

BMJ Open Maternal death audit in Rwanda 2009–2013: a nationwide facility-based retrospective cohort study

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ABSTRACT

Objective: Presenting the results of 5 years of implementing health facility-based maternal death audits in Rwanda, showing maternal death classification, identification of substandard (care) factors that have contributed to death, and conclusive recommendations for quality improvements in maternal and obstetric care.

Design: Nationwide facility-based retrospective cohort study.

Settings: All cases of maternal death audited by district hospital-based audit teams between January 2009 and December 2013 were reviewed. Maternal deaths that were not subjected to a local audit are not part of the cohort.

Population: 987 audited cases of maternal death.

Main outcome measures: Characteristics of deceased women, timing of onset of complications, place of death, parity, gravida, antenatal clinic attendance, reported cause of death, service factors and individual factors identified by committees as having contributed to death, and recommendations made by audit teams.

Results: 987 cases were audited, representing 93.1% of all maternal deaths reported through the national health management information system over the 5-year period. Almost 3 quarters of the deaths (71.6%) occurred at district hospitals. In 44.9% of these cases, death occurred in the post-partum period. Seventy per cent were due to direct causes, with post-partum haemorrhage as the leading cause (22.7%), followed by obstructed labour (12.3%). Indirect causes accounted for 25.7% of maternal deaths, with malaria as the leading cause (7.5%). Health system failures were identified as the main responsible factor for the majority of cases (61.0%); in 30.3% of the cases, the main factor was patient or community related.

Conclusions: The facility-based maternal death audit approach has helped hospital teams to identify direct and indirect causes of death, and their contributing factors, and to make recommendations for actions that would reduce the risk of reoccurrence. Rwanda can complement maternal death audits with other strategies, in particular confidential enquiries and near-miss audits, so as to inform corrective measures.

Strengths and limitations of this study

- Rwanda is the first among low-income countries to implement maternal death audits (MDA) on a routine basis nationwide.
- Five years of MDA implementation in Rwanda provides a huge body of evidence on causes of death, substandard service factors and recommendations made to reduce the chance of reoccurrence, even though the occurrence of various forms of substandard case management and systemic flaws remains not entirely clear.
- This nationwide initiative to conduct audits of all cases of maternal death that occurred in health facilities is a demonstration of strong political will to improve maternal and newborn health.
- Not all maternal deaths were audited: cases that occurred in the community and some cases in health facilities are not included.
- Some information was incomplete or missing altogether; for instance, data on antenatal care attendance, gestational age, whether or not the woman was referred, and initial diagnosis and classification of the cause of death according to the International Classification of Diseases, 10th Revision (ICD-10).

INTRODUCTION

Globally, the maternal mortality ratio (MMR) has fallen by 45% between 1990 and 2013.¹ In the past 10 years, Rwanda has witnessed unprecedented improvements in many health outcomes, including those related to maternal health. The United Nations (UN) listed Rwanda as one of 11 countries that are ‘on track’ to achieve the Millennium Development Goal 5 (MDG5).² The WHO Countdown to 2015 report ranked Rwanda as the country with the highest average annual rate of maternal death reduction at 9%.³ From 1071 deaths per 100 000 live births in 2000,⁴ the MMR decreased to 320 per 100 000 live births in 2013.² Despite this achievement, Rwanda needs to do more for mothers and newborns in order to sustain

the trend and achieve the MDG5 target, set at 268 per 100 000 live births in 2015. One way of reducing maternal mortality is by improving the availability, accessibility, quality and use of services for the treatment of complications that arise during pregnancy and childbirth.⁵ Maternal death audit (MDA) is one of the strategies that have proven effective in improving the quality of obstetric care in Ethiopia, Nigeria and Senegal, and there are indications that the audits have helped reduce maternal mortality.^{6–10}

More than 90% of all deliveries in Rwanda nowadays take place in health centres and are assisted by trained health workers. Women who are detected with high-risk pregnancies are advised to deliver at the nearest district hospital. Those who are referred and in the possession of a community health insurance card pay a reduced fee when they deliver at a district hospital. Rwanda has 30 district hospitals that each serve a population of 200 000–350 000 and provide emergency obstetric care.

