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Complete List of Authors:	Sayinzoga, Felix; Ministry of Health, Maternal, Child and Community Health Bijlmakers, Leon; Radboud University Medical Center, Radboud Institute for Health Sciences (RIHS), Health Evidence Van Dillen, Jeroen; Radboud University Medical Center, Obstetrics Mivumbi, Victor; Ministry of Health, Maternal, Child and Community Health Ngabo, Fidèle; Ministry of Health, Maternal, Child and Community Health Van der Velden, Koos; Radboud University Medical Centre, Primary and Community Care
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Maternal death audit in Rwanda 2009-2013: a nationwide facility-based retrospective cohort study

Felix Sayinzoga, Rwanda Ministry of Health, Rwanda Biomedical Center, Maternal, Child and Community Health Division, Maternal Health Senior Officer. Rwanda Ministry of Health Office, PO Box 84 Kigali. felix.sayinzoga@gmail.com +250788517814

Leon Bijlmakers, Radboud University Medical Centre Nijmegen, the Netherlands, Department for Health Evidence, senior researcher. leon.bijlmakers@radboudumc.nl +31243613337

Jeroen van Dillen, Radboud University Medical Centre Nijmegen, the Netherlands, Department of Obstetrics and Gynaecology, gynaecologist, chef de clinique. jeroen.vandillen1@radboudumc.nl

Victor Mivumbi, Rwanda Ministry of Health, Rwanda Biomedical Center, Maternal, Child and Community Health Division, Maternal death audit focal point. mivumbi.victor@gmail.com

Fidèle Ngabo, Rwanda Ministry of Health, Rwanda Biomedical Center, Maternal, Child and Community Health Division, Head of division. ngabog@yahoo.fr

Koos van der Velden, Radboud University Medical Centre Nijmegen, the Netherlands, Department of Primary and Community Care, professor of Public Health. koos.vandervelden@radboudumc.nl

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ABSTRACT

Objective: Presenting the results of five years of experience with 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 committees 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 committees.

Results: 987 cases were audited, representing 93.1% of all maternal deaths reported through the national health management information system over the five-year period. Almost three quarters of the deaths (71.6%) occurred at district hospitals. In 44.9% of these cases, death occurred in the postpartum period. Seventy percent were due to direct causes, with post-partum haemorrhage as leading cause (22.7%), followed by obstructed labour (12.3%). Indirect causes accounted for 25.7% of maternal deaths, with malaria as 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, sub-standard service factors and recommendations made to reduce the chance of reoccurrence.
- 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 new-born 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 ICD-10.

INTRODUCTION

Globally, the maternal mortality ratio (MMR) has fallen by 45% between 1990 and 2013.[1] In the last ten years, Rwanda has witnessed unprecedented improvements in many health outcomes, including those related to maternal health. The UN listed Rwanda as one of 11 countries that are 'on track' to achieve the 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 1,071 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 MDG 5 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 is one of the strategies that have proven effective to improve the quality of obstetric care.[6, 7]

Since 2008, the Rwanda Ministry of Health has adopted three distinct approaches to maternal death audit (MDA), namely, confidential enquiry into maternal deaths, 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. Maternal death audit committees have been established in all hospitals.

The objective of this study is to present the results of the first five 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, maternal death audit committees have been established in all hospitals in Rwanda. These committees are chaired by the medical chief of staff or the head of the maternity department and they are further composed by staff working in maternity and the neonatology department. All health providers who were involved in the provision of care of a particular woman who died of pregnancy-related causes while pregnant or around delivery are also supposed to attend the audit session. All cases that occurred at health centres are audited by the MDA committee of the district hospital, which would then include health providers who were involved in case management at the health centre. All hospitals started conducting facility-based maternal death audits 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 data base. 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. 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.

Study design

All cases of maternal death audited by hospital-based audit committees 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 five-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 (HMIS). Maternal characteristics and causes of death were compared between the five one-year periods using X^2 test for dichotomous variables and T-test for numerical variables. 95% confidence intervals for maternal mortality rates are calculated using Fisher's exact test.

