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Child survival in Rwanda: Challenges and potential for improvement

Population- and hospital-based studies

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Abstract
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After the 1994 genocide and collapse of the health system, Rwanda initiated major social and health reforms in order to reduce child mortality and health inequities in accordance with the Millennium Development Goals. The aim of this thesis was to assess trends in under-five mortality (U5M) and equity in child survival, to study social barriers for improved perinatal and neonatal survival, and to evaluate Helping Babies Breathe (HBB), a newborn resuscitation program.

In paper I we analysed trends and social inequities in child mortality 1990−2010, using data from national Demographic and Health Surveys conducted in 2000, 2005, and 2010. The following papers were based on hospital studies in the capital of Rwanda. In paper II we explored social inequities in perinatal mortality. Using a perinatal audit approach, paper III assessed factors related to the three delays, which preceded perinatal deaths, and estimates were made of potentially avoidable deaths. Paper IV evaluated knowledge and skills gained and retained by health workers after training in HBB.

Under-five mortality declined from the peak of 238 deaths per 1000 live births (95% CI 226 to 251) in 1994 to 65 deaths per 1000 live births (95% CI 61 to 70) in 2010 and concurred with decreased social gaps in child and neonatal survival between rural and urban areas and household wealth groups. Children born to women with no education still had significantly higher under-five mortality. Neonatal mortality also decreased but at a slower rate as compared to infant and U5M. Maternal rural residence or having no health insurance were linked to increased risk of perinatal death. Neither maternal education nor household wealth was associated with perinatal mortality risks. Lack of recognition of pregnancy danger signs and intrapartum-related suboptimal care were major contributors to perinatal deaths, whereof one half was estimated to be potentially avoidable. Knowledge significantly improved after training in HBB. This knowledge was sustained for at least 3 months following training whereas practical skills had declined.

These results highlight the need for strengthening coverage of lifesaving interventions giving priority to underserved groups for improved child survival at community as well as at hospital levels.

Keywords: Trends, social differentials, child mortality, perinatal mortality, perinatal audit, three delays model, training healthcare workers, Helping Babies Breathe, urban hospitals, Kigali, Rwanda

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To all mothers who lose their
children due to avoidable causes

List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

I. Musafili A, Essén B, Baribwira C, Binagwaho A, Persson LÅ, Selling KE. (2015) Trends and social differentials in child survival in Rwanda 1990–2010: results from three demographic and health surveys. *J Epidemiol Community Health*, doi: 10.1136/jech-2014-204657

II. Musafili A, Essén B, Baribwira C, Selling KE, Persson LÅ. (2015) Social equity in perinatal survival. A case-control study at hospitals in Kigali, Rwanda. *Acta Paediatrica*, doi: 10.1111/apa.12951

III. Musafili A, Persson LÅ, Baribwira C, Påfs J, Mulindwa PA, Essén B. Case review of perinatal deaths with application of a three delays model at hospitals in Kigali, Rwanda. *Submitted manuscript*

IV. Musafili A, Essén B, Baribwira C, Rukundo A, Persson LÅ. (2013) Evaluating Helping Babies Breathe: training for healthcare workers at hospitals in Rwanda. *Acta Paediatrica*, 102(1):e34-8

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Cover photo: A mother with her two children in Kigali, Rwanda; one child is a three-year old girl; another is a preterm baby boy aged six days. We obtained the permission to publish the photo from the mother. Photo taken by A Musafili

Contents

Abbreviations

AIDS	Acquired Immune Deficiency Syndrome
CI	Confidence Interval
CSDH	Commission on Social Determinants of Health
DH	District Hospital
DHS	Demographic and Health Survey
GLMM	Generalized Linear Mixed effect Models
HBB	Helping Babies Breathe
HIV	Human Immunodeficiency Virus
HR	Hazard Ratio
IGME	Inter-agency Group for Child Mortality Estimation
MDG	Millennium Development Goals
OR	Odds Ratio
PBF	Performance-based Financing
PMTCT	Prevention of Mother-to-Child Transmission of HIV
TRH	Tertiary Referral Hospital
U5M	Under-five Mortality
UN	United Nations
WHO	World Health Organization

Glossary of terms

Early neonatal deaths: Number of deaths occurring during the first seven days after birth.

Early neonatal mortality rate: Number of deaths within the first seven days of life per 1000 live births in a given time period.

Early neonatal period: A period that commences at birth and ends on seventh day of life.

Fresh stillbirth: A foetal death occurring during labour or delivery with no signs of skin maceration.

Infant mortality rate: Number of deaths within the first year of life per 1000 live births in a given time period.

Macerated stillbirth: A foetal death occurring during pregnancy and before labour and presenting with signs of skin deterioration.

Neonatal mortality rate: Number of deaths within the first 28 days of life per 1000 live births in a given time period.

Neonatal period: A period that extends from birth up to twenty-eighth day of life.

Perinatal deaths: The total of stillbirths and early neonatal deaths

Perinatal mortality rate: Number of stillbirths and early neonatal deaths per 1000 live births in a given time period.

Perinatal period: A period that extends from 22 weeks of pregnancy up to seventh day of life.

Stillbirth: A foetal death occurring at or after 22 weeks of gestation or weighing at least 500 grams.

Under-five mortality rate, also considered as child mortality: Number of deaths occurring in children before reaching five years of age per 1000 live births in a given time period.

Preface

My interest in research and child health area began to develop in the early 2000s, when I was studying at the Faculty of Medicine of University of Rwanda. At the time, I had the opportunity to attend some tutorials on research methods and learn basic computing skills required to perform data management and analysis. These tutorials were delivered by well-skilled staff, which stimulated my curiosity and interest in the research. The knowledge and skills acquired were essential for carrying out a study, of which results must be presented through a public defence before completing undergraduate studies in Medicine. My study focused on clinical signs of uncomplicated malaria in children younger than five years of age. The choice of this subject was motivated by a general interest in controlling malaria, which was a major public challenge in the country, especially in pregnant women and young children. Government and various stakeholders had stepped up efforts to reduce morbidity and mortality due to malaria, which became drug resistant. Many studies and workshops were undertaken to increase knowledge and change wrong perceptions and beliefs about malaria transmission, clinical signs and management. After attending most of these workshops and being involved in training healthcare providers working in different levels of healthcare system, I decided to focus my study on malaria in young children and I was encouraged by my advisor. The main objective of our study was to improve child survival through improved clinical diagnosis and management of malaria in low-income setting. In this setting, laboratory investigations could not be feasible due to the lack of skilled laboratory staff, equipment or lack of money by patients, especially in remote rural areas. Thus, it was needed to strengthen clinical diagnosis of malaria in order to guide appropriate use of antimalarial treatment and prevent resistance to drugs. This attitude seemed particularly relevant to a context where providers might tend to treat every child with fever as having malaria.

In 2003, I graduated in Medicine with a bachelor degree in medical sciences. Based on my previous experience of assessing children suspected of malaria, I developed further interest in child health and survival area, which influenced my decision to undertake a Master's programme in Paediatrics. In 2004, I was hired as a general practitioner in the largest tertiary referral hospital in Rwanda. I was deployed in the Department of Paediatrics while waiting to further improve my skills in Paediatrics. During the time I spent in this department, I was mostly involved in neonatal intensive care unit. My expe-

rience in this unit made me realise the importance of reducing perinatal and neonatal deaths in order to improve child survival. Later, I was admitted to do a Master's programme in Paediatrics at University of Rwanda. During that time, I got an opportunity to pursue PhD studies in child survival funded by Swedish International Development Cooperation Agency within the collaboration between Uppsala University and University of Rwanda. After graduating with a Master of Medicine in General Paediatrics at University of Rwanda, this allowed me to focus on hospital-based data collection. Analysing data from three Demographic and Health Surveys conducted in 2000, 2005, and 2010 and from hospital-based studies gave us an opportunity to identify challenges and potential for improved child survival. I hope the results of this thesis will contribute to improve knowledge in the field of child survival in Rwandan setting and other similar contexts.

Introduction

Improving child health and survival is a global priority. After the United Nations' declaration in 2000, 189 countries adopted the Millennium Development Goals that include the 4th goal (MDG4), which calls for a two-thirds reduction of mortality under the age of five years (U5M) from 1990 to 2015 (1). Thus, a regular assessment of mortality levels and trends has become a necessity in order to inform policy and programmes to accelerate the reduction of child deaths by 2015 and beyond.

The latest report from the United Nations Inter-agency Group for Child Mortality Estimation (UN IGME) showed that global mortality in children younger than five years of age has declined over time. However, this decline has been slower for neonatal mortality than for infant and U5M, as reflected by an increasing proportion of neonatal deaths among the total number of under-five deaths. The progress in mortality reduction has also been judged to be insufficient in many low-income countries, especially in sub-Saharan Africa and South Asia, if the MDG4 should be reached (2).

Inequalities in child survival chances are not only a grim reality when comparing countries. Even within countries, the risk of dying before five years of age is still increased among socially disadvantaged groups (3, 4). Social inequalities across population subgroups are also observed in perinatal mortality, which includes stillbirths and the first week of newborn deaths that contributes to a considerable proportion of neonatal and U5M rates (5).

Scaling up cost-effective interventions and securing that poor people and other vulnerable groups are covered seem to be key strategies for reducing child mortality. However, there is a need to prioritize interventions addressing neonatal mortality, which is a major challenge for improved child survival.

Perinatal audit is a widely used approach to analyse factors underlying perinatal mortality and improving standards of health care (6). A growing body of evidence has shown that this approach could help prevent a substantial number of stillbirths and early neonatal deaths (7). Another intervention, which could contribute to better neonatal survival, refers to as the Helping Babies Breathe (HBB) programme. This programme was recently designed by American Academy of Paediatrics to improve neonatal resuscitation at birth in low- and middle-income countries (8-10). There is a need to scale up such cost-effective interventions, which also is in line with the World Health

Organization' (WHO) recommendations suggesting health system strengthening in order to improve health outcomes (11).

After the 1990s civil war and genocide, Rwanda has initiated major social and health reforms in order to reduce health inequities and child mortality (12-17). A recent progress report on the MDGs indicated that the country has achieved considerable improvements in health (18). Preliminary results from the demographic and health surveys of 2015 indicated that Rwanda has reached the MDG4 (19). However, there is still a need to sustain such progress by increasing the availability of data for guiding effectively interventions to address major health problems, including child and neonatal mortality.

Trends in child mortality

The latest worldwide estimates showed that the number of children dying before reaching their fifth birthday had dropped from 12.7 million in 1990 to 6.3 million in 2013. During this period, the U5M declined from 90 to 46 deaths per 1,000 live births, which is an overall decrease by 49%.

However, this reduction was not equally distributed across the WHO regions. All regions have lowered the U5M rate by more than 50% except sub-Saharan Africa and Oceania. Even if sub-Saharan Africa has shown an overall reduction of 48%, individual African countries have not been successful in reducing U5M and are not on track to reach the goal (2).

In 2013, the highest number of under-five deaths was also found in sub-Saharan Africa, where almost half of the global under-five deaths occurred (20). Nigeria and the Democratic Republic of the Congo were two of the countries having the greatest number of under-five deaths in sub-Saharan region with Nigeria having 13% of global child deaths (2). The second region carrying a considerable burden of U5M was South Asia, which accounted for 32% of under-five deaths worldwide (20).

Sub-Saharan Africa had also the highest U5M rate in the world, 92 deaths per 1000 live births, followed by South Asia, 55 deaths per 1000 live births. These rates were more than 15 and 9 times the average observed in high-income countries, respectively (2).

Although the annual rate of reduction in U5M increased five-fold in sub-Saharan Africa from 1990−1995 to 2005−2013, this decline remained insufficient to reach the MDG4 (21). In addition, a huge variability in child survival was noted between countries in this part of Africa. While a few countries showed accelerated decline in child mortality over the last decade, others recorded little improvement during the same period (22, 23).

At current pace of child mortality decline, it is estimated that most low-income countries in the sub-Saharan area will not meet the MDG4 target in 2015 (23). Even among countries, which have achieved this target, the rates

of mortality are still unacceptably high as compared to the global average. For others, which are not on track towards the MDG4, a dramatic progress is required to reach the goal (2).

Globally, 4.6 million children also died before completing one year of age, which constituted 74% of under-five deaths reported in 2013. This corresponds approximately to half the number of infant deaths, which occurred in 1990. Concurrently, the infant mortality rate has declined by 46% from a level of 63 deaths per 1000 live births recorded in 1990.