Since 2008, the Rwanda Ministry of Health has adopted three distinct approaches to MDA, namely Confidential Enquiry into Maternal Deaths (CEMD), facility-based death reviews, and community-based death reviews (also called verbal autopsy). Standard tools for these three approaches were adapted to the local context and health providers from all hospitals were trained. MDA committees have been established in all hospitals.

The objective of this study is to present the results of the first 5 years of MDA implementation in Rwanda including maternal death classification, identification of substandard (care) factors that have contributed to death, and conclusive recommendations for quality improvement in maternal and obstetric care.

METHODS

Maternal death audit

Since 2008, MDA committees have been established in all Government-owned, private-owned and church-owned hospitals in Rwanda. These committees are chaired by the medical chief of staff or the head of the maternity department and they further typically comprise staff working in the maternity and/or neonatology departments. All health staff who provided care to a woman who died of pregnancy-related causes while pregnant or around delivery are supposed to attend the audit session. Cases that occurred at health centres are audited by the MDA committee of the nearest district hospital; the committee will then include staff who were involved in case management at that particular health centre.

All hospitals started conducting facility-based MDA in January 2009 and have since been making recommendations aimed at reducing maternal and neonatal mortality. The soft or hard copies of all audit session reports are being collected at the central level (Ministry of Health), where a designated focal person from the

Maternal and Child Health department saves these in an electronic database. The individual case reports are compiled by the local audit committees. They contain information on women's individual characteristics, the place of delivery and death, the reported causes of death, any substandard factors detected and the recommendations made by the respective hospital MDA committees. When auditing a maternal death, the committee reviews and sometimes further specifies the cause of death recorded in the patient notes. The cause of death is reported in narrative form, without necessarily using the International Classification of Diseases, 10th Revision (ICD-10) classification. The audit committee sessions attempt to distinguish factors on the side of health services that have contributed to maternal death from behavioural factors on the side of the patient and the community. Confidentiality of both the patient and the clinician is maintained during the auditing process. The standard form that is used and the reports that are submitted to the Ministry of Health do not indicate any names; and the protocol stipulates that 'no one should be blamed'.

Study design

All cases of MDA by hospital-based audit teams between January 2009 and December 2013 were reviewed. These constituted our retrospective cohort. Maternal deaths that happened over this period at district hospitals or one of the surrounding health centres, but which were not subjected to a local audit, are not part of the cohort. The latter cases might have been reported through the routine health management information system.

Data analysis

The data were stored in Microsoft Excel, and the variables included age of the woman, residence, number of children alive and number who had died, timing of onset of complications, place of delivery, place of death, parity, gravida, antenatal clinic attendance, reported cause of death, service factors and individual factors identified by committees as having contributed to maternal death and recommendations made by the district MDA committee. All cases saved in the database over the 5-year period were analysed. Data on the number of maternal deaths and births reported by health facilities were obtained from the national Health Information Management System (HIMS), which captures data from public and private facilities. Maternal characteristics and causes of death were compared between the five 1-year periods using χ^2 test for dichotomous variables and Student t test for numerical variables; 95% CIs for maternal mortality rates were calculated using Fisher's exact test.

RESULTS

Over the 5-year period, 1060 maternal deaths were recorded through HIMS on a total of 1 533 177 births that occurred in health facilities. Over the same period,

987 MDA reports were received from three referral hospitals, 42 district hospitals and 62 health centres. Table 1 shows the health facility-based MMR and the proportion of deaths audited by local committees. The overall facility-based MMR using maternal deaths and births reported by HIMS was calculated at 69.1 per 100 000 live births (95% CI 65.1 to 73.4) with 93.1% of all deaths that were audited. Since 2011, there has been a decrease in facility-based MMR.

Maternal characteristics

The mean age of the women who died was 29.7 years (± 7.0). Only 26 (2.7%) of the audited cases involved women aged 18 years or less. Women were on average at their third pregnancy (± 2.4). The median parity was 2 (range 1–14). Among the audited cases, women had an average of 2.2 children alive (± 2.0). The average number of antenatal care (ANC) visits was 2.1 (± 1.3), with 12.4% of women who had never attended ANC and 7.5% who had attended four times or more (table 2).

