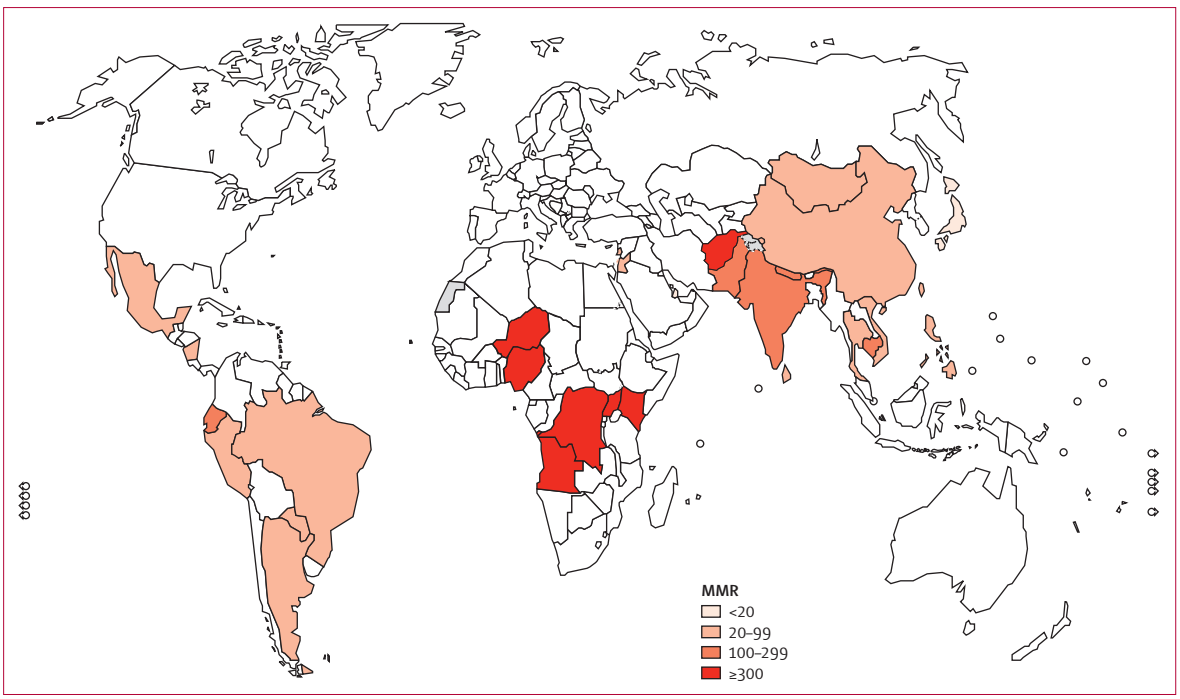

Figure 1: **Countries included in the WHO Multicountry Survey on Maternal and Newborn Health**
Countries are stratified by MMR (deaths per 100 000 livebirths). MMR=maternal mortality ratio.

(Prof C Crowther MD); **Emory University, Atlanta, GA, USA** (Prof C Hogue MD); **Uppsala University, Uppsala, Sweden** (Prof G Lindmark MD); **All India Institute of Medical Sciences, New Delhi, India** (Prof S Mittal MD); **University of Pretoria, Pretoria, South Africa** (Prof R Pattinson MD); **United States Agency for International Development, Washington, DC, USA** (M E Stanton MSN); **and WHO, Geneva, Switzerland** (R Bahl MD, J Martines MD, M Mathai MD)

Correspondence to:
Dr João Paulo Souza, UNDP/UNFPA/UNICEF/WHO/Word Bank Special Programme of Research, Development and Research Training in Human Reproduction, WHO, Geneva 1211, Switzerland
souzaj@who.int

See Online for appendix

during data collection. A manual of operations for data collectors was developed and used to reduce the need for judgment and interpretation. The data collection techniques were pretested on a convenient sample of records and clinical settings before the study. Training workshops at country and facility level were done and tailored according to specific needs. In each country, a short pilot phase was implemented to test the overall data management process. We undertook intra-form validity cross-checks in addition to random cross-checks comparing hospital records against recorded data. Because most of the facilities in WHOMCS had participated in the WHO Global Survey,[19] we emphasised training in the facilities that were new to the network.

Data were entered into a web-based data management system developed by the Centro Rosarino de Estudios Perinatales (CREP, Rosario, Argentina). Data entry was done at the health facility or at a central level, dependent on logistics and available infrastructure. Data managers in Argentina (LC, CCu, and DG) and Thailand (ML and NI) monitored the study data flow and data quality by use of validation procedures and progress reports for all countries. Data inconsistencies were identified and corrected by contacting centres as they occurred. These procedures have been used in previous multicentre studies, including the WHO Global Survey.[19]

Statistical analysis

Because the primary objectives of the WHOMCS were wide-ranging and related to maternal mortality and severe morbidity, which are relatively rare events in individual health facilities, a very large sample size was necessary to capture a statistically meaningful number of maternal deaths and near-miss cases. Based on previous maternal near-miss studies and the WHO Global Survey,