In 2013, the risk of dying within the first year of life was the highest in sub-Saharan Africa, 61 deaths per 1000 live births. This risk was almost five times the average in the European region that was 11 deaths per 1000 live births. Sub-Saharan Africa was also the region showing the lowest progress in reducing infant mortality rate, followed by South Asia (2).

Infant and under-five deaths have declined faster than deaths occurring during the neonatal period or the first four weeks after birth. The global number of neonatal deaths has decreased by 40%, from 4.7 million in 1990 to 2.8 million in 2013. During the same period, the proportion of neonatal deaths among under-five deaths has increased from 37% to 44%, reflecting the relatively slow decline of neonatal mortality compared to the infant and U5M.

The risk of dying within the neonatal period is still high. In 2013, 2 million of the neonatal deaths occurred within the first week of birth, which corresponded to 73% of all neonatal deaths or 32% of all under-five deaths. Half of these deaths occurred within 24 hours after birth, which corresponded to 36% of the total number of neonatal deaths or 16% of the under-five deaths (20).

While some regions of the world have halved the number of neonatal deaths, sub-Saharan Africa has remained one of the regions with the least advancement in the reduction of neonatal mortality rates. Sub-Saharan Africa has also persistently presented the highest risk of death in neonatal period, from 46 deaths per 100 live births in 1990 to 31 deaths per 1000 live births in 2013 (2, 24). This latest mortality rate was 10-fold higher than that found in high-income countries.

Progress in neonatal survival was unequally distributed across countries with almost two-thirds of neonatal deaths concentrated to 10 countries. India and Nigeria accounted for more than a quarter and a tenth of these deaths, respectively (2).

Causes of child mortality

The global rates of child mortality have substantially decreased, especially over the past decade, where the annual rate of mortality reduction has accelerated more than before. These gains have been achieved as a result of increased efforts to prevent causes of death and to improve management and treatment of diseases. Thus, frequent updates on causes of mortality are needed for setting up new strategies to address child mortality.

Current data show that the main causes of death in children below the age of five years at the global level include complications related to preterm birth, pneumonia, intrapartum-related complications, complications during labour and delivery, diarrhoea and malaria. However, there is a variation in the geographical distribution of the causes of child mortality.

In sub-Saharan Africa, where about half of the global under-five deaths occurred in 2013, the causes of mortality were mainly attributable to infectious diseases such as malaria, HIV/AIDS, pneumonia and complications of preterm birth. In that year, South Asia accounted for approximately a third of the global burden of under-five deaths, which were largely due to complications of preterm birth, pneumonia and intrapartum-related complications (25). Around 40% of the under-five deaths occurring in sub-Saharan Africa and 25% of those in South Asia were due to pneumonia, diarrhoea and malaria (2).

The epidemiological profile of causes of mortality has changed over time as advances have been made in the prevention of major health problems. For example, from 2000 to 2013, the annual rate of reduction in under-five deaths was 18 % for measles, 9% for neonatal tetanus and 8% for HIV/AIDS in sub-Saharan Africa. During the same period, most causes of death have had an annual rate of reduction of at least 4.4% in South Asia except for complications to preterm birth, which were reduced by only 0.6% (25).

In 2013 the two major causes of mortality during the neonatal period were complications to preterm birth and intrapartum-related complications, which accounted for 35% and 24% of neonatal deaths worldwide, respectively. Another 15% of neonatal deaths were caused by sepsis, 5% by pneumonia, 2% by tetanus and 1% by diarrhoea. These four last causes were responsible for 27% of neonatal deaths in sub-Saharan Africa and 23% in South Asia as compared to only 7% in high-income countries (2, 26).

In a global perspective, most causes of neonatal deaths are preventable conditions including consequences of poor quality of care during labour, delivery and in the early neonatal period. Despite available cost-effective interventions, neonatal mortality continues to be a challenge worldwide. Improving child survival will greatly depend upon how mortality during the neonatal period including underlying factors is addressed.

Perinatal mortality

The World Health Organization estimated the number of stillbirths to be 2.6 million in 2009 (27). A slightly lower number, 2 million, of deaths occurred during the early neonatal period in 2013 (2). Perinatal deaths, which refer to the sum of stillbirths and early neonatal deaths, represent a major public health problem, particularly in low-income countries that account for 98% of the global burden (5).

Perinatal mortality rates vary according to the international definitions applied. The International Classification of Diseases includes all deaths occurring from 22 weeks of gestation or with a weight of at least 500 grams as stillbirths, and adds live births that die during the first week after birth, i.e. early neonatal deaths (5). Another definition is based on the WHO recommendation for international comparison. This considers a cut-off at 28 weeks of gestation instead of 22 weeks (27), which can lead to a reduction of stillbirths by 40% (28).

The distribution according to regions shows the highest rates of perinatal mortality in Central and Western Africa, with rates of 75 and 76 deaths per 1000 births, respectively (5). The size of the perinatal mortality problem remains invisible due to poor vital registration systems, especially regarding stillbirths (29). Thus, perinatal mortality seems to be ignored in global and national policy agendas, and this problem is not well understood due to the lack of reliable data (27).

This has resulted in slow improvement in perinatal mortality compared to neonatal and U5M. The global estimates indicate that the number of stillbirths has declined from 3.0 million in 1995 to 2.6 million in 2009. Sub-Saharan Africa and South Asia has a large share of stillbirths, where an estimated 76% of the total amount was concentrated in 2009. The global stillbirth rate has gradually dropped by almost 15% from 22 stillbirths per 1000 births recorded in 1995 (30).

Despite the slow progress in reducing perinatal mortality, particularly in low- and middle-income countries, most causes of these deaths are preventable. In 2011, most antepartum stillbirths were due to maternal infections and intrauterine growth restriction, whereas intrapartum stillbirths were attributed to the obstetric complications (28). These complications also led to intrapartum-related neonatal deaths, formerly called *birth asphyxia*, and preterm birth, which together constituted the main causes of early neonatal deaths (31). The potential impact is great of tackling such avoidable causes of perinatal and neonatal death.

Conceptual framework

A conceptual framework in health research may help to characterize a problem and identify entry points for interventions (32, 33). Recently, a Commission on Social Determinants of Health (CSDH) set up by the WHO developed a conceptual framework to help advance research on social determinants of health and guide policy makers and planners. This framework explains causal pathways of health inequities observed among individuals or social groups by tracing back these pathways up to their origin. It also delineates areas through these pathways, which require action for tackling health inequities (34). The latter refers to the avoidable disparities observed in health outcomes, which are unfair and unjust (35, 36).

The CSDH conceptual framework suggests that the patterns of health inequities observed among population groups are closely related to social determinants of health referred to as intermediary determinants of health. These determinants are mainly based on material and social circumstances, behavioural and biological factors, and psychosocial factors. The effects of these factors are mediated by the health system, which plays a particular role in the access to care and improvement of health status through an intersectoral action. Thus, the health system was also conceptualised as an intermediary determinant.

The intermediary determinants are directly influenced by a set of upstream determinants including ethnicity, education, occupation, income and other social factors, which define socioeconomic position of individuals. This stratification of individuals according to their socioeconomic position is generated by complex mechanisms operating through socioeconomic and political contexts. These contexts are also shaped by factors such as governance, macroeconomic conditions, social and public policies as well as culture and social values.

Socioeconomic and political contexts together with socioeconomic conditions give rise to these factors that are labelled structural determinants, also known as social determinants of health inequities. These structural determinants influence health outcomes by acting through intermediary determinants of health. Health outcomes could in turn affect socioeconomic and political contexts and socioeconomic positions. This may be observed, for example, in the case of catastrophic health expenditures, where people's income or government economy are affected by illnesses or epidemic diseases (34).

However, factors underlying socioeconomic and political contexts are sometimes difficult to measure at the individual level. Thus, health inequities are commonly assessed using markers of socioeconomic position (4, 37, 38).

This thesis adapted the CSDH conceptual framework by incorporating social determinants of health and health inequities, which were considered relevant and measurable when analysing child survival (Figure 1).
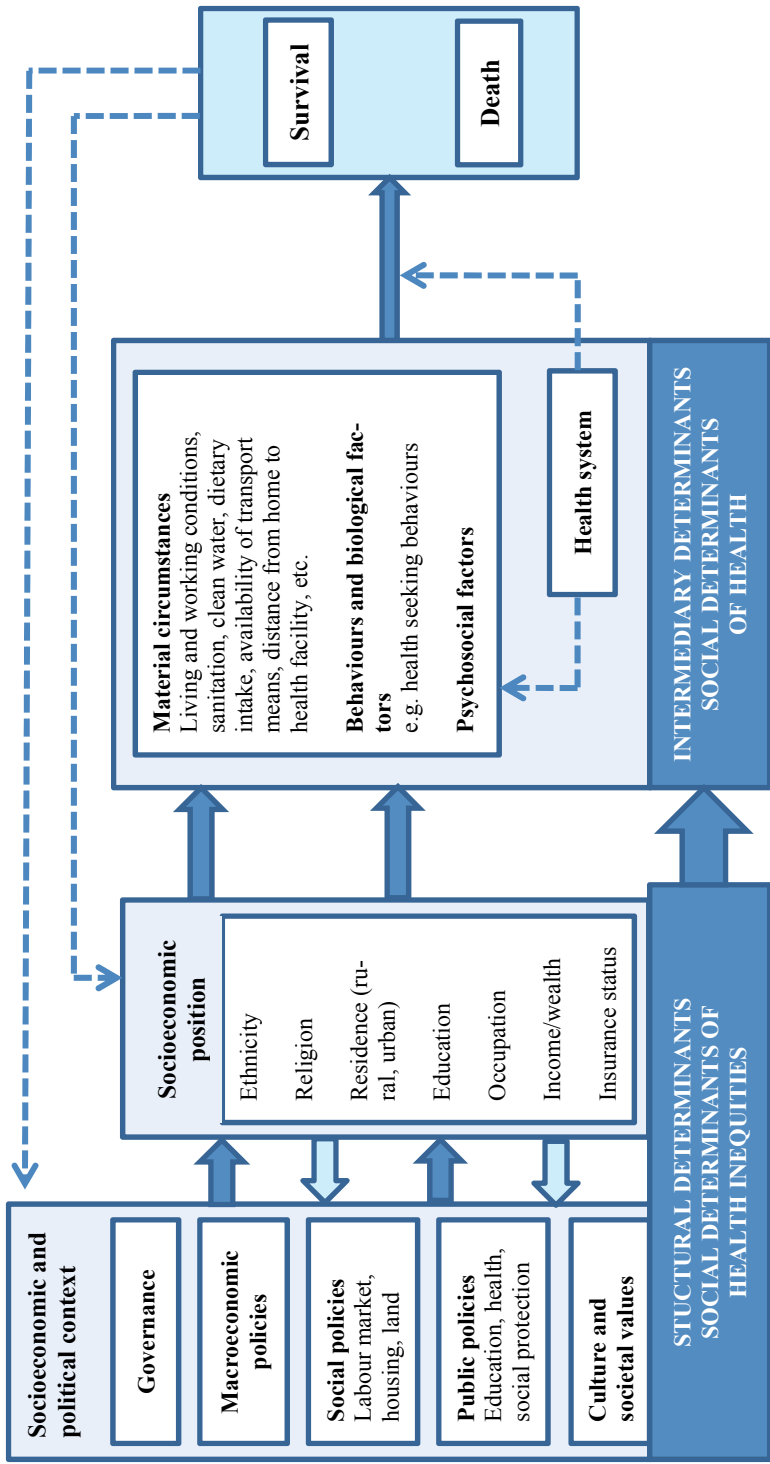
Socioeconomic and political context

Governance

Macroeconomic policies

Social policies
Labour market, housing, land

Public policies
Education, health, social protection

Culture and societal values

STUCTURAL DETERMINANTS SOCIAL DETERMINANTS OF HEALTH INEQUITIES

Socioeconomic position

Ethnicity

Religion

Residence (rural, urban)

Education

Occupation

Income/wealth

Insurance status

Material circumstances
Living and working conditions, sanitation, clean water, dietary intake, availability of transport means, distance from home to health facility, etc.