The cases were similar across the five calendar years (excluding missing data) with respect to age, marital status, gravida and number of children alive, but they were different with respect to parity and number of antenatal consultations. The proportion of women who did not attend ANC decreased significantly over time ($p=0.03$). Over time, there was a significant decrease in missing data for all relevant maternal characteristics.

Place of death, place of delivery and onset of complications

Of all maternal deaths, 71.6% occurred at district hospitals, 7.2% at health centres and 21.1% at referral hospitals. Only 4.6% of women had delivered at home and most deliveries (57.1%) occurred at a district hospital. Of the cases who died at a health centre, 62% had also delivered at a health centre; likewise, 67.7% of cases who died at a district hospital had delivered their baby at the same place. In 44.9% of the cases, death occurred in the post-partum period with 33.9% who died during pregnancy, while 21.2% died in the intra-partum period (not shown in the tables).

Cause of death

Seventy per cent of maternal deaths were due to direct causes, with post-partum haemorrhage as the leading direct cause (22.7% of all cases; table 3). Obstructed labour was the second most important direct cause (12.3%), followed by obstetric infection (10.3%) and eclampsia (9.4%). The proportion of cases due to abortion increased significantly in the latter 2 years, from around 3% earlier on to 5.7% in 2012 and 7% in 2013 ($p<0.001$). Indirect causes accounted for 25.7% of maternal deaths, with malaria as the leading cause (7.5%), followed by non-obstetric infection, such as pneumonia and other sepsis (4.5%). While malaria as the reported main cause of death was very low in 2011, a huge increase was observed in 2013 ($p<0.001$). The

Table 1 Health facility-based MMR and proportion of maternal deaths audited

	2009	2010	2011	2012	2013	Total 5 years
Health facility deliveries	334 510	341 066	277 508	285 385	294 708	1 533 177
Maternal deaths reported through HIMS	174*	198*	248	221	219	1060
Deaths audited	171	229	198	175	214	987
Percentage audited	98.3	115.7	79.8	79.2	97.7	93.1
Facility-based MMR per 100 000 live births (95% CI)	52.0 (44.8 to 60.4)	67.1 (69.0 to 76.4)	89.4 (78.9 to 101.2)	77.4 (67.9 to 88.4)	74.3 (65.1 to 84.8)	69.1 (65.1 to 73.4)

*Up to 2010, maternal deaths reported through HIMS were limited to cases that had happened in maternity departments; from 2011 onwards, maternal deaths that occurred in other hospital departments were included.

HIMS, Health Information Management System; MMR, maternal mortality ratio.

Table 2 Characteristics of deceased women

	2009 (N=171)	2010 (N=229)	2011 (N=198)	2012 (N=175)	2013 (N=214)	Total for 5 years (N=987)	Significance (p value)
Age, mean 29.7 years (± 7.0)							
≤18	4.1	0.9	1.5	4.6	2.8	2.6	NS
19–34	64.9	69.9	66.7	65.7	74.3	68.6	
≥35	28.7	28.4	31.3	29.1	22.0	27.8	
Missing	2.3	0.9	0.5	0.6	0.9	1.0	
Marital status							
Married	71.3	72.1	84.3	85.7	93.0	81.4	NS
Unmarried	8.2	8.3	7.1	7.4	6.1	7.4	
Missing	20.5	19.7	8.6	6.9	0.9	11.2	
Gravida, mean 3.4 (± 2.4)							
G1	7.0	29.3	23.7	29.7	26.2	23.7	NS
G2–G4	12.9	31.9	42.9	36.0	44.9	34.3	
G5+	9.4	33.6	31.3	31.4	26.6	27.1	
Missing	70.8	5.2	2.0	2.9	2.3	14.9	
Parity, median: 2, (range 1–14)							
P0	5.8	15.3	8.1	9.7	7.9	9.6	0.003
P1	7.0	22.7	25.8	32.0	31.8	24.2	
P2–P4	8.8	35.8	38.4	33.1	44.4	33.0	
P5+	7.6	20.5	25.8	22.3	13.6	18.1	
Missing	70.8	5.7	2.0	2.9	2.3	15.0	
ANC visits, mean 2.1 (± 1.3)							
0	24.6	12.7	9.1	3.4	12.6	12.4	0.03
1	9.9	8.3	7.1	6.9	6.5	7.7	
2–3	29.8	26.6	29.8	22.3	18.2	25.2	
4 or more	8.8	7.9	9.6	6.9	4.7	7.5	
Missing	47.2	26.9	44.5	44.4	60.6	57.9	