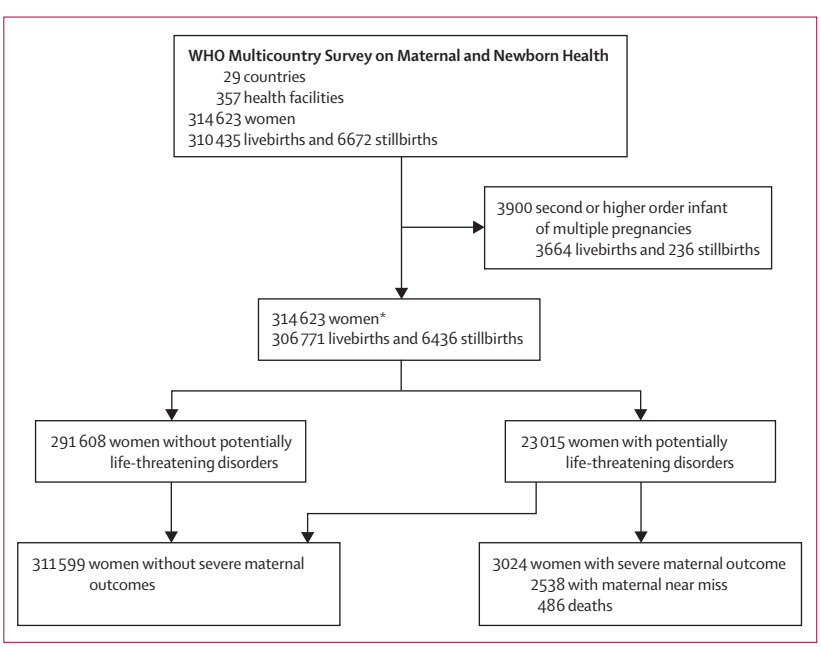

Figure 2: **Study profile**
*Sum of livebirths and stillbirths does not equal the number of women because some women had abortions or did not have a delivery.

	All women	Women without an SMO	Women with an SMO	p value
Women	314 623 (100·0%)	311 599 (99·0%)	3024 (1·0%)	
Age				<0·0001
Data available	313 689	310 672	3017	
<20 years	32 328 (10·3%)	32 048 (10·3%)	280 (9·3%)	
20–35 years	254 307 (81·1%)	252 054 (81·1%)	2253 (74·7%)	
>35 years	27 054 (8·6%)	26 570 (8·6%)	484 (16·0%)	
Marital status				0·0337
Data available	310 934	307 956	2978	
Without partner	31 693 (10·2%)	31 458 (10·2%)	235 (7·9%)	
With partner	279 241 (89·8%)	276 498 (89·8%)	2743 (92·1%)	
Schooling				<0·0001
Data available	288 775	286 075	2700	
<5 years	58 630 (20·3%)	57 500 (20·1%)	1130 (41·9%)	
5–8 years	65 718 (22·8%)	65 137 (22·8%)	581 (21·5%)	
9–11 years	73 611 (25·5%)	73 101 (25·6%)	510 (18·9%)	
>11 years	90 816 (31·4%)	90 337 (31·6%)	479 (17·7%)	
Number of previous births				<0·0001
Data available	313 969	310 955	3014	
0	132 672 (42·3%)	131 692 (42·4%)	980 (32·5%)	
1–2	130 245 (41·5%)	129 220 (41·6%)	1025 (34·0%)	
>2	51 052 (16·3%)	50 043 (16·1%)	1009 (33·5%)	
Number of previous caesarean sections				<0·0001
Data available	310 355	307 364	2991	
0	272 302 (87·7%)	269 806 (87·8%)	2496 (83·5%)	
1	29 307 (9·4%)	28 987 (9·4%)	320 (10·7%)	
>1	8746 (2·8%)	8571 (2·8%)	175 (5·9%)	
Onset of labour				<0·0001
Data available	312 581	310 845	1736	
Spontaneous	241 724 (77·3%)	240 794 (77·5%)	930 (53·6%)	
Induced	32 784 (10·5%)	32 556 (10·5%)	228 (13·1%)	
Caesarean section with no labour	38 073 (12·2%)	37 495 (12·1%)	578 (33·3%)	
Mode of delivery				<0·0001
Data available	312 660	310 955	1705	
Vaginal	223 145 (71·4%)	222 505 (71·6%)	640 (37·5%)	
Caesarean section	89 515 (28·6%)	88 450 (28·4%)	1065 (62·5%)	

SMO=severe maternal outcome (ie, maternal near miss or maternal death).

Table 1: **Demographic and labour characteristics of women, according to maternal outcome**

the target sample size was estimated at 275 000 women to capture at least 2000 women with an SMO.[13,19,20] To reduce variation in cluster size, we collected data for a period of 2 months in facilities that had at least 6000 deliveries every year and for 3 months in facilities with fewer than 6000 deliveries every year. In countries where a 3 month collection period was anticipated to include fewer than 3000 deliveries overall, we extended the period to 4 months in all health facilities.

We used frequencies to describe maternal characteristics, modes of onset of labour and delivery, and perinatal outcome, with stratification by the maternal outcome. We used frequencies to describe the proportion of women affected by specific types of morbidities and assessed the distribution of selected pregnancy-related complications (ie potentially life-threatening conditions) in women without SMO, maternal near-miss cases, and maternal deaths. We stratified frequencies by MMR group to further explore the reported associations.