Behaviours and biological factors
e.g. health seeking behaviours

Psychosocial factors

Health system

INTERMEDIARY DETERMINANTS SOCIAL DETERMINANTS OF HEALTH

Survival

Death

Figure 1. Adapted conceptual framework of the Commission on Social Determinants of Health for analysing factors influencing child survival (34)

Social determinants of inequity in child survival

Inequities in child and perinatal survival are not only observed between countries but also within countries, where survival chances may differ according to the individuals' socioeconomic positions (2, 20). The interest is increasing of more knowledge on social inequities in child mortality in low-income countries, where such research was limited until recently (3). Education, occupation, residence, ethnicity, religious affiliation and household wealth are frequently used as proxies of socioeconomic position (3, 4).

Education is considered a powerful social indicator and may influence health through different mechanisms. It largely contributes to determine future occupation and income, which also have bearings on health and well-being. Formal education is further likely to make people more receptive to health messages, which may influence their behaviours in favour of better outcomes (20, 34). Such behaviours may include improved hygiene, nutrition and uptake of formal care (4, 34, 39).

Occupation is another key determinant of equity in health. This determines income and other rewards or privileges related to work, which influence material living standards and health. A relationship between occupational hazards and health should also be highlighted. The plausible mechanism underlying this relationship lies in parental exposures to mutagens, teratogens or stressful conditions in working environments (4, 34).

The association between income and health status was established in many studies. Income enables people to cover different needs in their daily lives. However, the quality of services and what facilities they can afford will depend upon the level of income, which may influence their health. Due to the difficulties to measure income, particularly in many low- and middle-income countries, health inequities are often assessed using household wealth index instead of incomes of family members. This index is calculated using households' assets and facilities including lands possession, cattle ownership and other possessions. The selection of these items is based on their relevance, which may differ between settings or countries and over time (3, 4, 34).

Individuals' residence defined as rural or urban setting is a widely used indicator to characterise socioeconomic position of individuals and its influence on health outcomes in many low- and middle-income countries. In these countries, an urban area is often associated with better outcome compared to rural areas. This is due to the unequal distribution of resources and opportunities with the urban area being most favoured. Urban residents are also generally better-off and more educated compared to those living in rural areas (4).

Categorising individuals according to their race or ethnic belonging is considered as a source of discrimination and social divisions. In some coun-

tries, members of privileged ethnic groups have more access to available resources compared to others, who often belong to minority groups. These groups also endure other discriminatory practices hindering their socioeconomic development and leading to health inequities (34, 39-42).

Religious affiliation is another factor determining health conditions of population groups. Perceptions of illness causation and management may vary according to religious beliefs and therefore influencing compliance to health practices. Some religions provide socioeconomic support to adherents, e.g. helping them to get education and health care. However, people affiliated to some religions and their offspring are sometimes found to be more likely to suffer from diseases than others (40-42).

Most studies, especially those conducted in low- and middle- income countries, have indicated that children born to mothers having low educational level or low socioeconomic status or living in rural areas or belonging to ethnic minority groups or indigenous religious groups present the highest mortality risks. This is often valid for different age groups, including newborn infants and children younger than five years of age, although they do not share same risk pattern (37, 43-46). With some variation increased mortality risks have also been observed for perinatal mortality among socially disadvantaged groups (47-49).

Intermediary determinants

Intermediary determinants may be divided into five main categories, which are related to material circumstances, psychosocial conditions, behavioural and biological factors and the health system. Most of these factors are intertwined and may directly affect child health or indirectly through maternal health or social living conditions.

Material circumstances include factors related to living conditions such as neighbourhood environment, housing conditions and quality of food, which may contain resources protecting health, e.g. access to clean water and adequate toilet facilities, or causing ill health, e.g. insect vectors (34). Psychosocial circumstances mainly refer to various stressful conditions, which affect people according to their vulnerability. These stressors are generally related to experiences of everyday life such as lack of financial means and social support and other challenges perceived as threatening. These experiences may influence health status by limiting access to healthcare and causing somatic diseases or trigging other illnesses. Health outcomes may also be affected by behavioural factors either compromising or promoting health such as alcohol consumption, smoking, hygiene, hand washing practice and individual health seeking behaviours. The most proximal category of intermediary determinants includes biological factors such as child sex and age, and genetic factors. This also applies to maternal characteristics such as age, parity and birth interval (3). Health system, also considered as an intermedi-

ary determinant, contributes primarily to the prevention and management of health problems, resulting from the effects of other social determinants. An effective health system must ensure optimal coverage of health interventions across all social segments. Thus, the performance of a health system may partly be reflected in the patterns of health inequities (34).

The adapted CSDH conceptual framework also incorporated factors that may contribute to the three delays, which are causally antecedents to various maternal and child adverse health outcomes (50, 51).

A three delays model

In 1994, a conceptual framework referred to as the three delays model of Thaddeus and Maine was developed to analyse contributing factors to maternal mortality in low- and middle-income countries. Three types of barriers to adequate maternal healthcare that may result in a maternal death were described. The phase one delay may occur when a woman or her family or both do not make a timely decision to seek care. The phase two delay may be experienced when there is difficulty in reaching the appropriate health facility while the phase three delay consists of a delay to receive adequate healthcare at the facility (50). The three delays model was successfully applied in some low-income settings to assess main obstacles to the access of care, leading to maternal, perinatal, neonatal, and child deaths (52-57).

The commonly reported factors in many settings influencing the decision to seek care included distance between home and health facility, financial means, perceptions of quality of care and sociocultural factors. A long distance from home to health facility is per se considered a major physical obstacle. It may also constitute a disincentive for users of health services. The users of these services may be further discouraged by poor road conditions and lack of transportation, aggravating the long distance to the health facility (50). The decision-making process may also be affected by various costs involved when seeking care such as transportation fees, payment for hospitalisation and other healthcare services received. Another element contributing to this process is related to the perceptions of quality of care by patients. Their previous experiences of utilization of healthcare services may constitute an incentive or disincentive to reuse these services according to whether they were satisfied or not. As per sociocultural factors influencing care-seeking decision, these mainly include severity and causation of illness and potential remedy, which are interrelated with other social characteristics such as educational level, sociocultural beliefs, woman's position in society and people involved in the decision-making process (58, 59).

After making decisions to seek care, some people may encounter difficulties to reach the health facility due to lack of transportation, long distance separating home and facility and lack of financial means to cover various

costs, including costs for transportation and healthcare services utilization (58, 60). In some instances, the clinical condition of patients may be deteriorated due to long walking distance or inadequate means of transportation used to access the health facility. These difficulties in accessing care due to lack of transportation to health institutions are often observed in rural areas.

Although most care seekers reach the facility, some of them may face barriers to get appropriate care. These barriers may be related to delay in making diagnosis or initiating adequate treatment or both. Such poor performance may be explained by several reasons, mainly including shortage of qualified and dedicated staff, lack of equipment, consumables, drugs and infrastructure. Another common factor affecting quality of care once at facility consists of delay in referral within or between institutions. This delay may underscore poor performance of staff that is unable to make a timely decision for patient referral. It may also result from lack of further transportation means such as ambulance (51, 61-63).

Strategies for improved child survival

Effective strategies are needed to address child mortality and improve equity in health. These strategies should build on insights generated through studies on social inequities and other health problems influencing outcome. Social inequities in health are rooted in society but they also operate through community and individual levels. Therefore, policy actions must be crafted at these different societal levels in order to tackle health inequities. These actions should embrace intersectoral efforts since unfair and unjust differences in survival stem from social influences in various sectors. The health sector does not constitute a panacea for driving forward improvements of health outcomes (34, 36, 64).

The promotion of context-specific strategies is also crucial for tackling barriers to improved survival since there are no single solutions fitting all social contexts. Increasing the visibility of these barriers is also required and should be based on local data in order to inform tailored policies. Some overarching strategies for reducing inequities in health have been suggested and these consist of improving daily life conditions, tackling unequal distribution of available resources and power, and increasing the availability of data and a skilled workforce that understands the complexity of social challenges that shape the health inequities and is prepared to raise public awareness about these challenges (36).

Improving daily living conditions begins in early childhood, where children should have equal opportunities to education, to adequate nutrition, and to healthcare so that they can fully develop to their potential (36, 65, 66). However, this could not be attained without removing barriers that limit the access to these basic needs such as user fees. Equally important, is the con-

trol of conditions generating or fostering inequalities among populations based in their home environment (67, 68). Hence, policies should emphasise equity in investment and distribution of infrastructure and amenities between settings; for example between rural and urban areas. Particular attention should also be given to strategies upgrading the quality of basic facilities such as dwelling, water and sanitation, especially among low-income households (69). This may contribute to reduce excess number of deaths often noted in these households (70, 71). Increasing opportunities for employment is recognised as another strategy to improve daily conditions of life. Income generated by working may increase the capacity to cater for various needs, which would influence health status (72). However, the conditions of work and salary or wage should be optimised to prevent detrimental effects of unsafe or stressful work and poor remuneration on health (73, 74). It is also important to support unemployed people and other socially disadvantaged groups through a social protection system, allowing them to have better standard of living. In some countries, a strong social protection has shown benefits in preventing child poverty in low-income families through transfer payments to these families (36, 75). All these efforts to improve living standards and health of population need to be strengthened by a good health system that can ensure universal health coverage. Such a system may contribute to mitigate effects of social determinants of health inequity such as ethnicity, education, income and residence through improved access to healthcare (34, 76).

Child health and survival is also closely linked to the availability of resources and how these are utilised (77). Therefore, governments across the world need to raise funds required to sustain all activities aiming at improving health. To achieve this goal, strengthening taxation and other mechanisms to increase country domestic income seems to be of utmost importance. This may also prevent the reliance of some countries on external support, which may be temporarily unavailable. However, the availability of funds may not be sufficient without their rational use, especially in low-income countries. Thus, a fair distribution of resources together with a coherent action across various sectors of society turns out to be a cornerstone for a country development and improved health. Evidence shows that action coherence across social areas— including financing system, education, housing conditions, employment situation, transport, and health sector—can significantly contribute to reduce health inequity. However, such an action requires adequate policy guidance, which may be relevant to the development of other areas, influencing health such as markets. A marketplace is considered a vital area since it may contribute to improved standards of life by increasing availability of technologies and other essential goods and services. However, the marketplace may also generate conditions, affecting negatively health such as environmental pollution and commercialisation of unhealthy or unaffordable goods. Hence, there is a need to regulate markets

locally and internationally in order to maximise their benefits and prevent their negative effects on health. In line with this, priority should be given to strategies aiming at increasing access to healthcare, education, clean water and sanitation, which are basic human needs essential to health (36).

Another areas requiring strengthening for improved child survival include gender equity and women's empowerment, empowerment of groups and communities, and good governance at national and global levels. Therefore, it is necessary to increase women's participation to all levels of decision-making and implementation of programmes to strengthen their social position and prevent various forms of discrimination and gender-based violence (78).

In addition, for a sustainable development of a country and health improvements, all social groups and communities need to be adequately represented across society to safeguard their rights and interests. This may be achieved through a global action emphasising good governance within a multilateral system, where all countries can participate equitably in decision-making regarding their priorities. At national level, good governance will ensure that zero tolerance to corruption policy, empowerment of communities and institutions, adequate use of resources, coordination of services and accountability are strengthened across the country.

However, effective action on problems affecting child health needs to be based on reliable data, which can be utilised to set more effective policies and programs. Increasing the availability of data requires strengthening health information system and research. This may contribute to improve poor health indicators found in many countries lacking vital information (34, 64).

Health systems building blocks

A health system refers to "all organizations, people and actions whose primary intent is to promote, restore or maintain health" (79). A well-functioning health system is critically needed for improved health within a country. Thus, increasing attention is being focused on effective strategy, which would enable planners to accurately monitor the health system performance and evaluate the impact.

In 2007, the WHO developed an analytical framework to describe a health system. This framework is based on six building blocks, which are core components of a health system. These blocks include health services delivery; human resources for health; health information system; medicines, vaccines and technologies; health financing; leadership and governance. A strong health system should ensure the quality and safety of health services, which need to be equitable and efficient in order to successfully achieve desired outcomes. Such a health system should have skilled human resources, who are responsive, productive, available in adequate numbers, and

fairly distributed. A good health system is one that can ensure the availability of reliable information on health system performance and health situation. In addition, a well-functioning health system needs to use medical technologies consisting of essential medical products, vaccines and other technologies, which are safe, cost-effective and based on scientific evidence. A properly functioning health system is expected to allocate adequate financial means for health to ensure universal health coverage and prevent the impoverishment due to out-of-pocket payments. Further, this system should incentivise providers and encourage people to use health services. A well-functioning health system also requires a strong leadership with a strategic vision and capable to implement good governance. This governance should be based on policy framework, facilitating interactions and collaborations among stakeholders and promoting ownership and accountability at all levels. Ultimately, a good leadership is expected to provide adequate stewardship for health programmes (11).