ANC, antenatal care; NS, not significant.

proportion of unknown causes of death decreased over the 5 years, from 6.4% in 2009 to 1.4% in 2013, although this is not statistically significant. Online supplementary figure S1 depicts the trends.

Substandard care versus community factors

Factors related to provision of substandard care were identified for 61.1% of the cases, against almost one-third of the cases (30.3%) in which the main contributory factors were patient or community related; for the remaining 7.9%, the committees did not or were not able to assess the main contributory factor and in seven cases (0.7%) they did not identify any factor (see online supplementary box 1).

Recommendations made by audit committees

Table 4 summarises the types of recommendations made by the respective audit committees for 902 cases, out of the total of 987 maternal deaths. For the remaining 85 deaths, the audit committees did not make any recommendation, mostly because the death could not be attributed to any factors or the cause of death was not established.

DISCUSSION

This is the first study that reports the results of a national health facility-based review of maternal deaths in a low-

income country for such a long period (5 years). In resource-constrained environments, MDA may be done in certain types of health facilities only, in some regions only and not for an extended period of time.^{6–18} Our study provides an analysis of nearly 1000 women who died during pregnancy, childbirth or in the post-partum period, and of the reported causes of death, the factors surrounding their death and the recommendations made by the respective audit committees to avoid similar deaths in the future. This nationwide initiative to conduct clinical audits of all cases of maternal death that occur in health facilities is a demonstration of strong political will to improve maternal and newborn health. As has been shown elsewhere, political will is of prime importance to bring about change.^{19–20} MDA as a nationwide strategy in Rwanda is part of a much broader package of interventions aimed at improving maternal and child health indicators and strengthening the national health system as a whole. These include national-level support to a dense network of community health workers, community-based health insurance, the use of Information and Communication Technology (ICT) and mobile telephones for performance monitoring and performance-based financing, among others.^{21–23}

The 5 years average health facility-based MMR (64.4 per 100 000) found in this study is much lower than the ratio reported in the 2010 Rwanda Demographic and Health Survey (DHS; 476 per 100 000)²⁴ and other

Table 3 Causes of maternal death

	2009	2010	2011	2012	2013	Total for 5 years	Significance (p value)
Direct causes	63.7	68.6	71.7	72.6	71.0	69.6	NS
Post-partum haemorrhage	15.8	20.1	25.8	27.4	24.3	22.7	NS
Obstructed labour	14.6	11.8	11.6	9.1	14.0	12.3	NS
Obstetric infection*	9.9	8.7	13.6	10.9	8.9	10.3	NS
Eclampsia	8.8	8.3	9.1	14.3	7.5	9.4	NS
Abortion	2.9	3.1	3.0	5.7	7.0	4.4	<0.001
Anaesthesia complication	3.5	4.8	2.5	1.1	2.8	3.0	NS
Amniotic embolism	1.8	5.2	1.0	0.0	2.8	2.3	0.005
Intra-partum haemorrhage	2.9	1.3	1.5	2.3	0.9	1.7	NS
Abnormal pregnancy†	2.3	2.2	0.5	1.7	1.4	1.6	NS
Ante-partum haemorrhage	0.6	2.2	3.0	0.0	0.0	1.2	0.013
Other direct causes	0.6	0.9	0.0	0.0	0.9	0.5	NS
Indirect causes	29.8	26.2	23.2	21.7	27.6	25.7	NS
Malaria	11.1	8.3	0.5	6.3	11.2	7.5	<0.001
Non-obstetric infection‡	4.7	4.4	6.6	2.3	4.2	4.5	NS
AIDS	5.3	3.9	4.5	1.1	1.9	3.3	NS
Other indirect causes	2.3	3.1	4.0	2.9	2.3	2.9	NS
Cardiac failure	1.2	3.1	3.0	2.3	1.9	2.3	NS
Anaemia	2.9	2.2	1.5	2.9	1.9	2.2	NS
Pulmonary embolism	0.6	0.9	1.0	1.7	3.3	1.5	NS
Gynaecological cancer	1.8	0.0	0.0	1.1	0.9	0.7	NS
Other cancers	0.0	0.9	1.5	0.6	0.9	0.8	NS
Unknown cause	6.4	5.2	5.1	5.7	1.4	4.7	0.135