RESULTS

Over the five-year period, 1060 maternal deaths were recorded through HMIS on a total of 1,533,177 births that occurred in health facilities. Over the same period, 987 maternal death audit reports were received, from three referral hospitals, 42 district hospitals and 62 health centres. Table 1 shows the health facility-based maternal mortality ratio (MMR) and the proportion of deaths audited by local committees. The overall facility-based MMR using maternal deaths and births reported by HMIS was calculated at 69.1 per 100,000 live births (95% CI 65.1-73.4) with 93.1% of all deaths that were audited. Since 2011, there has been a decrease in facility-based MMR.

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
% 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 (44.8-60.4)	67.1 (69.0-76.4)	89.4 (78.9-101.2)	77.4 (67.9-88.4)	74.3 (65.1-84.8)	69.1 (65.1-73.4)

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

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 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).

Table 2. Characteristics of deceased women

	2009 (N=171)	2010 (N=229)	2011 (N=198)	2012 (N=175)	2013 (N=214)	Total for 5 yrs (N=987)	Significance (p value)
Age Mean 29.7 years (±7.0)							
≤ 18 years	4.1	0.9	1.5	4.6	2.8	2.6	NS
19-34 years	64.9	69.9	66.7	65.7	74.3	68.6	
≥35 years	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 to 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	

Compared among the five calendar years and not considering missing data, the cases were similar with respect to age, marital status, gravida and number of children alive, but differed 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, 62.0% 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 postpartum 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

70% 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 last two 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 proportion of unknown causes of death decreased over the five years, from 6.4% in 2009 to 1.4% in 2013, although this is not statistically significant. Figure 1 in the Appendix depicts the trends.

Sub-standard care versus community factors

Factors related to provision of sub-standard care were identified for 61.1% of the cases, against almost a 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 (Box 2 and Figure 1 in Appendix).

Table 3. Causes of maternal death

	2009	2010	2011	2012	2013	Total for 5 years	Sign.
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: Post-operative peritonitis, post-partum peritonitis, amnionitis
** Abnormal pregnancy: Ectopic pregnancy, molar pregnancy
*** Non-obstetric infection: Pneumonia, meningitis

Recommendations made by audit committees

Box 1 summarizes 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.

Box 1. Recommendations made by maternal death audit committees

Management of obstetric complications	**Population sensitization on**
• Reinforce post-operative follow up • Close monitoring after anaesthesia injection • Reinforce post-partum follow up • Reinforce the use of partograph • Reinforce hygienic measures in 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 pre-operative preparation	• Consulting health facility on time • Complying with medical advice and treatment • Using of mosquito net by pregnant women • Delivering at a health facility • Improving hygiene especially in post-partum period • Not relying on traditional medicine • Preparing for delivery and buy their medical insurance
Availability of medicines and infrastructure	**Human resources**
• Ensure the availability of blood, especially Rhesus negative • Avail emergency kits, lab test • Avail resuscitation materials and anaesthesia equipment • Avail intravenous anti-hypertensive treatment • Refer patient in critical condition in ICU	• Training on emergency obstetric and neonatal care, especially on surgery • Increase number of health providers • Hire an anaesthesia technician • Training on resuscitation procedures
Referral system	**Communication**
• Refer patient with complications on time to a higher level • Provide adequate pre-transfer treatment • Avail more ambulances	• Reinforce communication among staff and between departments within the hospital • Reinforce communication between health facilities • Reinforce communication between health providers and patients

DISCUSSION

This study is the first one that reports the results of a national health facility-based review of maternal deaths in a low-income country for such a long period (five years). In resource constrained environments maternal death audits 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 one thousand women who died during pregnancy, childbirth or in the postpartum 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 new-born health. As has been shown elsewhere, political will is of prime importance to bring about change.[19,20]