We calculated the frequency of women with potentially life-threatening conditions per 1000 livebirths, the maternal near-miss ratio (ie, number of maternal near-miss cases per 1000 livebirths), the severe outcome ratio (SMOR; number of SMOs per 1000 livebirths) and the intra-hospital MMR (ie, number of maternal deaths that took place in-hospital per 100 000 liverbirths, limited to the first 7 post-partum days). To complement this analysis, we assessed the severity of cases with organ dysfunction with the maternal severity score (MSS) and MSI. The MSS is the total number of markers of organ dysfunction; highest scores suggest highest severity and mortality.[15] The MSI is the probability of maternal death for each woman as estimated by the MSI model.[15]

We determined coverage of key maternal health interventions as the proportion of the target population who received the indicated intervention (ie, the proportion of women giving birth who received a prophylactic uterotonic, the proportion of women with post-partum haemorrhage who received a therapeutic uterotonic, the proportion of women with eclampsia who received magnesium sulphate, the proportion of women giving birth by caesarean section who received a prophylactic antibiotic, and the proportion of women with sepsis who received a parenteral antibiotic).

We defined a missed opportunity of care as an event in which a woman did not receive an indicated essential intervention (eg, a woman giving birth who did not receive a prophylactic uterotonic or a woman with eclampsia who did not receive magnesium sulphate). We determined the proportion of women with SMO with at least one missed opportunity of care and assessed the risk of mortality associated with these missed opportunities.

The MSI model was developed in a large, multicentre study[15] in Brazil to assess ability of a health service for management of women with life-threatening complications related to pregnancy. It was developed with binary logistic regression and internally validated through random split-sample methods. In the present study, we applied the previously reported MSI model in this independent multicountry population database to assess health service performance in a wide range of settings. Because the MSI model was developed in a country with moderate maternal mortality, we used the standardised mortality ratio (SMR) of countries with moderate MMR (ie, 20–100 deaths per 100 000 livebirths) to assess the calibration of the MSI estimates. The SMR is the ratio between observed maternal mortality risk and predicted maternal mortality risk—ie, SMR is equal to the number of observed maternal deaths per population size divided by the predicted number of maternal deaths per population size (which can be simplified to the number of observed

maternal deaths divided by the number of predicted maternal deaths); the predicted number of maternal deaths is equal to MSI×population size. In a population receiving a level of care equivalent to the level of care received by the population in which the MSI model was developed, the MSI model is expected to predict a similar number of maternal deaths by comparison with the reported number of maternal deaths (ie, SMR ~1·0).[15–17] We used the area under the receiver operator characteristics curves (95% CI) to externally validate the MSI as indicators of severity in this multicountry population and show its capacity to predict maternal deaths in women with organ dysfunction related to pregnancy.[16]

We assessed overall care performance (ie, ability to produce a positive effect in health outcomes) with the SMR. An SMR of about 1·0 suggests an intermediate performance of care (ie, an observed mortality akin to the expected for the level of severity, in countries with moderate MMR). Low SMRs suggest good performance of care (ie, an observed mortality lower than expected for the level of severity) and high SMRs suggest poor performance of care (ie, an observed mortality higher than expected for the level of assessed severity).[17]

Because health facilities were the primary sampling unit of this study, we assumed that individual-level analyses might have been affected by cluster effects.[21] Therefore, we adjusted all estimates of association for cluster effect (health facilities as the primary sampling unit with stratification by country). We corrected the Pearson χ^2 statistic for the survey design with the Rao-Scott correction, following the standard procedure in Stata statistical software.[22] Other *F* tests were corrected by dividing the *F* statistic by the design effect (ie, designed effect = $1+(n-1)\times$ICC, where n is the average cluster size and ICC is the intracluster correlation coefficient).[23] We used logistic regression, with the "svy logistic" procedure in Stata statistical software, to generate odds ratio estimates accounting for multistage cluster sampling. Because the SMR is a risk ratio involving low or very low rates of events at the level of MMR country groups, we calculated estimates of SMR standard errors with Mantel-Haenszel methods at that level; we generated overall SMR estimates with random-effects models.

Statistical analyses were done with PASW statistics 18, release version 18.0.0 (SPSS, Chicago, IL, USA), Stata statistical software, release 11 (StataCorp, College Station, TX, USA), and RevMan version 5·2 (Cochrane Collaboration, Copenhagen, Denmark).

Role of the funding source

The sponsors had no role in data collection, analysis, or interpretation of the data, the writing of the report, or the decision to submit for publication. All authors had access to the analysis plan, the outputs of that analysis, and could see the full data if they wished to do so. All authors participated in the final discussion and approved the report. The corresponding author had full access to all the

	All women		Women without an SMO		Women with an SMO		p value
	N	Events per 1000 livebirths	n	Events per 1000 livebirths	n	Events per 1000 livebirths	
Livebirths	306 771	..	305 369	..	1402	..	..
Early neonatal deaths	2712	8·8	2623	8·6	89	63·5	<0·0001
Fetal deaths	6436	21·0	5918	19·4	518	369·5	<0·0001
Perinatal deaths*	7935	25·9	7414	24·3	521	371·6	<0·0001
Preterm births	20 941	68·3	20 542	67·3	399	284·6	<0·0001
NICU admission	20 599	67·1	20 164	66·0	435	310·3	<0·0001

NICU=neonatal intensive-care unit. *The perinatal mortality ratio was calculated as the number of late fetal deaths (death occurring in a fetus weighing ≥1000 g at birth, or if birthweight was unknown at ≥28 weeks' gestation) plus early neonatal deaths per 1000 livebirths.