*Obstetric infections: postoperative peritonitis, post-partum peritonitis, amnionitis.

†Abnormal pregnancy: ectopic pregnancy, molar pregnancy.

‡Non-obstetric infection: pneumonia, meningitis.

NS, not significant.

estimates.^{2 25} This could be due to the under-reporting of maternal deaths through HIMS, especially before 2011, when only deaths that occurred in maternity departments were reported. This also explains why there were more audited maternal deaths in 2010 than cases of maternal mortality reported through HIMS (table 1). In addition, there may be other maternal deaths that happened in the community and these are neither captured in the HIMS nor by audits. One could assume that the direct and indirect causes of death, and the role of community versus service factors, among cases that do not get notified are different from the picture that emerges from the MDA. Under-reporting of maternal morbidity and mortality is a very common phenomenon, even in specialised healthcare facilities in Europe, where sometimes over half of the deaths are missed.^{26 27}

Even though the national health policy in Rwanda recommends that all cases of maternal death be reviewed, this does not always happen. However, the proportion of maternal deaths actually audited was high compared with that in other low-income countries, where facility-based maternal death review is usually introduced in some parts of the country only (eg, in Senegal, Ethiopia, Nigeria).^{8–10}

The percentage of unknown causes decreased, which suggests an improvement in the quality of the internal audits. Characteristics of deceased women were similar

to those found in maternal death reviews conducted in other countries.^{11–15} Only 2.7% of deceased women were aged 18 years or below, unlike in other countries, where teenagers formed a much larger proportion of maternal deaths.^{9 10 16} This may be due to the relatively low rate of teenage pregnancies in Rwanda (6% of all pregnancies).⁴ In many low-income countries, low antenatal clinic attendance is considered a risk factor for maternal death and this also holds for Rwanda.^{10 11 17} According to the 2010 DHS, 98% of women visited antenatal clinics at least once, while only 35% attended at least four times (the minimum recommended number), which is high compared with the population study.⁴ Having the first antenatal consultation during the first trimester of pregnancy with regular follow-up visits allows for early detection of risk factors for eclampsia and other conditions that are dangerous for mother and child, such as HIV and malaria, and therefore it can contribute to maternal mortality reduction.¹⁶ The fact that only 4.6% of the women who died delivered at home does not warrant any conclusions about home deliveries as a risk factor. The figure is in line with HIMS data (<10% of home deliveries in 2013),²⁸ although it is much lower than the latest DHS estimate (31% home deliveries in 2010).⁴ We may expect a much lower proportion of home deliveries in the next DHS in 2015.