The five-years average health facility-based maternal mortality ratios (64.4 per 100,000) found in this study is much lower than the ratio reported in the 2010 Rwanda demographic and health survey (476 per 100,000)[21] and other estimates.[2,22] This could be due to underreporting of maternal deaths through HMIS, especially before 2011, when only deaths that occurred in maternity departments were reported. This also explains why in 2010 there were more audited maternal deaths than cases of maternal mortality reported through HMIS (Table 1). In addition, there may be other maternal deaths that happened in the community and these are neither captured in the HMIS, nor by audits. Underreporting of maternal morbidity and mortality is a very common phenomenon, even in specialized health care facilities in Europe, where sometimes over half of the deaths are missed.[23,24]

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 to other low-income countries, where facility-based maternal death review is usually introduced in some parts of the country only (e.g. in Senegal, Ethiopia, Nigeria).[8-10] The percentage of unknown causes decreased, which suggest an improvement of the quality of the internal audits. Characteristics of deceased women were similar with 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 demographic and health survey, 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 to 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 is in line with HMIS data (less than 10% of home deliveries in 2013),[25] although 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, due in 2015.

Direct obstetric causes were found to be the underlying cause in the majority of cases of maternal death reviewed during the five year period; this finding is in line with studies in other low- 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.[26] 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,[27,28] especially in Southern Africa, HIV related infection is the predominant indirect cause and also indirect causes were the major causes in many developed countries.[22,29] The present study identified post-partum haemorrhage as the leading cause of maternal death and this is similar to many other African countries.[15,30] In other studies haemorrhage is reported as a cause of death without specifying the time of its occurrence (before, during or after delivery).[11,31] 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%,[25] which is on the higher end of the WHO recommended range of 5 to 15%. This calls for further investigation.[32,33,34]

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 decentralize post-abortion 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%) and also the third most important cause of morbidity among outpatients at health facilities (10.6%).[25] The fact that the proportion of unknown causes of death decreased significantly over the five years suggests that the audit committees gradually gained more confidence in establishing and reporting the cause of death.

The committees identified various aspects of substandard care as contributing to the majority of deaths, many of which are avoidable (Figure 2). This is in line with findings from other studies from both high- and low-income countries.[7,15,26,27,29,35,36] Implementation of the recommendations highlighted in Box 1 should be prioritized in order to further improve the quality of maternal and obstetric services.

CONCLUSIONS

Maternal death audit 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. 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. For better close up and surveillance of death, a national surveillance committee would need to be put in place so as to regularly inform policy makers. Since maternal death can be seen as the tip of an iceberg of 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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Authors' contributions

Study design, data analysis, interpretation and writing of the manuscript by FS and LB; data collection, handling and preliminary analysis by VM; FN, JD and KV provided critical intellectual input to the study design and to earlier versions of the manuscript.

Data sharing statement

No additional data is available.

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APPENDIX

Box 2. Substandard factors identified in maternal death audits

61.1% Health system factors (N=603)	30.3% Patient/community factors (N=299)
• Poor case management (248) • Delay to refer the patient at high level (105) • Lack of skilled staff (48) • Insufficient diagnostic means (40) • Inadequate monitoring of labour and/or use of partograph (33) • Delay to recognize the complication (28) • Insufficient follow up in post-operative period (22) • Delay of the ambulance to reach the health centre (14) • No respect of asepsis (14) • Insufficient follow up in post-partum period (8) • Lack of isogroup blood (8) • Inadequate post-partum follow up (6) • Not following protocol (6) • Inadequate resuscitation (5) • Insufficient follow-up of anaesthesia induction (4) • Delay to administer the correct treatment (3) • Insufficient pre- operative preparation (2) • Poor quality of ANC visit (2) • Other factors (7)	• Delay to consult the health facility (183) • Poor maternal compliance (77) • No use of health facility (8) • Refusal to comply with treatment (7) • Poor hygiene (6) • Refusal to be referred at high level (6) • No use of mosquito nets (5) • Refusal blood transfusion (3) • Consulted traditional healers (2) • No respect of ANC visit (1) • Patient refusal to be operated (1)

Figure 1. Trends in maternal death causes, from 2009 to 2013 (N= 987)