Table 2: **Perinatal outcome, stratified by absence or presence of severe maternal outcomes**

	All women (N=314 623)	Women with an SMO (n=3024)
Haemorrhage		
Placenta praevia	1304 (0·4%)	187 (6·2%)
Accreta, increta, or percreta placenta	484 (0·2%)	106 (3·5%)
Abruptio placenta	1082 (0·3%)	186 (6·2%)
Ruptured uterus	316 (0·1%)	131 (4·3%)
Post-partum haemorrhage	4716 (1·5%)	808 (26·7%)
Other obstetric haemorrhage	655 (0·2%)	141 (4·7%)
Infection		
Puerperal endometritis	321 (0·1%)	49 (1·6%)
Pyelonephritis	542 (0·2%)	74 (2·5%)
Influenza-like illness	253 (0·1%)	37 (1·2%)
Sepsis and other systemic infections	1216 (0·4%)	229 (7·6%)
Hypertensive disorders		
Chronic hypertension	1362 (0·4%)	118 (3·9%)
Pre-eclampsia (excludes eclampsia)	7001 (2·2%)	493 (16·3%)
Eclampsia	1008 (0·3%)	291 (9·6%)
Abortion and ectopic pregnancy*		
Abortion-related haemorrhage	Not applicable*	280 (9·3%)
Abortion-related infection	Not applicable*	63 (2·1%)
Ectopic pregnancy	Not applicable*	121 (4·0%)
Other complications or diseases		
HIV-positive, AIDS, or HIV wasting syndrome	1326 (0·4%)	47 (1·6%)
Severe anaemia	5015 (1·6%)	1039 (34·4%)
Malaria or dengue	461 (0·2%)	145 (4·8%)
Embolic disease†	55 (0·0%)	26 (0·9%)
Cancer	56 (0·0%)	14 (0·5%)
Heart disease	513 (0·2%)	84 (2·8%)
Lung disease	405 (0·1%)	117 (3·9%)
Renal disease	340 (0·1%)	78 (2·6%)
Hepatic disease	506 (0·2%)	116 (3·8%)
Coincidental disorders	714 (0·2%)	91 (3·0%)
Other disorder leading to organ dysfunction	188 (0·1%)	188 (6·2%)

SMO=severe maternal outcome (ie, maternal near miss or maternal death). *Women who had an abortion and ectopic pregnancy were only included in the study if they had an SMO. †Thromboembolism, amniotic embolism, or air embolism.

Table 3: **Frequency of potentially life-threatening disorders**

data in the study and had final responsibility for the decision to submit for publication.

Results

Between May 1, 2010, and Dec 31, 2011, we included 314 623 women attending 357 health facilities in 29 countries (figure 2). Most health facilities were located in urban or periurban areas and 132 (37%) were tertiary hospitals (further details of the health facilities are contained in the appendix). The mean period of data collection in each facility was 89 days (SD 21).

Compared with women without an SMO, women with an SMO were more often older than 35 years, multiparous, with a partner, and had less than 5 years of education and had undergone a previous caesarean section (table 1). Women with an SMO had a higher rate of induced labour than did women without an SMO (13·1% with an SMO *vs* 10·5% without an SMO) and caesarean section without labour (33·3% *vs* 12·1%). The overall rate of caesarean section was 28·6% compared with 62·5% for women with an SMO. Proportionally fewer SMOs were reported in women without partners (ie, single, divorced, separated, or widowed) in countries with very high MMRs (appendix). The perinatal mortality ratio in women with SMOs was nearly 15 times higher than it was for women without SMOs (table 2). Other adverse perinatal outcomes, including rates of preterm birth and admission to neonatal intensive care units, were also substantially increased in women with SMOs.

Post-partum haemorrhage and pre-eclampsia or eclampsia were the two most frequent obstetric complications noted in women with SMO (table 3). Figure 3 shows the relative contribution of key groups of complications according to the maternal outcome (we excluded severe anaemia post-hoc because of a very high prevalence that distorted the distributions). Cardiovascular, respiratory, and coagulation disorders were the most frequent organ dysfunctions in women with SMO (table 4). In general, SMO prevalence increased as level of maternal mortality increased (table 5). Women with SMO in countries with a low MMR had a reduced severity of illness compared with other groups. Overall, 2164 (9·5%) of 22 840 women with potentially life-threatening disorders were referred to study centres from other hospitals. Mean length of hospital stay for all women was 2·84 days (SD 2·74). Women with an SMO had a mean hospital stay of 4·86 days (4·44), compared with 2·82 days (2·71) for women without an SMO (p=0·0146).