Table 4 Recommendations made by maternal death audit committees

<p>Management of obstetric complications</p> <ul style="list-style-type: none"> ▶ Reinforce postoperative follow-up ▶ Close monitoring after anaesthesia injection ▶ Reinforce post-partum follow-up ▶ Reinforce the use of partograph ▶ Reinforce hygienic measures in the post-operative period ▶ Reinforce follow-up for patient admitted for obstetrical pathology ▶ Reinforce quality of ANC ▶ Adhere to protocols ▶ Close follow-up in case of blood transfusion ▶ Reinforce HIV patient follow-up by including home visit ▶ Reinforce preoperative preparation <p>Availability of medicines and infrastructure</p> <ul style="list-style-type: none"> ▶ Ensure the availability of blood, especially Rhesus negative ▶ Avail emergency kits, laboratory test ▶ Avail resuscitation materials and anaesthesia equipment ▶ Avail intravenous antihypertensive treatment ▶ Refer patient in a critical condition to the ICU <p>Referral system</p> <ul style="list-style-type: none"> ▶ Refer patient with complications on time to a higher level ▶ Provide adequate pretransfer treatment ▶ Avail more ambulances 	<p>Population sensitisation on</p> <ul style="list-style-type: none"> ▶ Consulting health facility on time ▶ Complying with medical advice and treatment ▶ Use of mosquito net by pregnant women ▶ Delivering at a health facility ▶ Improving hygiene especially in the post-partum period ▶ Not relying on traditional medicine ▶ Preparing for delivery and buying their medical insurance <p>Human resources</p> <ul style="list-style-type: none"> ▶ Training on emergency obstetric and neonatal care, especially on surgery ▶ Increase number of health providers ▶ Hire an anaesthesia technician ▶ Training on resuscitation procedures <p>Communication</p> <ul style="list-style-type: none"> ▶ Reinforce communication among staff and between departments within the hospital ▶ Reinforce communication between health facilities ▶ Reinforce communication between health providers and patients
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ANC, antenatal care; ICU, intensive care unit.

Direct obstetric causes were found to be the underlying cause in the majority of cases of maternal death reviewed during the 5-year period; this finding is in line with studies in other low-income and middle-income countries.^{7 12 13 15} Some European countries experienced similar situations; for instance France, where direct causes accounted for 66.2% of all maternal deaths.²⁹ Indirect causes accounted for about a quarter of all maternal deaths, with malaria as the leading cause in that category, followed by non-obstetric infection such as pneumonia and other sepsis. In some African countries,^{30 31} especially in Southern Africa, HIV-related infection is the predominant indirect cause and also indirect causes were the major causes in many developed countries.^{25 32} The present study identified post-partum haemorrhage as the leading cause of maternal death and this is similar to the case in many other African countries.^{15 33} In other studies, haemorrhage is reported as a cause of death without specifying the time of its occurrence (before, during or after delivery).^{11 13} In other settings, hypertensive disorders were the leading cause.^{12 16} In our case, obstructed labour was the second most important cause of death. However, Rwanda has a caesarean section rate of 14%,²⁸ which is on the higher end of the WHO recommended range of 5–15%. This calls for further investigation.^{34–36}

The proportion of cases due to complications around abortion increased significantly since 2011. The latter two causes need further research to analyse the underlying reasons. The government of Rwanda has recently started to decentralise postabortion care services at health centres and our findings underscore the importance of doing so. The fluctuation in maternal deaths due to malaria can be attributed to the general variation in morbidity due to malaria in the whole population. Malaria was the third most frequent cause of death in 2013 (7.2%) among the general population and also the third most important cause of morbidity among outpatients at health facilities (10.6%).²⁸ The significant decrease in the proportion of unknown causes of death over the 5 year period suggests that the audit committees gradually gained more confidence in establishing and reporting the cause of death. Some of the changes observed over time, however, may not reflect real trends because of inadequate diagnostic capacity, under-reporting of induced abortion as a cause of death, or increased awareness of a particular condition following training and/or closer monitoring.

The committees identified various aspects of substandard care as contributing to the majority of deaths, many of which are avoidable (see online supplementary figure S2). This is in line with findings from other studies from

both high-income and low-income countries.^{7 15 29 30 32 37 38}

However, there is room to improve the template used in Rwanda to audit and report maternal deaths; in particular, the precise inadequacies in obstetric case management would need to be spelt out in greater detail, which could help the audit teams to come up with remedial actions that are more concrete. Implementation of the recommendations highlighted in table 4 should be prioritised in order to further improve the quality of maternal and obstetric services.