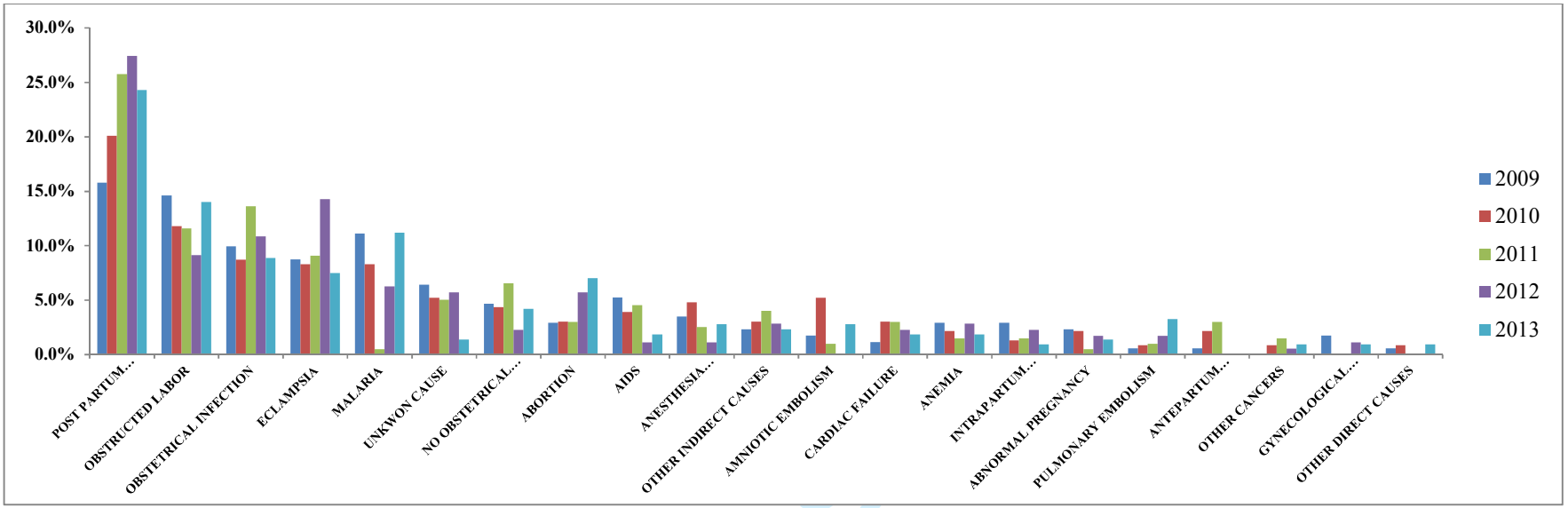
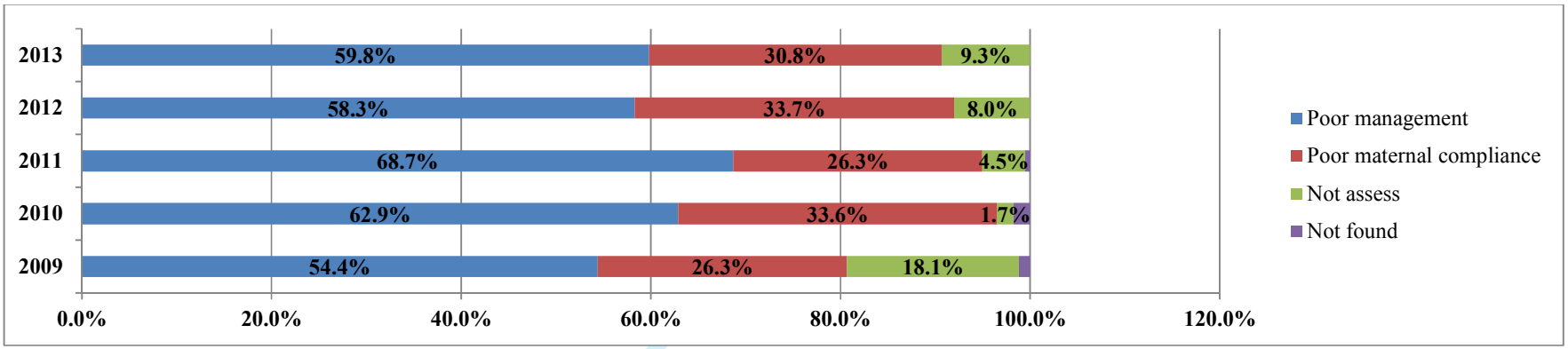