We noted a high coverage of maternal health interventions in health facilities in the different country groups (table 6, appendix). However, 550 (18%) of 3024 women with an SMO did not receive at least one of the indicated essential interventions (eg, magnesium sulphate in the case of eclampsia). Overall, we regarded 638 of these occurrences in women with an SMO as missed opportunities. Risk of mortality was not increased in women with missed opportunities in the SMO group (103 deaths in 550 women with missed opportunities *vs* 383 deaths in 2474 women without missed opportunities; cluster-effect adjusted odds ratio 1·26 [95% CI 0·81–1·97], p=0·3296).

The MSI model had good accuracy for prediction of maternal death in women with markers of organ dysfunction (AUROC for the MSI-derived estimates 0·826 [95% CI 0·802–0·851]). The observed mortality in countries with a moderate MMR was similar to the predicted (SMR 0·91 [95% CI 0·62–1·32]). The MSI receiver operating characteristic curves, data for the capacity of health facilities to assess the markers of severity, an estimation of the level of underestimation in under-resourced settings and further methodological details are shown in the appendix.

Observed mortality in health facilities located in countries with high and very-high MMRs was 2–3-times higher than that expected for the level of assessed severity (figure 4). The appendix includes a breakdown of selected maternal health care indicators by country.

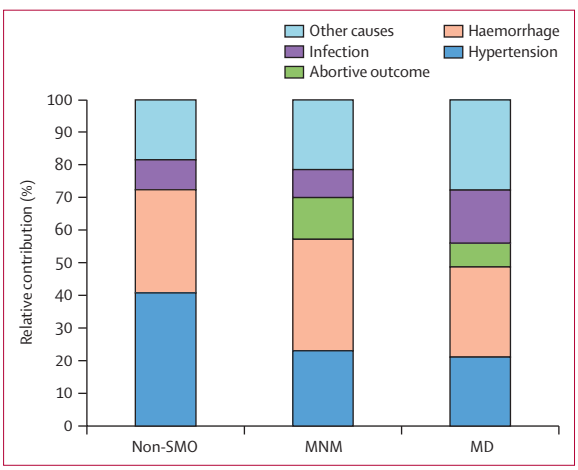

Figure 3: **Relative contribution of pregnancy-related complications by severity group**
Non-SMO=women without severe maternal outcomes. MNM=maternal near miss. MD=maternal deaths.

	Women	Proportion of all women (N=314 623)	Proportion of women with an SMO (n=3024)
Cardiovascular dysfunction	1495	0·5%	49·4%
Respiratory dysfunction	920	0·3%	30·4%
Coagulation or haematological dysfunction	832	0·3%	27·5%
Uterine dysfunction or hysterectomy	473	0·2%	15·6%
Neurological dysfunction	341	0·1%	11·3%
Hepatic dysfunction	310	0·1%	10·3%
Renal dysfunction	281	0·1%	9·3%
Unspecified organ dysfunction	23	0%	0·8%
Any organ dysfunction	3024	1·0%	100%

*Identified by presence of life-threatening disorders (markers of organ dysfunction) listed in the appendix.

Table 4: **Frequency of organ dysfunction related to pregnancy***

	Low MMR	Moderate MMR	High MMR	Very high MMR	Overall
Countries	2	15	5	7	29
Hospitals	11	156	68	122	357
Women	7487	135795	70753	100588	314623
Livebirths	7459	134545	68565	96202	306771
Women with complications	1164	9969	5452	6430	23015
Women with severe maternal outcomes	35	873	591	1525	3024
Maternal near-miss cases	35	824	422	1257	2538
Maternal deaths	0	49	169	268	486
Indicators					
Ratio of potentially life-threatening complications per 100 livebirths*	15·6	7·4	8·0	6·7	7·5
Maternal near-miss ratio†	4·7	6·1	6·2	13·1	8·3
Severe maternal outcome ratio‡	4·7	6·5	8·6	15·9	9·9
Intrahospital maternal mortality ratio§	0·0	36	246	279	158
Maternal severity score¶	1·5 (0·9)	2·3 (2·5)	3·0 (2·9)	1·9 (1·8)	2·2 (2·3)
Maternal severity index||	2·3% (9·3)	6·2% (18·3)	13·5% (25·0)	5·4% (15·8)	7·2% (18·8)

Data are n or mean (SD). SMO=severe maternal outcome (ie, maternal near miss or maternal death). *Number of women with potentially life-threatening disorders per 100 livebirths. †Number of maternal near-miss cases per 1000 livebirths. ‡Number of women with severe maternal outcomes per 1000 livebirths. §Limited to 7 days after pregnancy termination, per 100 000 livebirths. ¶Total number of markers of organ dysfunction (ie, life-threatening disorders listed in the appendix) in women with SMO (between-group difference p=0·0001). ||Model-estimated probability of maternal deaths in women with SMO (between-group difference p<0·0001).