CONCLUSIONS

MDA can be implemented routinely and nationwide even in low-income countries as shown by the high coverage of maternal deaths audited in Rwanda. Implementation of audit recommendations is likely to have contributed to the reduction of maternal deaths in the past few years. There do not seem to be major barriers among clinicians and other health workers to conduct audits and investigate the possible role of systemic or incidental flaws in service delivery. The audits have helped to classify the causes of maternal deaths and identify factors surrounding them, and to make recommendation for changes in professional care and behaviour in the community. The standard forms that are used for such audits should be reviewed in order to capture important information that is currently missing, such as the gestational age, whether or not the woman was referred as well as the initial diagnosis and classification of the causes of death according to the ICD-10. There is scope for inclusion of information from verbal autopsy in order to complete the facility-based approach by assessing community factors contributing to maternal death. A national maternal death surveillance committee would need to be put in place so as to regularly inform policymakers. Since maternal death can be seen as the tip of an iceberg of wider problems in maternal and obstetric care, near-miss audits could be considered so as to better understand the processes leading to poor maternal outcomes. The experience gained from facility-based approaches provides a good opportunity to introduce both confidential enquiry and near-miss audit as complementary methods to address maternal morbidity and mortality.

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REFERENCES

1. WHO, UNICEF, UNFPA, World Bank and the United Nations Population Division. Trends in Maternal Mortality: 1990 to 2013. Estimates by WHO, UNICEF, UNFPA, World Bank and the United Nations Population Division. WHO Geneva, 2014.
2. WHO. Global Health Observatory (GHO) data/Maternal and reproductive health. Maternal mortality 2013. http://www.who.int/gho/maternal_health/en/ (cited 1/10/2013).
3. Countdown to 2015: building a future for women and children. The 2012 report.
4. Rwanda National Institute of Statistics. *Rwanda Demography and Health Survey 2000*. Rwanda, 2002.
5. WHO. *Integrated Management of Pregnancy and Childbirth. WHO Recommended Interventions for Improving Maternal and Newborn Health*. Geneva, 2009.
6. Dumont A, Gaye A, de Bernis L, *et al*. Facility-based maternal death reviews: effects on maternal mortality in a district hospital in Senegal. *Bull World Health Organ* 2006;84:218–24.
7. Gebrehiwot Y, Tewolde B. Improving maternity care in Ethiopia through facility based review of maternal deaths and near misses. *Int J Gyn Obst* 2014;127:S29–34.
8. Hofman J, Mohammed H. Experiences with facility-based maternal death reviews in northern Nigeria. *Int J Gyn Obst* 2014;126:111–14.
9. Dumont A, Tourigny C, Fournier P. Improving obstetric care in low-resource settings: implementation of facility-based maternal death reviews in five pilot hospitals in Senegal. *Hum Resour Health* 2009;7:61.
10. Samuel H, Fikre E, Yemane B. Health facility-based maternal death audit in Tigray, Ethiopia. *Ethiop J Health Dev* 2009;23:115–19.
11. Onesmus M, Agnes W. Maternal mortality in Central Province, Kenya, 2009–2010. *Pan Afr Med J* 2014;17:201.
12. Olufemi T, Mustafa A, Tuminu A. Maternal deaths in Sagamu in the new millennium: a facility-based retrospective analysis. *BMC Pregnancy Childbirth* 2006;6:6.
13. Asamoah BO, Moussa KM, Stafstrom M, *et al*. Distribution of causes of maternal mortality among different socio-demographic groups in Ghana; a descriptive study. *BMC Public Health* 2011;11:159.
14. Lori JR, Starke AE. A critical analysis of maternal morbidity and mortality in Liberia, West Africa. *Midwifery* 2012;28:67–72.
15. Kongnyuy EJ, Mlava G, Van den Broek N. Facility-based maternal death review in three districts in the central region of Malawi—an analysis of causes and characteristics of maternal deaths. *Womens Health Issues* 2009;19:14–20.
16. Nyamtema A, Bartsch A, Urassa D, *et al*. Using audit to enhance quality of maternity care in resource limited countries: lessons learnt from rural Tanzania. *BMC Pregnancy Childbirth* 2011;11:94.
17. Ujah I, Aisien O, Muthir J, *et al*. Factors contributing to maternal mortality in North-Central Nigeria: a seventeen-year review. *Afr J Reprod Health* 2005;9:27–40.
18. Yego F, D'Este C, Byles J, *et al*. Risk factors for maternal mortality in a tertiary hospital in Kenya: a case control study. *BMC Pregnancy Childbirth* 2014;14:38.
19. van Lerberghe W, Matthews Z, Achadi E, *et al*. Country experience with strengthening of health systems and deployment of midwives in countries with high maternal mortality. *Lancet* 2014;384(9949):1215–25.
20. van Dillen J, Stekelenburg J, Schutte J, *et al*. The use of audit to identify maternal mortality in different settings: is it just a difference between the rich and the poor? *World Health Popul* 2007;9:5–13.
21. Binagwaho A, Farmer PE, Nsanzimana S, *et al*. Rwanda 20 years on: investing in life. *Lancet* 2013;384:371–5.
22. Bucagu M, Kagubare JM, Basinga P, *et al*. Impact of health systems strengthening on coverage of maternal health services in Rwanda, 2000–2010: a systematic review. *Reprod Health Matters* 2012;20:50–61.
23. Basinga P, Gertler PJ, Binagwaho A, *et al*. Effect on maternal and child health services in Rwanda of payment to primary health-care providers for performance: an impact evaluation. *Lancet* 2011;377:1421–8.