Figure 2. Trend in detection of poor case management versus poor maternal compliance as factors having contributed to maternal death, over five years (N= 987)



STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies* :

completed for the manuscript 'Maternal death audit in Rwanda 2009-2013: a nationwide facility-based retrospective cohort study'

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	**Title page: #1**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	**#2**
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	**3**
Objectives	3	State specific objectives, including any prespecified hypotheses	**3**
Methods			
Study design	4	Present key elements of study design early in the paper	**4**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	**4**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	**4**
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	**Not applicable**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	**4**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	**4**
Bias	9	Describe any efforts to address potential sources of bias	**Not applicable**
Study size	10	Explain how the study size was arrived at	**4**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	**4**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	**4**
		(*b*) Describe any methods used to examine subgroups and interactions	**Not applicable**
		(*c*) Explain how missing data were addressed	**Not applicable**
		(*d*) If applicable, explain how loss to follow-up was addressed	**-**
		(*e*) Describe any sensitivity analyses	**Not applicable**

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	4
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Considered not appropriate
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	4-5
		(b) Indicate number of participants with missing data for each variable of interest	Table 2, on page 5
		(c) Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures over time	Table 1, on page 4
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6-7
		(*b*) Report category boundaries when continuous variables were categorized	Table 2, on page 5
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8 (Grouping of recommendations made by audit committees)
Discussion			
Key results	18	Summarise key results with reference to study objectives	8, 9
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10
Generalisability	21	Discuss the generalisability (external validity) of the study results	9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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

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

Felix Sayinzoga, Rwanda Ministry of Health, Rwanda Biomedical Center, Maternal, Child and Community Health Division, Maternal Health Senior Officer. Rwanda Ministry of Health Office, PO Box 84 Kigali. felix.sayinzoga@gmail.com +250788517814

Leon Bijlmakers, Radboud University Medical Centre Nijmegen, the Netherlands, Department for Health Evidence, senior researcher. leon.bijlmakers@radboudumc.nl

Jeroen van Dillen, Radboud University Medical Centre Nijmegen, the Netherlands, Department of Obstetrics and Gynaecology, gynaecologist, chef de clinique. jeroen.vandillen1@radboudumc.nl

Victor Mivumbi, Rwanda Ministry of Health, Rwanda Biomedical Center, Maternal, Child and Community Health Division, Maternal death audit focal point. mivumbi.victor@gmail.com

Fidèle Ngabo, Rwanda Ministry of Health, Rwanda Biomedical Center, Maternal, Child and Community Health Division, Head of division. ngabog@yahoo.fr

Koos van der Velden, Radboud University Medical Centre Nijmegen, the Netherlands, Department of Primary and Community Care, professor of Public Health. koos.vandervelden@radboudumc.nl

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ABSTRACT

Objective: Presenting the results of five 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 five-year period. Almost three quarters of the deaths (71.6%) occurred at district hospitals. In 44.9% of these cases, death occurred in the postpartum period. Seventy percent were due to direct causes, with post-partum haemorrhage as leading cause (22.7%), followed by obstructed labour (12.3%). Indirect causes accounted for 25.7% of maternal deaths, with malaria as 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, sub-standard 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 new-born 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 ICD-10.

INTRODUCTION

Globally, the maternal mortality ratio (MMR) has fallen by 45% between 1990 and 2013.[1] In the last ten years, Rwanda has witnessed unprecedented improvements in many health outcomes, including those related to maternal health. The UN listed Rwanda as one of 11 countries that are 'on track' to achieve the 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 1,071 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 MDG 5 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 is one of the strategies that have proven effective to improve the quality of obstetric care in Ethiopia, Nigeria and Senegal, and there are indications that the audits have helped reduce maternal mortality.[6,7,8,9,10]. 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 maternal death audit (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. Maternal death audit committees have been established in all hospitals.