All six building blocks are interrelated and function synergistically to produce an impact, which converts them into a system. In a large project implemented in Tanzania in the middle of the 1990s, multiple interventions were simultaneously applied to strengthen all blocks of a health system according to the needs. This resulted in an increased performance of health system and U5M reduction by 40% within a 5-year period. Although the financing block was considered essential, increasing funds may not have been sufficient to achieve such results without other interventions (80). The building blocks framework is increasingly employed to map and understand challenges faced by a health system, which is crucial for any effort to strengthen a health system (81-84). Recently, a modified version of this framework, which emphasises improved communication across a health system and patient engagement, was suggested (85).

Perinatal audit

Perinatal audit is a clinical approach commonly used to assess the quality of perinatal care. The assessment focuses on procedures applied to make diagnosis and treat the cause of morbidity, using available resources. The relationship between these procedures and resulting health outcomes for mothers and their babies is also analysed. As such, perinatal audit may contribute to improved health services and outcomes by giving opportunity to healthcare providers to learn from unwanted events related to their inadequate practices (6, 86). A recent meta-analysis has shown that the implementation of perinatal audit in the routine practices at health facility level could potentially prevent up to 30% of perinatal deaths in low- and middle-income countries (7).

The quality of care emphasised by perinatal audit refers to the "degree to which the treatment dispensed increases the patient's chances of achieving the desired results and diminishes the chances of undesirable results, having

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regard to the current state of knowledge" (87). The review of quality of care may be explicit or implicit. The explicit review is based on predefined criteria, which are consistent with evidence or established guidelines, while implicit review is guided by opinions from experts involved in the audit (88). The implicit review has been criticised for being influenced by auditors' judgements compared to the explicit review, which is a method relatively easy to replicate (89).

The audit may be performed internally by healthcare providers who assess the quality of care provided in their own unit. Such a procedure is called internal audit as opposed to external audit, which is conducted by an independent team of external reviewers. After the external audit, the reviewers provide a feedback to healthcare providers regarding their performance. The internal audit is expected to reveal detailed information about the quality of care since the auditors are also involved in care provision (86, 90). However, the analysis may be affected by interpersonal relationships or competing interests among auditors. Evidence shows that the inter-rater agreement often is low between internal and external auditors (56, 91). The audit has also been employed to explore patient-related factors, which may affect the timely access to adequate care. These factors often include delays in decision-making to seek care or reaching health facilities (51).

Helping babies breathe programme

Scaling-up of cost-effective interventions to improve neonatal survival is increasingly recognized as a key strategy to accelerate child mortality reduction. Such interventions must emphasize the quality improvement of perinatal and neonatal care, as suggested by the WHO and collaborators in the *Every Newborn Action Plan*, which recently was adopted by governments and various stakeholders. The plan was conceived to prevent stillbirths and neonatal deaths using a specific roadmap based on various approaches and strategies (92). In 2014, countries with high neonatal mortality rates were urged to reduce these rates to less than 10 deaths per 1000 live births by 2035 through addressing the main causes of death, including preterm birth complications, intrapartum-related neonatal deaths and infections. These causes were considered preventable by using high-impact and affordable interventions such as exclusive breastfeeding, Kangaroo Mother Care approach and attendance of each birth by a skilled healthcare provider who is ready to initiate neonatal resuscitation when needed. The healthcare provider must also be equipped with basic commodities such as resuscitation equipment and injectable antibiotics as well as chlorhexidine solution for umbilical cord care (2, 93).

The Helping Babies Breathe programme is a new approach developed by the American Academy of Paediatrics and partners to equip birth attendants in low- and middle-income countries with basic knowledge and skills to

perform proper neonatal resuscitation (94). The programme emphasizes practical hands-on and the first minute after birth or Golden Minute, which is a critical step during neonatal resuscitation. The equipment used is rudimentary and may be readily accessible. The HBB programme was piloted in some countries in Africa and Asia. Preliminary results in terms of perinatal and neonatal survival after training in HBB were encouraging though they were not consistent in all settings (8, 9, 95). Further evaluation of this programme is needed for better understanding of its contribution to the prevention of intrapartum-related neonatal deaths and neurologic sequellae among survivors. There is also a need to assess the effect of HBB programme on knowledge and skills retention in neonatal resuscitation since this dimension was not addressed previously.

Recent social and health development in Rwanda

Recent social development

Rwanda is a sub-Saharan country and one of the poorest countries in the world (96). From 1990 to 1994, the country experienced a civil war between Rwanda Patriotic Front and the former government. The war was followed by the 1994 genocide, which left a death toll of more than one million people and the national economy in ruins. In the aftermath of genocide, the Rwandan government restarted building the country and particular attention was given to political stability. During this period, the country benefited from a substantial humanitarian aid, which contributed to reinvigorate the economy and rebuild infrastructure. From late 1990s onwards, major social and health reforms were initiated and guided by a long-term development framework known as Rwanda vision 2020, which was developed in the early 2000 (97). This framework is based on various socioeconomic pillars, which seek to lift the country from low- to middle-income country by 2020. In line with the vision 2020, pro-poor interventions were scaled up in order to reduce social inequities. One Cow per Poor Family Programme or *Girinka* may be mentioned as one of the programmes employed to improve equity (98). Initiated in 2006, this programme aims at increasing the availability of milk and family income, which may contribute to decrease morbidity and mortality due to severe malnutrition. Between 2000 and 2010, the proportions of poverty and extreme poverty decreased from 59% to 45% and from 40% to 24%, respectively, (99). Like many other United Nations member states, Rwanda subscribed to a development agenda including MDGs and committed to reach these goals by 2015 (100). The recent assessment of MDGs showed progress, especially in education, gender equity and health (18).

Health system strengthening

Health system structure

The Rwanda health system has a three-tier pyramidal structure, consisting of central, intermediary and peripheral levels (101). This architecture was adopted in the middle of the 1980s after the decentralisation of healthcare services management to the district level (12). The central level is composed of central directorates of the Ministry of Health, Rwanda Biomedical Centre and tertiary referral hospitals. The Rwanda Biomedical Centre was created in 2011 by merging various specialised divisions such as Malaria and other Parasitic Diseases Division, HIV/AIDS and Sexually Transmitted Infections Diseases Division (102). The central level is responsible for developing health policies and strategic plans, overseeing the implementation of health programmes, evaluating national health situations and coordinating resources for health sector.

The intermediary level refers to a specific unit dealing with health matters within an administrative district. This level facilitates the development process of peripheral level, by providing guidance through continuous supervision. The peripheral level includes district hospitals and pharmacies, health centres and health posts. In each administrative district, there is at least one district hospital, providing advanced care compared to health centres, which cover basic promotional, preventive and curative care. The district hospital also ensures the supervision of activities at health centres and health posts within its catchment area. Usually, a patient is referred from a lower to higher level health facility when needed. There is also a network of community health workers. Each village is served by three community health workers who are supervised by the nearest health staff.

Alongside the public sector, there are a number of faith-based health facilities, which are also assisted by the government, and private clinics, which are more developed in urban areas. There is also a legal framework indicating how traditional medicine can be implemented in the country. Traditional practitioners are encouraged to form associations through which they can provide their services but only few associations are currently registered (12, 101).

Six building blocks of health systems

In line with the Vision 2020 strategy, the MDGs and other global policies, the Rwandan government has initiated various reforms in the health sector during the last decade. These reforms relate to the six building blocks of the health system, as expressed by WHO (11).

Health service delivery

Since 2005 geographical accessibility to health services has been improved by construction of 3 new district hospitals and 14 health centres (12, 103). In

2007, 4 tertiary referral hospitals, 38 district hospitals, and 401 health centres were functional. By 2010, 2 new district hospitals and 35 health centres were added to the existing facilities while 98 dispensaries and health posts were available all over the country (104). In 2007, an emergency transportation service was launched, and by 2011 it included 168 ambulances (105). Programmes specifically targeting maternal, newborn, and child health and survival were extensively developed and special consideration was given to their coordination by creating a Maternal and Child Health unit in 2005 (106). In 2006, an Emergency Obstetric and Newborn care package was implemented and strategies to promote basic and intensive care in neonates were reinforced (107, 108). Family planning, antenatal care, use of iron and folic acid, control of sexually transmitted diseases, facility-based childbirth, and postnatal care policies and other aspects of a continuum of care for maternal, newborn, and child health were strengthened during the last decade (12, 109, 110). In 2008, maternal mortality audit was adopted and scaled up at all hospitals. The Integrated Management of Childhood Illnesses strategy was introduced and became operational from 2006 (107). A few years later, a newborn care package was incorporated into the IMCI approach (108). In 2002, the Prevention of Mother-to-Child Transmission of HIV (PMTCT) programme was initiated and the number of health facilities offering PMTCT services increased from 53 in 2003 to 382 in 2010. The Vaccine Preventable Diseases Division extended the immunization schedule by introducing a pentavalent vaccine. From 2004 vitamin A supplementation was integrated into this programme (107, 111, 112). Pneumococcal, Human Papilloma Virus, and rotavirus vaccines were later added to the vaccination list (111). In 2005, the Ministry of Health developed a national nutrition policy and a strategic plan to fight malnutrition, which has been sustained as a public health challenge in Rwanda, especially in young children. In 2008, the Kangaroo Mother Care approach was implemented at health facility levels (113). By the end of 2010, child and neonatal deaths audits were implemented at health facilities and then expanded to community level. Zinc administration during diarrhoea and systematic deworming in children below five years were also implemented, as well as efforts to promote exclusive breastfeeding and the use of oral rehydration therapy (108). These initiatives were supported by malaria, HIV-AIDS, and tuberculosis programmes that were in turn strengthened, while their implementation was facilitated by a concurrent reinforcement of health infrastructure and human resources as well as by a decentralization process of health and administrative sectors (12, 108). From 2005 to 2008 health facilities reported a reduction by 32% of deaths due to malaria in children under five years while the prevalence of HIV in the general population was 3% and remained stable from 2005 to 2010 (13, 114).

Human resources for health

In 1999, there were 148 physicians and 1,143 nurses working in the public sector. These constituted 3.6% and 27.6% of all employees of the Rwanda Ministry of Health, respectively. Moreover, this health staff was unevenly distributed between rural and urban areas (12). To address this shortage, the government of Rwanda adopted a strategy of increasing the quantity and quality of healthcare providers and other human resources for health. Thus, educational institutions for health professionals were strengthened in order to increase their productive capacity. This was reinforced by other strategies such as fair distribution of human resources, continuous accreditation and professional development through continuous training and supervision, and performance-based financing approach to improve the quality of care as well as the motivation and retention of health workforce. From 2005 to 2012, the number of medical doctors increased from 221 to 641 and nurses and midwives from 4,063 to 8,591 (12, 103, 108). This made a ratio of 1 physician per 15,428 inhabitants and 1 nurse per 1200 inhabitants in 2012. This ratio is close to the minimum ratio of 1 physician per 10,000 of population recommended by WHO for low- and middle-income countries (115). Community health workers were also involved in healthcare delivery under supervision of nearest health centres and their number increased from 1,200 up to 45,000 from 1995 to 2010. They have contributed to improve access to healthcare especially in remote rural areas where geographical constraints may limit the utilization of health facilities (108, 116).

Health information

Rwanda Health Management Information System has marked major milestones over the last decade by incorporating various electronic health records and software programmes, web-based platforms, and other modern technologies such telemedicine and cell phones (103, 108). These resources have improved the availability and quality of health information needed for prevention, management, and surveillance of diseases, monitoring and evaluation of programmes. An "alert system" known as Rapid Short Message Service (RapidSMS) is a mobile health (m-Health) system has been implemented for the prevention of maternal and infant mortality since 2009 (117). Pregnant women and children below one year of age are regularly monitored by community health workers who notify those who should be examined at the nearest health facility by SMS. Community health workers also report on a monthly basis information related to case management of childhood illnesses at community level, child nutritional status and vaccinations, maternal health and deaths at home using another m-Health system referred to as "mUbuzima" (118).