Table 5: **Frequency and severity of complications related to pregnancy**

	Low MMR countries	Moderate MMR countries	High MMR countries	Very high MMR countries	Overall	p value
Coverage of prophylactic oxytocin	6123/7487 (81·8%)	122326/135337 (90·4%)	62018/70364 (88·1%)	91208/99471 (91·7%)	281675/312659 (90·1%)	0·4902
Coverage of therapeutic oxytocin*	528/648 (81·5%)	1758/1996 (88·1%)	601/712 (84·4%)	1164/1360 (85·6%)	4051/4716 (85·9%)	0·4471
Coverage of magnesium sulphate for eclampsia	3/4 (75·0%)	192/216 (88·9%)	230/286 (80·4%)	439/502 (87·5%)	864/1008 (85·7%)	0·2694
Coverage of prophylactic antibiotics for caesarean section	553/1547 (35·7%)	49126/53572 (91·7%)	15727/18975 (82·9%)	12719/15421 (82·5%)	78125/89515 (87·3%)	<0·0001
Coverage of parenteral antibiotics for sepsis	47/68 (69·1%)	475/562 (84·5%)	214/342 (62·6%)	218/244 (89·3%)	954/1216 (78·5%)	0·0453

Coverage indicators were calculated as the proportion of the target population who received the intervention. MMR=maternal mortality ratio.*For post-partum haemorrhage.

Table 6: **Coverage of key interventions by country group**

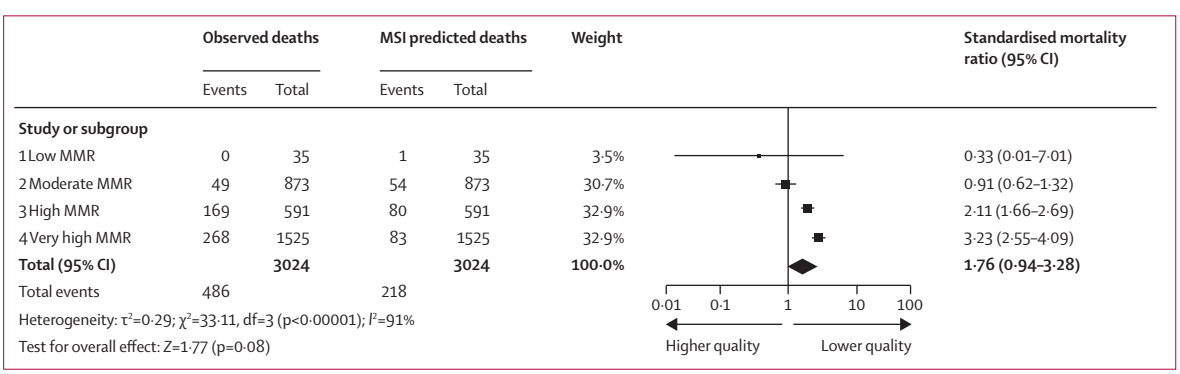

Figure 4: **Forest plot of standardised mortality ratio estimates according to country maternal mortality ratio**

Discussion

About 7% of our study population of 314623 women had potentially life-threatening disorders and about 1% developed an SMO. Despite the high coverage of interventions regarded as essential to prevent and treat key causes of maternal deaths in participating facilities, care performance and the outcomes of women overall were very variable. In our large network of health facilities, only a small proportion of women with an SMO did not receive the recommended essential intervention. The MSI was validated in this multicountry population.

To our knowledge, our investigation is the largest study to date assessing management of severe complications and the prevalence of maternal near miss by use of

Panel: **Research in context**

Systematic review

The WHO Department of Reproductive Health and Research periodically reviews studies of severe maternal morbidity and maternal near miss. In two published systematic reviews,[10,12] a growing interest was observed in the application of the idea of maternal near miss as an adjunct to maternal mortality reviews and assessments. However, the published literature has notable variation in the criteria used to identify maternal near-miss cases. This inconsistency triggered WHO to develop a standard set of criteria for identification of maternal near-miss cases, which focus on the recognition of organ dysfunction through clinical, laboratory, or management markers.[11]

Interpretation

In this study, the WHO criteria for identification of maternal near-miss cases were used with a criterion-based clinical audit approach to assess the quality of maternal health care in a large network of health facilities from 29 countries. This study improves on the methods previously used to assess the performance of maternal health care by providing external validation to the maternal severity index, which is a model-derived estimate of the probability of maternal mortality.[15] The findings provide information that can enable more objective assessment and benchmarking of the management of severe maternal morbidity. They also draw attention to the role of the so-called essential interventions for the reduction of maternal mortality. If substantial reductions in maternal mortality are to be achieved, universal coverage of life-saving interventions must be matched with comprehensive emergency care and overall improvements in the quality of maternal health care.