The objective of this study is to present the results of the first five 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, maternal death audit committees have been established in all Government, private abd 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 maternal death audits 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

data base. 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 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 maternal death audited 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 five-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 (HMIS), which captures data from both public and private facilities. Maternal characteristics and causes of death were compared between the five one-year periods using X^2 test for dichotomous variables and T-test for numerical variables; 95% confidence intervals for maternal mortality rates were calculated using Fisher's exact test.

RESULTS

Over the five-year period, 1060 maternal deaths were recorded through HMIS on a total of 1,533,177 births that occurred in health facilities. Over the same period, 987 maternal death audit reports were received, from three referral hospitals, 42 district hospitals and 62 health centres. Table 1 shows the health facility-based maternal mortality ratio (MMR) and the proportion of deaths audited by local committees. The overall facility-based MMR using maternal deaths and births reported by HMIS was calculated at 69.1 per 100,000 live births (95% CI 65.1-73.4) with 93.1% of all deaths that were audited. Since 2011, there has been a decrease in facility-based MMR.

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
% 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 (44.8-60.4)	67.1 (69.0-76.4)	89.4 (78.9-101.2)	77.4 (67.9-88.4)	74.3 (65.1-84.8)	69.1 (65.1-73.4)

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

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 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).

Table 2. Characteristics of deceased women

	2009 (N=171)	2010 (N=229)	2011 (N=198)	2012 (N=175)	2013 (N=214)	Total for 5 yrs (N=987)	Significance (p value)
Age Mean 29.7 years (±7.0)							
≤ 18 years	4.1	0.9	1.5	4.6	2.8	2.6	NS
19-34 years	64.9	69.9	66.7	65.7	74.3	68.6	
≥35 years	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 to 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	

Compared among the five calendar years and not considering missing data, the cases were similar with respect to age, marital status, gravida and number of children alive, but differed 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, 62.0% 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 postpartum 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

70% 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 last two 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 proportion of unknown causes of death decreased over the five years, from 6.4% in 2009 to 1.4% in 2013, although this is not statistically significant. Supplementary file Figure 1 depicts the trends.

Sub-standard care versus community factors

Factors related to provision of sub-standard care were identified for 61.1% of the cases, against almost a 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 (Supplementary file Box 2).

Table 3. Causes of maternal death

	2009	2010	2011	2012	2013	Total for 5 years	Sign.
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: Post-operative peritonitis, post-partum peritonitis, amnionitis
** Abnormal pregnancy: Ectopic pregnancy, molar pregnancy
*** Non-obstetric infection: Pneumonia, meningitis

Recommendations made by audit committees

Box 1 summarizes 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.

Box 1. Recommendations made by maternal death audit committees

Management of obstetric complications	**Population sensitization on**
• Reinforce post-operative follow up • Close monitoring after anaesthesia injection • Reinforce post-partum follow up • Reinforce the use of partograph • Reinforce hygienic measures in 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 pre-operative preparation	• Consulting health facility on time • Complying with medical advice and treatment • Using of mosquito net by pregnant women • Delivering at a health facility • Improving hygiene especially in post-partum period • Not relying on traditional medicine • Preparing for delivery and buy their medical insurance
Availability of medicines and infrastructure	**Human resources**
• Ensure the availability of blood, especially Rhesus negative • Avail emergency kits, lab test • Avail resuscitation materials and anaesthesia equipment • Avail intravenous anti-hypertensive treatment • Refer patient in critical condition in ICU	• Training on emergency obstetric and neonatal care, especially on surgery • Increase number of health providers • Hire an anaesthesia technician • Training on resuscitation procedures
Referral system	**Communication**
• Refer patient with complications on time to a higher level • Provide adequate pre-transfer treatment • Avail more ambulances	• Reinforce communication among staff and between departments within the hospital • Reinforce communication between health facilities • Reinforce communication between health providers and patients