Medicines, vaccines, and technologies

In Rwanda, the priority is to ensure the availability and quality of cost-effective medicines, vaccines, consumables, and medical equipment. In 1998, a Centre for Purchasing of Essential Medicines (CAMERWA) was created to provide public health institutions with these commodities (12, 119). The rest of suppliers include an Office of Government-approved Health Facilities of Rwanda (BUFMAR) for purchasing and importing drugs for government-assisted health facilities, and private wholesale pharmacies, which have increased in number. In 2005, a pharmacy task force was created and assigned a mission for the development and implementation of national medicines policies, regulation of drugs importers and distributors across public and private networks (120). In 2011, the role of CAMERWA was assigned to Rwanda Biomedical Centre to improve the quality of services and management (108).

Health financing

Health insurance and pay-for-performance are key strategies for improving health financing, which is a prerequisite for increasing accessibility to health services and sustaining health sector activities (80). In 1999, a community health insurance scheme or *Mutuelle de Santé* was established in Rwanda to improve universal coverage to healthcare (106). In 2010 91% of the population had been enrolled into this insurance scheme (121). In 2002, the performance-based financing (PBF) strategy aiming at enhancing the performance of the health system was tested in Rwanda and implemented by the Ministry of Health in many health centres and district hospitals with successful results. In 2006, the PBF was scaled up throughout the country (122). The government budget earmarked for health also increased from 8.6 % in 2002 to 9.5% in 2007, and further increased to 11.5% in the fiscal year 2010–2011(108).

Leadership and governance

In 1996, the Rwandan government of national unity adopted the Lusaka declaration that stressed gender equity, decentralization of health system and strengthening of primary healthcare and community participation (12, 13). In 2000, a decentralization process of health and administrative sectors was initiated and became a genuine reality from 2006 and concerned all levels down to the grassroots of the local community (12, 15, 107, 123). The main objective was to increase administrative and financial autonomy and accountability of the district health system with positive impact on quality of service delivery at health facilities. To achieve this target, a particular attention was given to strengthening of supervision, evaluation, monitoring, and coordination of services at all levels of decision making and care provision. A zero tolerance policy to corruption was also emphasized, which valued the

country the high ranking among the least corrupt countries in Africa and in the world in 2012 (124). Good governance and better leadership were identified as main contributor factors to improved coverage of maternal healthcare in Rwanda (15).

Rationale

Reducing mortality in children younger than five years of age remains a global priority. Regular monitoring of mortality is considered a key strategy to track the progress towards this target and guide interventions and policies. Globally child mortality has markedly declined in recent years but this reduction has not been equally achieved across the countries. Mortality reduction has been especially been slow in many low- and middle-income countries (2, 125). There is a need to analyse the country-specific contexts that influence mortality trends.

Inequities in child survival are not only reported across but also within countries (126). Mortality rates are often high in socially deprived strata. This is also the case regarding perinatal mortality. Thus, social inequities in health require special attention since these differences can undermine progress towards better survival and social wellbeing. Each country's context is needed to consider, since inequities may differ from one country to another as well as over time (3). Some countries have experienced a decrease of mortality, which has concurred with improved equity in survival while others have shown a mortality reduction accompanied by an increasing social divide (127, 128). Therefore, improved coverage in health and social interventions needs to be combined with targeted interventions to ensure that socially disadvantaged groups are reached (129-132).

The risk of child death is at its peak during the first month of life, especially within the first seven days after birth or early neonatal period (20). Early neonatal deaths often share risk factors with stillbirths, which together constitute the perinatal deaths. Perinatal mortality is still high in many low- and middle-income countries despite the availability of cost-effective interventions such as perinatal audit and Helping Babies Breathe approach (5, 8). Scaling-up these interventions may be of great importance in reducing mortality burden related to stillbirths and early neonatal deaths.

After the 1994 genocide that claimed more than one million people and devastated social infrastructure, Rwanda has implemented comprehensive health and social reforms, which has resulted in improved health indicators (12, 17, 18, 133). However, an analysis of Rwandan child mortality trends and social inequities in child survival and how this may have been influenced by recent socio-political developments is needed. There is also a need to understand barriers to improved perinatal survival and the potential impact when removing these barriers.

Aims

The overall aim of this thesis is to assess the magnitude and trends in child mortality in Rwanda, to analyse social barriers to improved perinatal and neonatal survival, and to evaluate the educational effect of Helping Babies Breathe, a new resuscitation programme developed for resource-limited countries in order to reduce intrapartum-related deaths.

Specific aims

1. To analyse trends and social differentials of child mortality based on three Rwanda Demographic and Health Surveys carried out in 2000, 2005, and 2010 (Paper I).

2. To investigate social equity in perinatal survival at hospital level (Paper II).

3. To assess contributing factors to the three delays, which precede perinatal deaths, and identify potentially avoidable deaths using a clinical audit approach (Paper III).

4. To evaluate the effect of Helping Babies Breathe educational programme on knowledge and skills of health workers at hospitals in Rwanda (Paper IV).

Subjects and methods

Study design and participants

This thesis includes one population study based on secondary analysis of three Rwanda Demographic and Health Surveys data and three hospital-based studies, as indicated in Table 1.

Table 1. Summary of methods used and subjects included in four papers

Paper	Study design	Source of data	Subjects	Outcomes	Main analysis
I	Secondary analyses of data from Demographic and Health Surveys carried out in 2000, 2005 and 2010	Birth cohorts created by use of data from Demographic and Health Surveys data	34 790 children born between 1990 and 2010	Neonatal and under-five mortality	Generalized linear mixed effect models and Mixed effect Cox model (frailty model)
II	Case-control study	Antenatal cards, hospital birth registry, medical records, interviews with mothers and healthcare workers	234 perinatal deaths and 468 surviving neonates	Perinatal mortality	Conditional logistic regression
III	Perinatal audit	Antenatal cards, hospital birth registry, medical records, interviews with mothers and health workers	250 perinatal deaths	Factors contributing to three delays, potentially avoidable deaths	Audit of narratives and descriptive statistics
IV	Evaluation of training in Helping Babies Breathe programme	Pretest, post-test and follow-up test on knowledge and skills of health workers	123 healthcare providers	Knowledge and skills gained and retained	Paired t-test and McNemar's test

Population-based study (Paper I)

The study was based on secondary analyses of data obtained from three rounds of Demographic and Health Surveys (DHS) performed in 2000, 2005, and 2010 (134). The latest survey also covered the first three months of 2011. These surveys were designed to provide representative estimates for the entire country including both rural and urban areas as well as all provinces. A two-stage stratified cluster sampling approach was used; previously established sampling frames were employed, stratification was achieved by letting districts form strata, villages (clusters) were randomly selected with probability proportional to size and a systematic sampling of households was done within the selected villages. Similar approaches were used in all surveys.

A total of 35397 women aged between 15 and 49 years and living in sampled households were successfully interviewed (10421 in 2000, 11321 in 2005, and 13655 in 2010). These face-to-face interviews focused on their reproductive history, demographic characteristics of themselves and their offspring as well as socioeconomic characteristics of their households. Only children born from 1990 to 2010 were included in the analyses of Paper I. Data from the DHS 2000 covered 10 years preceding the survey (1990−1999), from the DHS 2005 five years preceding the survey (2000−2004), and from the DHS 2010 six years preceding the survey (2005−2010) to avoid overlap between these surveys. The final weighed sample included 15,189 births from DHS 2000, 8,753 from DHS 2005 and 10,848 from DHS 2010. Procedures related to sampling and details of the fieldwork of these cross-sectional surveys were described in the final DHS reports (13, 135, 136).

Hospital-based studies (Paper II, III and IV)

Paper II and III were based on data collected to study perinatal mortality, which were divided into two sub-studies. The first was a matched case-control study designed to assess social equity in perinatal survival. Cases were matched to controls on hospital and day of birth. A case was defined as a stillbirth or early neonatal death born to women delivering at selected hospitals in Kigali. A stillbirth was a foetal death, which occurred from 22 weeks of pregnancy or weighing 500 g or more at birth. An early neonatal death was a death of a neonate during the early neonatal period, with gestational age of 22 weeks or more or weighing at least 500 g at birth (5). The next two surviving neonates were selected as controls. These consisted of singleton preterm or term babies, who survived the first week after birth or until discharge. Neonates born outside the hospitals involved in the study and those admitted to neonatal intensive care units for life-threatening conditions were excluded.

Sample size was assessed by estimating the proportion of women with low educational levels in control group at 25% and considering 80% power with level of confidence at 95% in order to be able to detect an odds ratio of 1.7. The sample was increased by 10% to compensate for omissions. The final study sample included 234 cases of perinatal deaths, resulting from the sum of stillbirths and early neonatal deaths, and 268 controls.

The second sub-study was a perinatal mortality audit consisting of clinical case review of perinatal deaths enrolled in the study and these deaths included both singleton and twin births. In two sub-studies, information on perinatal deaths was extracted from hospital records and patients' files and also obtained through interviews with mothers or relatives and healthcare providers that included midwives, nurses and doctors, using a semi-structured questionnaire. That information consisted of socioeconomic and demographic characteristics of mother and child, including maternal education and residence, health insurance possession, household wealth, maternal age and parity, age and sex of child.

In paper III, we also sought for information related to medical and obstetrical antecedents, history of pregnancy including vaccines received, pathologies or complications and intra-partum conditions; health care utilization described in terms of number of antenatal visits and newborn conditions at birth until death. In paper II, mothers or partners or other close relatives of controls were interviewed regarding the same socioeconomic and demographic background factors of mother and child.

In both sub-studies, the data collection was performed by one nurse and one midwife chosen from each hospital. The fieldwork was continuously supervised by the main investigator assisted by one doctor per hospital. Interviews with respondents were randomly repeated in order to check the quality of data. The accuracy of information gathered by data collectors was systematically assessed by cross-checking this information with that in different hospital records. In cases of discrepancies, different sources of information were rechecked and discussions among field workers were undertaken until consensus was reached.

In paper III, the researcher, also a paediatrician, together with two other paediatricians and obstetricians, who worked in the two study hospitals, formed an audit committee that assessed the standards of care by midwives, nurses and doctors against local management guidelines or other acceptable practices and examined all potentially avoidable factors. Inadequate healthcare seeking behaviour of mother and substandard healthcare services provided at health facility were classified according to the framework of the three delays (50). The committee also reviewed causes of mortality and assigned a single cause to each case of perinatal death, where it was possible. Potentially avoidable deaths were assessed based on local resources and opportunities to make diagnosis and manage the case. The auditors considered a death to be potentially avoidable if a better management would have

changed the outcome (51, 137). The case review meetings of the audit committee were scheduled on days convenient to the auditors.

Paper IV evaluated knowledge and skills gained and retained by healthcare workers after attending 1-day Helping Babies Breathe course in hospitals involved in the study. The course consisted of didactic modules, including basic knowledge and skills as designed in the curriculum of Helping Babies Breathe (94), and was delivered by three instructors. These included the main investigator assisted by one midwife and one nurse anaesthetist, who had experience in simulation-based training in newborn resuscitation. Before the start of course, they also underwent a 2-day training in the HBB programme. The training was provided to midwives, nurses, nurse anaesthetists and doctors, who might be involved in the resuscitation of a neonate after birth. These healthcare providers were divided into different groups with five trainees in each, in accordance with requirements of the HBB programme. The trainers gave four lessons, which were based on preparation for birth, routine care, The Golden Minute or first minute after birth as well as ventilation with normal or slow heart rate (8).

A written test was applied to evaluate knowledge before and after the training (November and December, 2010). This evaluation also included immediate post training test of practical skills. A written test was based on 17 multiple-choice questions formulated in the HBB flipchart, whereas a practical performance test was based on clinical simulations including 18 items reflecting the content of the course. The simulations were performed using a Neonatalie Newborn Simulator and an Objective Structured Clinical Evaluation station B contained in the HBB flipchart. These tools were provided by Laerdal foundation (94). Each question or item was scored either 0=incorrect or 1=correct. After the test, participants were asked to fill in a questionnaire to assess the quality of the course scored according to a 5-point Likert scale of satisfaction; strongly disagree to strongly agree. A follow-up test of knowledge and practical skills was also performed three months later.

Study settings

Population-based study (Paper I)

Rwanda is located in the Central-Eastern region of Africa and has a total area of 26338 square kilometres. It is a landlocked country bordered by Uganda in the North, Burundi in the South, Tanzania in the East and Democratic Republic of the Congo in the West (Figure 2) (13).