24. Rwanda National Institute of Statistics. *Rwanda Demography and Health Survey 2010*. Rwanda, 2012.
25. Kassebaum N, Bertozzi A, Coggeshall M, *et al*. Global, regional, and national levels and causes of maternal mortality during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014;384:980–1004.
26. Clark S, Belfort M, Dildy G, *et al*. Maternal death in the 21st century: causes, prevention, and relationship to cesarean delivery. *Am J Obstet Gynecol* 2008;199:36.e1–5; discussion 91–2. e7–11.
27. Zwart J, Yazdani S, Harvey M, *et al*. Underreporting of major obstetric haemorrhage in the Netherlands. *Transfus Med* 2010;20:118–22.
28. Rwanda Ministry of Health. *Rwanda Annual Health Statistical Booklet 2013*. Kigali, 2013.
29. Saucedo M, Tharaux C, Bouvier M. Ten years of confidential inquiries into maternal deaths in France, 1998–2007. *Obstet Gynecol* 2013;122:752–60.
30. South Africa Department of Health. *Saving Mothers 2008–2010: fifth comprehensive report on confidential enquiries into maternal deaths in South Africa*. South Africa, 2012.
31. van Dillen J, Meguid T, van Roosmalen J. Maternal mortality audit in a hospital in Northern Namibia: the impact of HIV/AIDS. *Acta Obstet Gynecol Scand* 2006;85:499–500.
32. Cantwell R, Clutton-Brock T, Cooper G, *et al*. Saving Mothers' Lives: reviewing maternal deaths to make motherhood safer: 2006–2008. The eighth report of the Confidential Enquiries into maternal deaths in the United Kingdom. *BJOG* 2011; 118(Suppl 1):1–203.
33. Dongol A, Shrestha A, Chawla C. Post partum haemorrhage: prevalence, morbidity and management pattern in Dhulikhel Hospital. *Kathmandu Univ Med J* 2010;8:212–15.
34. Althabe F, Belizan JM. Caesarean section: the paradox. *Lancet* 2006;368:1472–3.
35. Ronsmans C, Graham W. Maternal mortality: who, when, where, and why. *Lancet* 2006;368:1189–200.
36. Vogel JP, Bétran AP, Vindevoghel N, *et al*. Use of the Robson classification to assess caesarean section trends in 21 countries: a secondary analysis of two WHO multicountry surveys. *Lancet Glob Health* 2015;3:e260–70.
37. van den Akker T, van Rhenen J, Mwagomba B, *et al*. Reduction of severe acute maternal morbidity and maternal mortality in Thyolo District, Malawi: the impact of obstetric audit. *PLoS ONE* 2011;6:e20776.
38. Gunawan S, Wirth E, Achadi E, *et al*. A district-based audit of the causes and circumstances of maternal deaths in South Kalimantan, Indonesia. *Bull World Health Organ* 2002;80: 228–34.