standardised definitions in several countries (panel). We were able to capture about 0·7% of the maternal deaths that occurred during a 3-month period worldwide. However, despite several procedures adopted to ensure appropriate study implementation and high quality data, some limitations need to be considered. The first limitation was the size of the WHOMCS and the number of personnel involved (>1500 collaborators). With a study of this size, standardisation of processes is a challenging task, but the different mechanisms we used (such as training, use of a visual check of the data collection forms before data entry, automated queries, double-checking of selected medical records, and thorough audit of unclear cases, especially maternal deaths) was expected to have reduced methodological heterogeneity and increased data quality as much as possible. The primary data source was routine hospital records, which might not be ideal in many settings. To address this issue, several facilities adopted the study data collection form as a platform for their medical records. In cases of unclear or missing information, medical staff were asked to complete the information in the record. To keep the data collection burden to a minimum and ensure feasibility, we only collected short-term (maximum 7 days after the end of pregnancy) in-hospital maternal and perinatal morbidity and mortality data. Some survivors might thus have died within the remaining puerperal and neonatal period. Moreover, in settings where basic laboratory tests were not available, underidentification of near-miss cases and underestimation of severity might have occurred. Unfortunately, in such settings, many women with unrecognised organ dysfunctions might die because of an absence of appropriate life support, worsening the ratio of maternal deaths to maternal near-miss cases. Another limitation was that the study design did not allow us to assess the adequacy of management of first and second stage of labour (eg, we did not assess the monitoring of labour and maternal-fetal wellbeing and the use of labour augmentation in case of delays or expedited delivery in case of fetal distress) and hence we report no data for the prevalence of prolonged or obstructed labour. Finally, the WHOMCS was done mainly in secondary and tertiary facilities, and these data might not be representative of maternal outcomes and coverage of essential interventions in smaller facilities or in the community.

Several factors potentially explain the mismatch between high coverage of essential interventions and the substantial variation in health outcomes noted in our study. The high coverage of essential interventions suggests that these interventions are available and used in most health facilities that took part in this study. Delays in implementation of these interventions or interventions poorly implemented could explain part of the excessive mortality and morbidity noted in some settings. Verticalisation of care (ie, application of single elements of care in disconnection of comprehensive care) could be an issue: other elements of care and quality might have a strong role in survival of severe maternal morbidity. In the context of post-partum haemorrhage, prophylactic and therapeutic uterotonics are essential but shock management and prompt surgical care are also vital. Magnesium sulphate is fundamental to the management of eclampsia, but other aspects of care (such as predelivery stabilisation, severe hypertension management, or airway management for adequate oxygenation and prevention of aspiration pneumonia) are also essential. The role of infection needs to be emphasised: prevalence of infection increased in our study as case severity increased (figure 3). Furthermore, prevalence of sepsis and other systemic infections was more than four times the prevalence of puerperal endometritis (table 3). This difference suggests that prevention, early identification, and appropriate management of secondary infections (eg, postoperative infection or aspiration pneumonia) and other non-obstetric infections should be regarded as a high priority. Another issue is that, in countries with a very high MMR, assessment of severity is often incomplete: severity is apparently underestimated because of a lack of information related to organ dysfunction. In settings where important constraints in the assessment of severity exist, the SMR tends to be somewhat inflated (SMR >3·0), suggesting not only excessive mortality but also underestimation of severity. Poor assessment of severity might contribute to delays in the implementation of effective interventions and poor clinical management. Health systems issues (such as referral processes), undernutrition, pre-existing moderate-to-severe anaemia and other factors could also have contributed to worse health outcomes.

In view of our study characteristics, our findings should not be regarded as representative of all countries, but indicative of the situation in a large sample of health facilities. The situation in the communities or in peripheral health facilities is likely to be different, especially in terms of coverage of essential interventions. The coverage of facility-based care in a specific geographical area might influence the frequency of complications reported at the facility level (eg, in countries with high coverage of births taking place in health-care facilities, the sample might have been diluted with low-risk cases). The external validation of the MSI model in this database encourages its use in other populations, and consideration should be given to the previously mentioned additional information provided by very high SMRs (>3·0). The MSI (and the derived SMR) can be used to monitor and assess the performance of health facilities providing care to women with complications related to pregnancy. The MSI allows adjustment for severity, improvements to comparisons between health facilities, and progress tracking over time. Finally, the MSI can assist health managers and policy makers in the decision-making process of allocation of resources: in a health system, facilities with poor performance and high burden of complications related to pregnancy can be objectively identified and clear prioritisation of investments can be made; in a single health facility, the MSI can be used to compare the facility performance of care against a benchmark and to track progress over time.

No quick fix exists to reduce maternal mortality. In our study, a high coverage of essential interventions did not imply reduced maternal mortality in the hospitals studied. If substantial reductions in maternal mortality are to be achieved, universal coverage of life-saving interventions needs to be matched with comprehensive emergency care and overall improvements in the quality of maternal health care.

Contributors

This project is the result of an international collaborative effort by a large group of institutions and researchers members of the WHO Multicountry Survey on Maternal and Newborn Health (WHOMCS) research group. JPS, JV, and AMG drafted the report on behalf of the WHOMCS Research Group with substantial contributions from BF, CCu, DG, EO-P, GC, JGC, KJ, LC, ML, MR, PL, RM, RP, and ZQ (alphabetical order). All members of the WHOMCS Research Group read and approved the final manuscript.

Conflicts of interest

We declare that we have no conflicts of interest.

Acknowledgments

The WHO Multicountry Survey on Maternal and Newborn Health is a research project implemented by the WHO in a global network of health facilities between 2010 and 2011. This project is part of the WHO response to the United Nations Secretary-General's call for action to improve women's and children's health around the world. WHO is grateful to the extensive network of institutions and individuals who contributed to the project design and implementation, including researchers, study coordinators, data collectors, data clerks, and other partners including the staff from the Ministries of Health and WHO offices. All listed authors are members of the WHOMCS Research Group. The WHOMCS Research Group is grateful to Maria Helena de Sousa (CEMICAMP, Campinas, Brazil) and Armando Seuc (WHO, Geneva, Switzerland) for their advice on statistical methods for analysis of complex samples and surveys.