Figure 2. Map of Rwanda showing its geographical location in Africa, bordering countries and its five provinces
Source: Rwanda Demographic and Health Survey report 2010 (13)

Between 1991 and 2012, the Rwandan population increased from 7.2 to 10.6 million and the density of population from 272 to 415 inhabitants per square kilometre, which makes Rwanda the most densely populated country in Africa (138). In addition, the rural part of the population decreased from 94 to 83%, implying a gradual urbanization.

The national population is relatively young as indicated by the proportion of citizens below 15 years of age that was 44% in 2000 as compared to 41% in 2012 (138, 139). In 2010 the fertility rate was reportedly 4.6 children per woman, the population annual growth rate 2.6% and only 45% of married women used modern contraceptive methods (13, 138).

Approximately 94% of women attended antenatal care at least once in 1991, 92% in 2000 and 98% in 2010. The proportion of deliveries occurring at health institutions has increased from 25 to 69% from 1991 to 2010. Breastfeeding was practised by 97% women in 1991 and 99% in 2010. Most mothers exclusively breastfed their children during the first six months of life. In 1991 87% of children from 12 to 23 months of age were fully immunised compared to 90% in 2010 (13, 136, 140).

Febrile diseases, mainly due to malaria, acute respiratory infection and diarrhoea, have since long been the main causes of morbidity among children younger than five years of age. However, from 1991 to 2010 the proportion of children having fever declined from 42 to 16% and those presenting with acute respiratory infection from 33 to 4% and those having diarrhoea from 23 to 13%. During the same period, the proportion of children, who were stunted, has slightly declined from 50 to 44% (13, 140).

Between 1996 and 2012 the literacy rate has increased from 68 to 82% in men and from 58 to 77% in women (13, 136). In 1990, the gross domestic product per capita was estimated at USD 354 (96), whereas in fiscal year 2011- 2012 it was USD 644 (141), which still was below the average of $US 1,391 in sub-Saharan Africa (142).

Data collection was performed at village level, which is the smallest administrative unit. The total number of villages included in the surveys was 445 in DHS 2000, 462 in DHS 2005 and 492 in DHS 2010, while the total number of households in these villages was 9,696 in DHS 2000, 10,272 in DHS 2005 and 12,540 in DHS 2010.

Hospital-based studies (Paper II, III and IV)

The fieldwork for paper II and III was conducted from July 2012 to May 2013 in one district hospital (DH B) and one tertiary referral hospital (TRH), which are main hospitals located in Kigali, the capital of Rwanda. The TRH is also a University hospital involved in the training of medical students and other health professionals.

In paper IV, the training and evaluation of the HBB programme were held in the DH B and TRH and another urban district hospital (DH A), also locat-

ed in the capital. From 2008 to 2010, the number of deliveries attended by midwives, nurses and doctors at DH A was on average 3400 per year, 9890 at DH B and 2640 at TRH. DH B attended the highest number of births in the country during that period. In 2010, health care staff that worked in maternities included 22 health workers at DH A, 33 at DH B and 33 at TRH.

Most patients attended at the three hospitals were urban residents while relatively few patients came from other cities or rural areas. Most of these had been referred from other public or private health institutions. Most patients initially sought care in public health centres or health posts, from where they were referred to district hospitals. The latter could eventually send some these patients to tertiary referral hospitals for advanced care.

In these three hospitals, most patients were covered by the community health insurance, but other insurance schemes, such as state, military and private insurances, were also used. Each patient had to contribute to the payment of health care received with the exception of the poorest people, who were covered by the community health insurance and other people that were covered by some private insurance policies. Such contributions made by patients in order to get healthcare services were known as co-payments and these were set at 10% for the community health insurance and 15% for the state and military health insurance schemes. People having no insurance had to pay the full costs required for the access to health care services. The same applied to patients covered by community health insurance, who did not follow the referral pathways, apart from the emergency cases.

Exposures and outcomes

The outcomes were neonatal and under-five mortality (paper I), perinatal mortality (paper II), factors contributing to three delays related to perinatal deaths (paper III) and knowledge and skills in newborn resuscitation, evaluated before and after the HBB course (paper IV). In Rwanda Demographic and Health Surveys reports, neonatal mortality was defined as the number of deaths occurring within the first month (actually 29 days) after birth per 1000 live births, infant mortality as the number of child deaths before the first birthday per 1000 live births and U5M as the number of deaths among children aged below five years per 1000 live births. Perinatal mortality was considered as the sum of stillbirths and early neonatal deaths per 1000 births. Stillbirths were categorised into macerated and fresh stillbirths. Macerated stillbirths were defined as foetal deaths occurring during pregnancy and before labour and presenting with signs of skin deterioration. Fresh stillbirths were defined as foetal deaths occurring during labour or delivery with no signs of skin maceration. Neonatal, infant, U5M and perinatal mortality were dichotomised into binary outcomes based on the survival status of the child.

Factors contributing to perinatal mortality were grouped according to the three phases of delay.

The first group of exposures included social determinants of health inequities. These variables were maternal education and residence, household wealth and health insurance possession. Maternal education was defined as the highest level of educational attainment. This was subdivided into no formal education, primary, and secondary or higher level. Maternal residence was designated as rural or urban area. Household wealth was considered as a proxy for socioeconomic status of household and was measured using a wealth index. This index had been developed through principal component analysis of assets and facilities owned by households. The household items included in this analysis were radio, television, electricity in the house, computer, refrigerator, mobile phone, landline phone, bicycle, motorcycle, car as well as the main sources of water supply and cooking energy. The total scores of these items were divided into quintiles. The two highest quintiles were assigned to households considered as richer, the middle quintile to the households of middle socioeconomic class, and the lowest quintiles to the households considered as poorer. Health insurance ownership during pregnancy was categorised as not insured, community health insurance, and state or other insurances. Other insurances included military and private health insurance schemes.

Another group of exposures were considered as proximate determinants of health. The latter consisted of maternal age in years, which was split into three groups: < 20, 20−34, and > 34 years; parity categorised as follows: zero, one to four, and more than four; birth order designated as first birth, second to sixth birth, and more than sixth birth; and sex of child.

Data analysis

Trends of mortality were analysed with 3-year moving averages in order to smooth the mortality figures. Weighting was applied for all descriptive statistics to obtain nationally representative estimates. The association between main predictors, namely maternal educational level, household wealth, and residence and the binary outcome neonatal mortality was analysed by means of Generalized Linear Mixed effect Models (GLMM) using R 26 package 'lme4' (143, 144). The mortality risks were presented as odds ratios and 95% confidence interval (CI). GLMM is equivalent to multi-level logistic regression, i.e. a logistic regression including fixed-, random-, and nested effects, and specifically used for data based on multistage cluster sampling methods such as those employed in the demographic and health surveys. The association between main predictors and under-five mortality was analysed by use of a mixed effect Cox regression model (Frailty model) available in the R package 'coxme' (144). The risks of death were presented as hazard

ratios with 95% CI. Frailty model is a multi-level (mixed effect) Cox regression, which is applied when data were generated from the same sampling methods as described above. The case-control study applied a conditional logistic regression analysis to analyse social differentials underlying perinatal deaths and mortality risks were expressed as odds ratios with 95% CI. The significance level of interactions was set at 0.10.

Factors contributing to the three delays underlying perinatal mortality were condensed into different themes based on their similarities. Descriptive statistics were applied to describe potentially avoidable perinatal deaths. Differences of scores between pre-test and post-test on knowledge evaluation was analysed using a paired t-test. The McNemar's test was applied to compare the immediate post-course and follow-up tests on abilities to resuscitate a newborn baby at birth. The analyses were limited to observations with non-missing data. Analyses were facilitated by SPSS version 18 and IBM SPSS Statistics 20 except for GLMM and Frailty model that were part of the R statistical packages.

Ethical considerations

The population-based study (paper I) did not require ethical clearance by an Ethical Review Board since it consisted of secondary analysis of data, which were released for public use. A request for access to and use of these data was sent to ICF International (145). For the hospital-based studies (paper II, III and IV), ethical approval was granted by the Rwanda National Ethics Committee. Before start of this fieldwork, research permission was also sought from the directors of the three hospitals that were involved in these studies.

Participants in these hospital-based studies were informed about the purpose and procedures of the study in which they consented to take part. They were also briefed about the potential benefits of these studies, what their participation implied, issues related to confidentiality and the right to consent to or decline participation at any time. Each invited participant was also given the opportunity to ask questions regarding the study.

Staff were not blamed for any critical events that were revealed during data collection or in the perinatal audit meetings (paper II and III). In paper IV, no names were written on questionnaires used to evaluate knowledge and skills of healthcare workers that were trained in the HBB programme in order to ensure confidentiality of their results. Further, the communication of individual results to each participant was handled anonymously to reinforce this confidentiality. All questionnaires used in the hospital-based studies were kept in a locked cabinet located in the office of the main investigator.

Results

Paper I: Trends and social differentials in child mortality in Rwanda during 1990–2010

A total of 34790 births, including 17 579 boys and 17 211 girls, were retained for analyses, which covered the period 1990–2010. The highest mortality rates occurred in 1994 with neonatal mortality peaking at 60 deaths per 1000 live births (95% CI, 51–65/1000), infant mortality at 137/1000 (95% CI, 129–149/1000) and U5M at 238/1000 (95% CI, 226–251/1000). These rates declined sharply until 1996, when mortality rose again with a second peak occurring in 1997. Afterwards, the mortality consistently decreased until 2010 with the fastest decline observed between the late 1990s and early 2000s as well as in the middle of last decade (Figure 3).
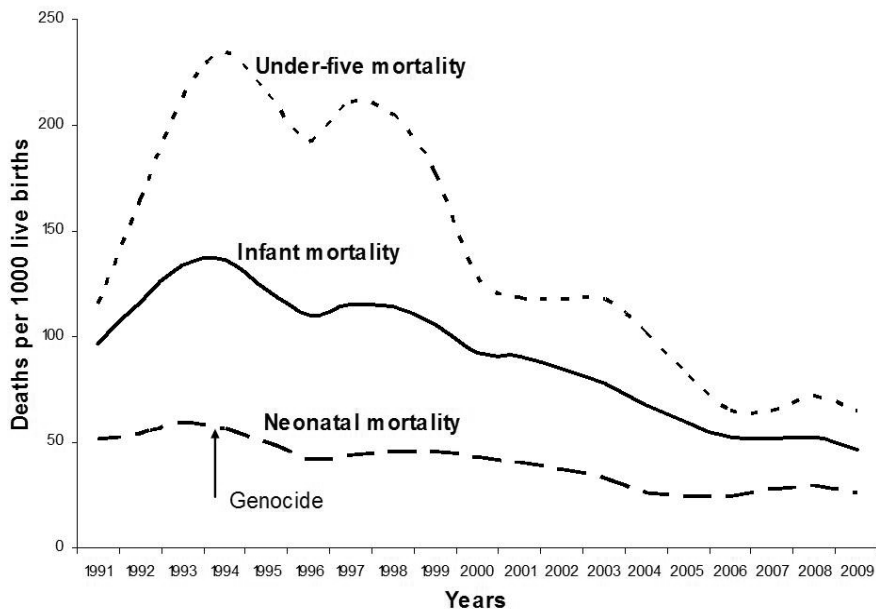
Figure 3. Neonatal, infant, and under-five mortality rates in Rwanda (3-year moving averages), from 1990 to 2010