DISCUSSION

This study is the first one that reports the results of a national health facility-based review of maternal deaths in a low-income country for such a long period (five years). In resource constrained environments maternal death audits 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 one thousand women who died during pregnancy, childbirth or in the postpartum 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 new-born health. As has been shown elsewhere, political will is of prime importance to bring about change.[19,20] Maternal death audits as a nation-

wide 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 ICT and mobile telephones for performance monitoring and performance-based financing, among others.[21,22,23]

The five-years average health facility-based maternal mortality ratios (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 estimates.[2,25] This could be due to underreporting of maternal deaths through HMIS, especially before 2011, when only deaths that occurred in maternity departments were reported. This also explains why in 2010 there were more audited maternal deaths than cases of maternal mortality reported through HMIS (Table 1). In addition, there may be other maternal deaths that happened in the community and these are neither captured in the HMIS, 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 maternal death audits. Underreporting of maternal morbidity and mortality is a very common phenomenon, even in specialized health care 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 to other low-income countries, where facility-based maternal death review is usually introduced in some parts of the country only (e.g. in Senegal, Ethiopia, Nigeria).[8-10] The percentage of unknown causes decreased, which suggest an improvement of the quality of the internal audits. Characteristics of deceased women were similar with 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 to 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 HMIS data (less than 10% of home deliveries in 2013),[28] although 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.

Direct obstetric causes were found to be the underlying cause in the majority of cases of maternal death reviewed during the five year period; this finding is in line with studies in other low- 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 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).[11,34] 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 to 15%. This calls for further investigation.[35,36,37]

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 decentralize post-abortion 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 five years 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, underreporting 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 (Supplementary file 3 Figure 2). This is in line with findings from other studies from both high- and low-income countries.[7,15,29,30,32,38,39] 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 Box 1 should be prioritized in order to further improve the quality of maternal and obstetric services.

CONCLUSIONS

Maternal death audit 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 policy makers. 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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Disclaimer

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Authors' contributions

Study design, data analysis, interpretation and writing of the manuscript by FS and LB; data collection, handling and preliminary analysis by VM; FN, JD and KV provided critical intellectual input to the study design and to earlier versions of the manuscript.

Data sharing statement

No additional data is available.

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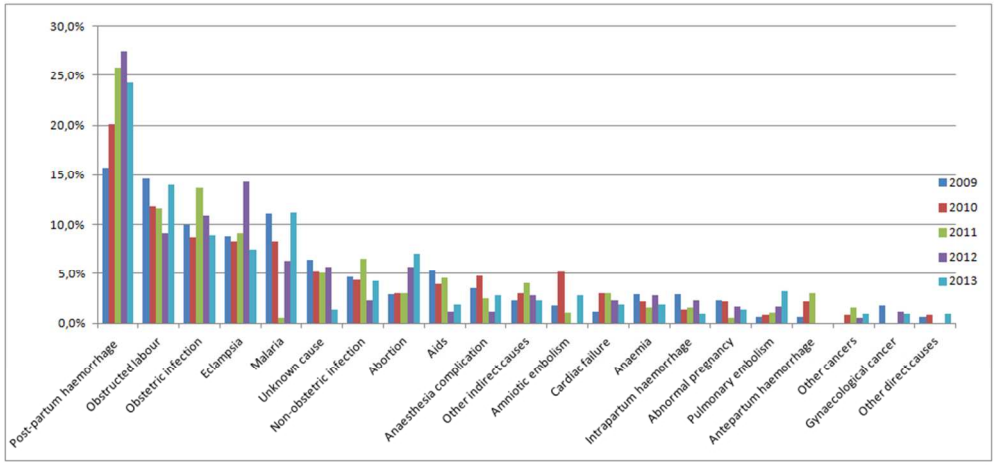
Figure 1: Trends in maternal death causes, from 2009 to 2013 (N=987)