References

1 WHO, UNICEF, UNFPA, World Bank. Trends in maternal mortality: 1990 to 2010. http://whqlibdoc.who.int/publications/2012/9789241503631_eng.psdf (accessed April 8, 2012).
2 United Nations. Global strategy for women's and children's health. http://www.who.int/pmnch/topics/maternal/201009_globalstrategy_wch/en/index.html (accessed Aug 3, 2012).
3 Darmstadt GL, Lee AC, Cousens S, et al. 60 million non-facility births: who can deliver in community settings to reduce intrapartum-related deaths? *Int J Gynaecol Obstet* 2009; **107** (suppl 1)**:** S89–112.
4 Wall SN, Lee AC, Carlo W, et al. Reducing intrapartum-related neonatal deaths in low- and middle-income countries—what works? *Semin Perinatol* 2010; **34:** 395–407.
5 Gabrysch S, Campbell OM. Still too far to walk: literature review of the determinants of delivery service use. *BMC Pregnancy Childbirth* 2009; **9:** 34.
6 WHO. Systems thinking for health system strengthening. http://whqlibdoc.who.int/publications/2009/9789241563895_eng.pdf (accessed Oct 11, 2012).
7 WHO. Quality of care: a process for making strategic choices in health systems. http://www.who.int/management/quality/assurance/QualityCare_B.Def.pdf (accessed Dec 3, 2012).
8 Campbell OM, Graham WJ, on behalf of *The Lancet* Maternal Survival Series steering group. Strategies for reducing maternal mortality: getting on with what works. *Lancet* 2006; **368:** 1284–99.
9 Pattinson R. Near miss audit in obstetrics. *Best Pract Res Clin Obstet Gynaecol* 2009; **23:** 285–86.
10 Say L, Pattinson RC, Gülmezoglu AM. WHO systematic review of maternal morbidity and mortality: the prevalence of severe acute maternal morbidity (near miss). *Reprod Health* 2004; **1:** 3.
11 Say L, Souza JP, Pattinson RC, WHO working group on Maternal Mortality and Morbidity classifications. Maternal near miss—towards a standard tool for monitoring quality of maternal health care. *Best Pract Res Clin Obstet Gynaecol* 2009; **23:** 287–96.
12 Tunçalp O, Hindin MJ, Souza JP, Chou D, Say L. The prevalence of maternal near miss: a systematic review. *BJOG* 2012; **119:** 653–61.
13 Souza JP, Cecatti JG, Faundes A, et al. Maternal near miss and maternal death in the World Health Organization's 2005 global survey on maternal and perinatal health. *Bull World Health Organ* 2010; **88:** 113–19.
14 Cecatti JG, Souza JP, Oliveira Neto AF, et al. Pre-validation of the WHO organ dysfunction based criteria for identification of maternal near miss. *Reprod Health* 2011; **8:** 22.
15 Souza JP, Cecatti JG, Haddad SM, et al, Brazilian Network for Surveillance of Severe Maternal Morbidity Group. The WHO maternal near-miss approach and the maternal severity index model (MSI): tools for assessing the management of severe maternal morbidity. *PLoS One* 2012; **7:** e44129.
16 Strand K, Flaatten H. Severity scoring in the ICU: a review. *Acta Anaesthesiol Scand* 2008; **52:** 467–78.
17 Higgins TL. Quantifying risk and benchmarking performance in the adult intensive care unit. *J Intensive Care Med* 2007; **22:** 141–56.
18 Souza JP, Gülmezoglu AM, Carroli G, Lumbiganon P, Qureshi Z; WHOMCS Research Group. The World Health Organization multicountry survey on maternal and newborn health: study protocol. *BMC Health Serv Res* 2011; **11:** 286.
19 Shah A, Faundes A, Machoki M, et al. Methodological considerations in implementing the WHO Global Survey for Monitoring Maternal and Perinatal Health. *Bull World Health Organ* 2008; **86:** 126–31.
20 WHO. Evaluating the quality of care for severe pregnancy complications: the WHO near-miss approach for maternal health. http://whqlibdoc.who.int/publications/2011/9789241502221_eng.pdf (accessed Nov 12, 2012).
21 Donner A, Klar N. Methods for comparing event rates in intervention studies when the unit of allocation is a cluster. *Am J Epidemiol* 1994; **140:** 279–89.
22 Rao JNK, Scott AJ. On chi-squared tests for multiway contingency tables with cell proportions estimated from survey data. *Ann Statist* 1984; **12:** 46–60.
23 Campbell MK, Mollison J, Steen N, Grimshaw JM, Eccles M. Analysis of cluster randomized trials in primary care: a practical approach. *Fam Pract* 2000; **17:** 192–96.

For more on the **Multicountry Survey on Maternal and Newborn Health and derivatives** see http://www.who.int/reproductivehealth/topics/maternal_perinatal/nearmiss