From 1990 to 2004, the gaps in U5M between different maternal educational groups (Figure 4) and rural or urban residence (Figures 5) were large but these gaps decreased over time.
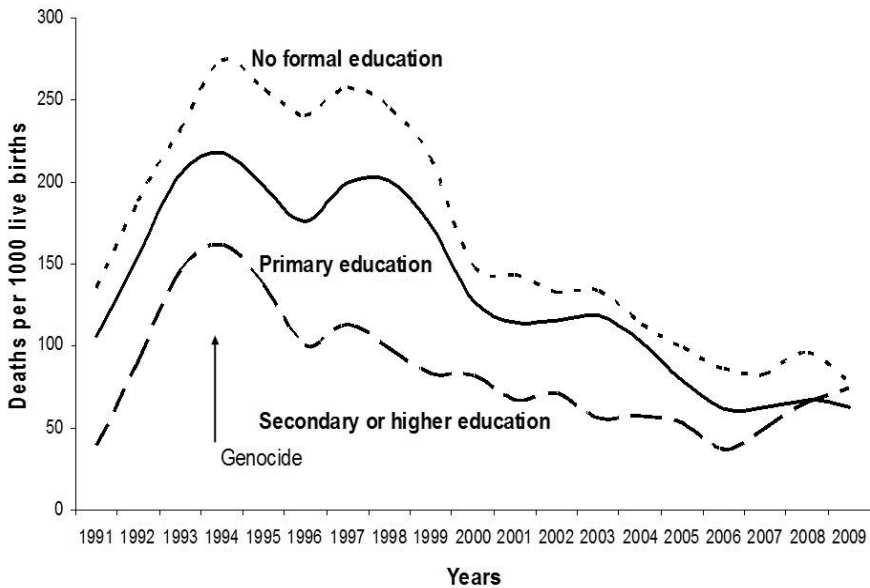
Figure 4. Under-five mortality rates in Rwanda (3-year moving averages) according to maternal educational level, from 1990 to 2010

During 2005–2010, the risk of death in neonates born to women having no formal education (OR=1.29, 95% CI 0.63–2.65) or primary education (OR=1.19, 95% CI 0.62–2.26) was comparable to that of their counterparts whose mothers had secondary or higher education. Neonates whose mothers lived in rural areas had similar mortality risks (OR=1.19, 95% CI 0.67–2.45) as compared to those of neonates whose mothers lived in urban settings. The risk of dying during the neonatal period for children born in poor households (OR=1.15, 95% CI 0.76–1.76) or in households of the middle wealth group (OR=0.86, 95% CI 0.51–1.45) was comparable to that of children born in rich households. Children whose mothers had no formal education had higher U5M risks (OR=1.42, 95% CI 1.00–2.01) than those whose mothers had primary (OR=1.10, 95% CI 0.81–1.51) and secondary or higher education. The risk of death in children younger than five years whose mothers lived in rural areas (HR=1.06, 95% CI 0.80–1.40) was comparable to that of children whose mothers lived in urban settings. Children born in poor households (HR=1.06, 95% CI 0.87–1.29) or in households of the middle wealth group (HR=1.04, 95% CI 0.82–1.31) shared U5M risks with those born in rich households.
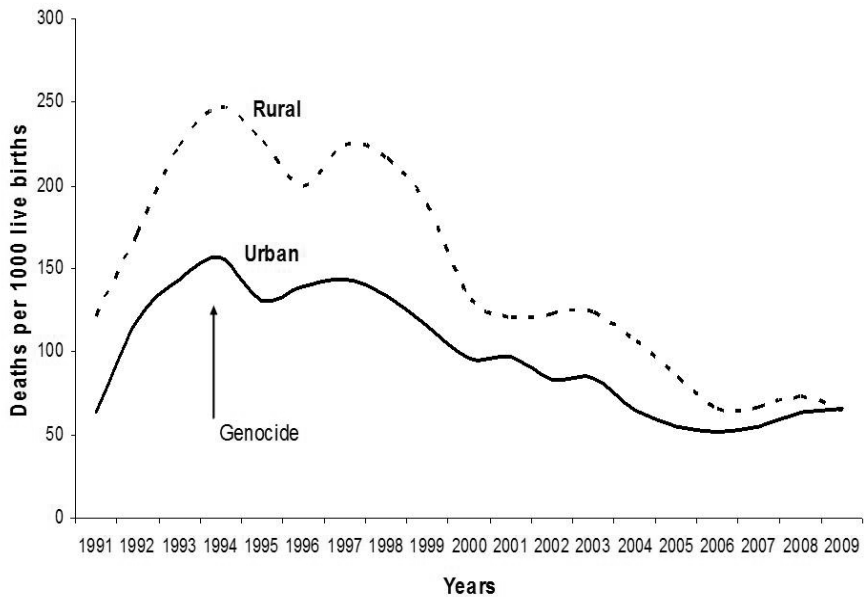
Figure 5. Under-five mortality rates in Rwanda (3-year moving averages) according to maternal residence, from 1990 to 2010

Paper II: Equity in perinatal survival at hospital level in the capital of Rwanda

A total of 8424 births including 269 perinatal deaths were recorded in two hospitals involved in the study, which corresponded to a mortality rate of 32 deaths per 1000 births. Of these births, we analysed 234 cases of perinatal deaths and 468 controls. The remaining 35 perinatal deaths were excluded due to different reasons, including twin deaths, maternal deaths, maternal discharge before enrolment of the baby, maternal refusal to participate in the study, and neonatal death occurring after referral to another hospital.

Approximately 97% of controls and 91% of cases were born to mothers living in urban areas. In the control group most mothers had primary (56%) and secondary or higher (39%) educational levels compared to 57% who had primary and 36% secondary or higher educational levels in the group of cases. Most cases (39%) were born in families of lower household wealth compared to controls (30%). The latter came from richer families (39%) compared to cases (30%). The proportions of mothers using community health insurance in the group of controls (80%) and cases (82%) were similar whereas state and other insurances were frequently used by mothers of controls (17%) compared to those of cases (11%). The proportions of uninsured

mothers were low in both cases (7%) and controls (3%) groups. The mean age of mothers in the cases (28.4 years, range 16–47) and controls (28.1, range 15–48) groups was comparable. Most women in the group of controls (55%) and cases (51%) had parity 1–4. The proportions of boys were higher in both cases (55%) and controls (52%) groups than those of girls.

Women having secondary or higher educational levels or coming from rich households frequently used state and other insurance policies ((p=0.01). Those who had no formal education or came from households with lower or middle wealth were likely to be uninsured or covered by community health insurance (p=0.01).

Maternal rural residence (OR = 4.15, 95% CI 1.88–9.16), lower household wealth (OR = 1.74, 95% CI 1.18–2.57), or having no insurance (OR = 2.08, 95% CI 0.96–4.50) were associated with increased perinatal mortality risks in crude analysis. There were low perinatal mortality risks for babies born to women using state and other insurance policies (OR = 0.46, 95% CI 0.25–0.84) compared to those covered by community health insurance. No significant association was found between maternal education and perinatal mortality.

Maternal rural residence (OR = 3.31, 95% CI 1.43–7.61) or having no insurance (OR = 2.11, 95% CI 0.91–4.89) was still associated with increased perinatal mortality risks in the adjusted model. Perinatal mortality risks remained low for babies whose mothers used the state and other health insurances (OR = 0.49, 95% CI 0.25–0.95) compared to those using community health insurance. There were no significant differences in perinatal survival between babies born in poor and rich households after adjustments.

Paper III: Case review of perinatal deaths with application of a three delays analysis at hospital level in the capital of Rwanda

Out of 269 perinatal deaths, which occurred during the study period, 106 were macerated stillbirths, 63 fresh stillbirths and 100 early neonatal deaths. Among stillbirths, foetal heartbeats were only audible for 40% of fresh stillbirths on admission. Most perinatal deaths were singleton (94%). We excluded 19 cases of deaths from the audit due to the mothers' discharge (n=14) or deaths (n=2) before interviews or because of maternal refusal to take part in the study (n=2). Another case of death was not reviewed because the death occurred at another hospital after referral. In total, 250 cases of perinatal deaths were analysed. Babies whose mothers lived in urban settings (90%) or had primary educational levels (57%) or lived with partners (82%) constituted the largest proportions. Most babies (73%) were born to women aged 20−34 years (median age 28 years, range 16−47) with parity 1−4

(50%). Most deaths occurred among preterm babies (53%). The highest proportions of babies were born to mothers, who attended 1−3 antenatal care visits (75%) and delivered vaginally (68%). Approximately 38% of babies were born to mothers who experienced complications during pregnancy. These complications mainly included preeclampsia, eclampsia, pre-existing hypertension and HIV/AIDS.

Overall, the factors related to three delays, which contributed to perinatal deaths, were assessed in 197 cases of deaths (79%). Several factors could be present in the same case of death, which resulted in a higher number of contributory factors to the mortality compared to the number of deaths. The phase one delay was identified in 98 cases of perinatal deaths, of which 75% were macerated stillbirths. The phase two delay was only reported in 24 cases. The phase three delay was found in 93 cases of deaths, of which 45% were early neonatal deaths and 36% fresh stillbirths. Factors, which contributed to the three phases of delays experienced by women or their babies, are shown in Table 2.

The most common contributing factor to the phase one delay – when a woman was delayed in making a decision to seek appropriate care – was lack of awareness or not reporting danger signs during pregnancy and childbirth. These signs mainly included poor foetal movements, preterm contractions and rupture of membranes and were found in 81 cases of perinatal deaths. The phase one delay could be compounded by the use of traditional medicines provided by traditional healers. The remaining contributing factors to the phase one delay were related to poor uptake of formal care by healthcare providers, as reflected by the non-attendance of antenatal care visits and non-compliance to the treatment or follow-up recommendations. This was especially noted in cases of unintended pregnancies, maternal single marital status, and lack of communication between care seekers and providers or without any specific context.

After deciding to seek care, some women had difficulties to reach health facilities, mainly due to lack of money to pay for transport or to cover other expenses related to hospitalisation. Other factors, which contributed to the phase two delay, were less common. These included long distance from home to a health facility, lack of transport or health insurance and illness among family's members. The phase two delay also occurred when a woman preferred to seek care during the day instead of the night with unclear reasons.

Table 2. Delays experienced by pregnant women and their babies in receiving adequate care, as reported from perinatal audit conducted at hospital level, Kigali, Rwanda July 2012–May 2013

Delays	Cases with delays
Phase one: care-seeking	**98**
Lack of recognition of danger signs	81
Poor uptake of or compliance to formal care	25
Phase two: reaching health facility	**24**
Lack of money	15
Long distance	6
Lack of health insurance	3
Social or family reasons	3
Phase three: quality of care at health facility	**93**
Before admission	
No or late diagnosis	9
Inadequate management	
Delay in the referral	13
Inadequate care or monitoring	12
After admission	
Late diagnosis	3
Inadequate management	
Inadequate monitoring or late intervention	41
Non-adherence to guidelines or best practices	5
After delivery	
Inadequate management	
Insufficient care	11
Inadequate monitoring	3
Total	**197**

Note that there were more contributing factors to mortality than cases of deaths since several factors could be identified in one case of death.

Barriers to the access of adequate care were also found when some women or their babies received suboptimal care at the health facility, which resulted in a phase three delay. This phase of delay encompassed suboptimal care factors, which occurred before or after admission to the hospitals involved in the study. Before admission, the most common contributor to the phase three delay was a delay in referral of women from health centres or private clinics or district hospitals to higher levels. These referral delays were found in 12 cases of death, mainly linked to intrapartum-related hypoxia, preterm labour and preterm rupture of membranes. Other common substandard care by healthcare providers included insufficient follow-up of women with high-risk pregnancies such as previous perinatal death. Substandard care factors

also included late diagnosis or management of some obstetric emergencies such as gestational diabetes, umbilical cord prolapse, hypertension or preeclampsia.

After admission, the most frequent suboptimal care factors related to the phase three delay were inadequate foetal monitoring and management of pregnancy and labour complications. These deficiencies were identified in 40 cases of perinatal deaths mainly related to preterm labour, prolonged and obstructed labour, maternal hypertension, preeclampsia and placenta abruption. Other inadequacies included the non-adherence to local protocols during labour induction and delivery of twin pregnancy. They also included late diagnosis of some complications related to pregnancy such as preeclampsia and placenta abruption.

After delivery, suboptimal care factors were mainly characterised by insufficient preparedness and skills for handling newborn emergencies such as intrapartum-related hypoxia. Appropriate management of intrapartum-related hypoxia was also limited by lack of essential drugs such as phenytoin. Other examples of suboptimal care consisted of inadequate monitoring of vital signs in preterm babies, who later presented hypothermia and bradycardia. The phase three delay was also reported in some cases, where death was related to inadequate management of emergency newborn conditions such jaundice, food intolerance, and severe anaemia.

Approximately 51% of perinatal deaths audited, i.e. 128/250, were likely preventable. Most of these avoidable deaths (70%) were fresh stillbirths and early neonatal deaths.

Paper IV: Evaluating Helping Babies Breathe programme at hospitals in the capital of Rwanda

A total of 118 healthcare workers attended the HHB course. Most of them (90%) were female. The majority of participants (63%) had graduated from higher learning institutions. Around 55% of trainees were nurses and 31% midwives and most of them (70%) were not formally trained in neonatal resuscitation. The highest proportion of healthcare workers (61%), who completed the course, worked in labour, delivery and operating rooms of maternity, where deliveries take place.