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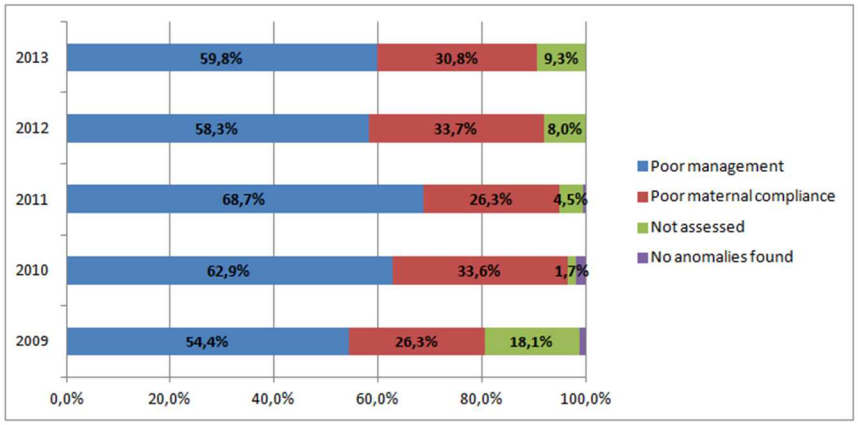
APPENDIX

Box 2. Substandard factors identified in maternal death audits

61.1% Health system factors (N=603)	30.3% Patient/community factors (N=299)
• Poor case management (248) • Delay to refer the patient at high level (105) • Lack of skilled staff (48) • Insufficient diagnostic means (40) • Inadequate monitoring of labour and/or use of partograph (33) • Delay to recognize the complication (28) • Insufficient follow up in post-operative period (22) • Delay of the ambulance to reach the health centre (14) • No respect of asepsis (14) • Insufficient follow up in post-partum period (8) • Lack of isogroup blood (8) • Inadequate post-partum follow up (6) • Not following protocol (6) • Inadequate resuscitation (5) • Insufficient follow-up of anaesthesia induction (4) • Delay to administer the correct treatment (3) • Insufficient pre- operative preparation (2) • Poor quality of ANC visit (2) • Other factors (7)	• Delay to consult the health facility (183) • Poor maternal compliance (77) • No use of health facility (8) • Refusal to comply with treatment (7) • Poor hygiene (6) • Refusal to be referred at high level (6) • No use of mosquito nets (5) • Refusal blood transfusion (3) • Consulted traditional healers (2) • No respect of ANC visit (1) • Patient refusal to be operated (1)

Figure 2: Distribution of substandard case management and poor maternal compliance identified in maternal death audits, 2009-2013



298x136mm (72 x 72 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies* :

completed for the manuscript 'Maternal death audit in Rwanda 2009-2013: a nationwide facility-based retrospective cohort study'

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	**Title page: #1**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	**#2**
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	**3**
Objectives	3	State specific objectives, including any prespecified hypotheses	**3**
Methods			
Study design	4	Present key elements of study design early in the paper	**4**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	**4**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	**4**
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	**Not applicable**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	**4**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	**4**
Bias	9	Describe any efforts to address potential sources of bias	**Not applicable**
Study size	10	Explain how the study size was arrived at	**4**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	**4**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	**4**
		(*b*) Describe any methods used to examine subgroups and interactions	**Not applicable**
		(*c*) Explain how missing data were addressed	**Not applicable**
		(*d*) If applicable, explain how loss to follow-up was addressed	**-**
		(*e*) Describe any sensitivity analyses	**Not applicable**

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	4
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Considered not appropriate
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	4-5
		(b) Indicate number of participants with missing data for each variable of interest	Table 2, on page 5
		(c) Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures over time	Table 1, on page 4
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6-7
		(*b*) Report category boundaries when continuous variables were categorized	Table 2, on page 5
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8 (Grouping of recommendations made by audit committees)
Discussion			
Key results	18	Summarise key results with reference to study objectives	8, 9
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10
Generalisability	21	Discuss the generalisability (external validity) of the study results	9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.