The mean scores obtained by trainees on a knowledge evaluation significantly increased from before (77 ± 15%) to after the course (91 ± 9%), p<0.01. On postcourse test, the mean score achieved on a practical performance evaluation was 89 ± 9%, and passing scores were obtained by 64% of participants. Their knowledge was sustained for at least three months following the course while their practical skills declined to 83 ± 16%, and the pass rate decreased significantly to 43%, p<0.01.

Discussion

The temporal trends in child mortality in Rwanda across the period 1990−2010 were markedly influenced by the social and political developments. The highest peak in neonatal and U5M occurred at the time of the 1994 genocide and was a few years later followed by another peak that coincided with the reintroduction of health care user fees and a decrease in external aid. Thereafter mortality has dramatically declined up to the latest figures in 2010 coinciding with the scale up of major social and health reforms that were initiated from late 1990s onwards. However, neonatal mortality showed a slower decline as compared to infant and U5M. The reduction in child mortality was accompanied by increased social equity in survival chances between rural and urban areas and between households of different wealth levels, but children born to women with no education still had significantly higher under-five mortality. In hospital-based studies conducted in the Rwandan capital we found increased perinatal mortality among children born to women living in rural areas and those having no health insurance. However, perinatal survival was neither associated with maternal education levels nor with household wealth. Major factors associated with perinatal mortality included lack of recognition of danger signs by pregnant women and intrapartum-related suboptimal care at health facilities, whereas lack of financial means by these women when seeking care was less common. Half of the reviewed perinatal deaths were considered potentially avoidable. A training programme to manage the first minutes of life, Helping Babies Breathe, significantly improved healthcare workers' knowledge. While this knowledge was maintained for at least three months that followed the training, practical skills had significantly decreased.

Methodological considerations

Paper I is the first of its kind in Rwanda to systematically describe trends and social differentials of childhood mortality across two decades. The results are representative of the country as a whole since they were based on data provided by nationwide demographic and health surveys. These surveys applied a two-stage stratified cluster sampling method that involved large sample sizes of women in reproductive ages. Based on their reproductive life reporting in the three surveys birth cohorts could be created. The procedures

and methods used in the DHS data collection are very strict. Maternal education and residence, which represent different aspects of socioeconomic conditions in these analyses, are determinants that are relatively constant and may allow comparisons over time periods. The findings of mortality trends across these determinants are likely to reflect the true figures at national level. Results may also be compared to results from other countries. However, comparisons regarding the patterns of child survival over time should be done cautiously due to the exceptional recent history of the country that includes the genocide in the mid-1990s.

Papers II and III focused on perinatal mortality, which has not received sufficient attention in Rwanda, maybe due to the lack of previous research in this area. In paper II the sample size was calculated based on local information on perinatal mortality. Controls were selected from the same population as cases and matched to cases for day and hospital of birth to prevent selection bias. In paper III mothers who were enrolled in the study were interviewed before their discharge from the hospital, which contributed to minimize recall bias. The results reported in papers II and III illustrate the situation of perinatal care and survival in the urban context, mainly the capital, and could thus not be generalized to the rest of the country.

The materials and programme used for teaching and evaluating the HBB course that formed the basis of Paper IV had been validated by the American Academy of Paediatrics (94, 146). This approach had also been used in other low-income countries, where the HBB programme was piloted or implemented (8, 9). The trainers, who also performed the evaluation of knowledge and practical skills of the healthcare workers, remained the same at all three sites and this reduced the risk of observational bias. These healthcare workers had professional experience, which could be comparable to that of their colleagues working in other urban hospital settings in Rwanda. Thus, the results from this study could be generalized to these settings and possibly to other parts of sub-Saharan Africa.

The studies have some limitations. Underreporting of births and deaths may occur in retrospective data collection such as the Demographic and Health Surveys. Children who die shortly after birth may be missing in interviews with mothers, and this risk of underreporting may be more pronounced if the event occurred back in time. The underreporting also includes births and deaths by women who died or emigrated out from the country before the survey (147). Misreporting of age at death with a tendency to round off the age can also result in misclassification of deaths between age different categories of under-five mortality. The most common form of the inaccurate report of age at death refers to the heaping of age at 12 months. Both underreporting and misreporting errors are considered to be small in the DHS due to very rigorous design and fieldwork (13, 147). We further reduced any potential recall bias by restricting the analysis to children born within 10 years prior to the survey except for the DHS of 2005 and 2010,

where data was limited to only five and six years preceding the survey, respectively, to avoid an overlap between these surveys. The data quality is less affected by recall errors when the information reported concern a 10-year period preceding the survey. Another issue related to the use of retrospective information is that mortality estimates relates to the past while social characteristics, such as mother's education and residence as well as household wealth, apply to the measures recorded at the time of survey (13, 147). Mother's education level and residence are relatively constant over time. Household wealth score is a relative indicator that applies to a given time and setting. Thus, it was not possible to compare the progress of child mortality according to this indicator across the four study periods (1990–1994, 1995–1999, 2000–2004, and 2005– 2010). In addition, disparities in child survival between social or demographic strata included in the DHS, e.g. rural or urban residency may be explained by factors that are not included in the DHS questionnaire (148).

During the study period, not all cases of perinatal deaths were captured. Family members took some dead babies away shortly after death and before data collectors were informed about the death. Misclassification between miscarriages and stillbirths constituted another potential bias, especially when the date of last menstrual period is unknown. This bias was minimised by considering a stillbirth as a foetal death weighing at least 500 g at birth and birth weight was available for all babies. In addition, ultrasound was performed in all pregnancies with suspicion of stillbirths in order to assess the status of the foetus and other information such as gestational age and foetal weight. The risk of misclassification between macerated and fresh stillbirths or between fresh stillbirths and early neonatal deaths (149, 150) was also avoided by considering clinical findings, including the conditions at birth for each case of death.

A study recently carried out in Tanzania showed that the 5-minute Apgar score was an unreliable indicator of intrapartum-related hypoxia (151). This is in accordance with our findings that showed that some neonates admitted in neonatal intensive care unit for intrapartum-related hypoxia were initially assigned normal 5-minute Apgar scores. However, when cross-checking data from various hospital records and mother's accounts it was noted that Apgar scores were incorrectly reported for some cases. This contributed to reduce misreporting, thereby minimising the underestimation of suboptimal care factors related to the quality of intrapartum care. When studying causes of perinatal mortality, lethal congenital malformations were assessed based on clinical and ultrasound findings since no autopsy was done. This may have led to misdiagnosis of these abnormalities with a risk of underestimating the number of non-avoidable perinatal deaths since all lethal congenital malformations were considered non-avoidable (152). The discussions undertaken during perinatal audit were mainly informed by data available in hospitals involved in the study. The access to detailed information related to the man-

agement of pregnant women before admission would have been difficult. This was a limitation for a complete assessment of the quality of care received elsewhere. When assessing avoidable perinatal deaths, the panellists have mainly applied an implicit review, which is likely dependent of reviewers' opinions (88). This may have influenced the estimated number of avoidable deaths. Household wealth was considered as a proxy of the socioeconomic status of the household and was developed based on household assets and facilities as suggested in the Demographic and Health Survey reports (13). However, some items, including roofs, walls and floors of houses and toilet facilities were not taken into account when developing these asset scores. This would have required a visit and assessment of these items at participants' home, which was out of scope for the study.

When evaluating the HBB programme we did not assess the clinical performance of the participants as a pretest, since it was considered too difficult to organize, although we made such an assessment after the course and in the follow-up three months later. We were not able to control whether trainees had been exposed to other learning experiences that would have improved their knowledge before the follow-up evaluation after three months. The HBB curriculum was designed in English and a translation into the other local languages (Kinyarwanda and French) would have been helpful for the trainees, who had some difficulties with the English language. This issue was addressed in our study by emphasizing practical hands-on experiences rather than theoretical procedures and by using simultaneous translation when needed. Although our findings revealed a potential benefit of HBB as an educational programme, we could not evaluate the impact of this training on perinatal and newborn survival.

Temporal trends in child mortality

The trends in child mortality 1990-2010 in Rwanda followed the course of socioeconomic and political developments in the country (Paper I). Mortality sharply increased from 1990 to 1994, when a first peak coincided with the genocide that claimed more than one million people and also destroyed the health infrastructure (13). In the aftermath of the genocide, the country started to recover from its consequences and to rebuild the health system. In the immediate post-genocidal period infant and under-five mortality was reduced when security improved and substantial international support was provided. Around 1996, when this assistance started to decrease, mortality once again increased. After the genocide healthcare had been provided free of charge, which has increased the use of health services with a positive impact on health outcomes (153). The removal of user fees in health services has been shown to decrease child mortality in many African countries (154, 155). This new increase of mortality could partly be explained by a partial

withdrawal of foreign emergency aid, which prompted the government to reintroduce the user fees in 1996 in order to recover healthcare costs (153). From 1999 onwards, the implementation of comprehensive social reforms including health reforms was scaled up. These efforts were backed by a political will to promote living standards of the population and empower women, as reflected in the long-term strategy Rwanda vision 2020 that was initiated in 2000 and embodied in the framework to accelerate the economic development and poverty reduction 2008–2012 (123). The synergy between these initiatives may have played a pivotal role in accelerating the decline in infant and under-five mortality observed from the early 2000s. In contrast, neonatal mortality did not show the same decline. This may reflect the little attention that was given to strategies and policies aiming at improving neonatal survival, as highlighted by other studies from low-income countries (156).

In 2010 Rwanda had a lower under-five mortality rate as compared to the bordering countries, i.e. the United Republic of Tanzania (81 per 1000 live births), Uganda (90 per 1000 live births), Burundi (96 per 1000 live births), and the Democratic Republic of the Congo (104 per 1000 live births in 2011) (134). However, the Rwandan under-five mortality rate was higher than that of Seychelles (14 per 1000 live births) and Mauritius (15 per 1000 live births), which were the lowest in Africa that year (115). Rwanda has had a similar average annual reduction in U5M rate as that of Ethiopia (3.6%) and has been in the third position within sub-Saharan Africa after Madagascar (4.6%) and Liberia (4.3%) from 1990 to 2011 (23). This reduction has been accelerated in the last few years and Rwanda has now reached the Millennium Development Goal number 4 by reducing the U5M to 50 deaths per 1000 live births (19).

Key drivers of child mortality reduction

Recent reports on factors contributing to the reduction of under-5 deaths in low- and middle-income countries have shown that the mortality reduction has been a result of investments made in the health system as well as in other sectors of society. This has been underpinned by other factors, including good governance and leadership and crosscutting strategies, such as strong collaboration between various stakeholders (157, 158).

From 1990 to 2010 estimates from low- and middle-income countries have indicated that half of deaths among children younger than five years have been prevented by strengthening of the health systems with special emphasis on scale-up of high impact interventions, such as family planning, skilled birth attendance and immunization, which are in line with the continuum of care for maternal, newborn and child health. The remaining gains in child survival may be a result of major reforms in other sectors of society, such as

education, women's empowerment, nutrition, clean water and sanitation and reduction of poverty and social inequities. These efforts were further reinforced by good governance and leadership, which emphasized control of corruption, decentralization of governance, strengthening the accountability and decision-making strategies and establishment of policies and laws enabling a favourable environment for health promotion at all levels. Progress towards improved survival was further strengthened by multisectoral collaboration, involving local and external partners. This collaboration was aligned to national policies and goals, which were continuously updated and tailored to the country-specific priorities (159).

The percentage of women using modern contraceptives increased from 13 to 45% from 1990 to 2010, skilled birth attendance from 26 to 69%, exclusive breastfeeding from 30 to 85% and the proportion of children aged 12 to 23 months fully immunized increased from 79 to 90% (13, 140). In 2010, the country had achieved or was on track to reach the MDG targets related to coverage of antenatal care, reduction of adolescent births, infants immunized against measles, reduction of underweight, prevalence of HIV/AIDS and malaria, and access to essential drugs (18). From 2000 to 2010, the adult literacy rate (15 years and above) increased from 68 to 82% in men and from 58 to 77% in women. In 2005, a national nutrition policy was adopted and operationalized through an interministerial action. The prevalence of underweight among children younger than five years of age decreased from 29 to 11% from 1990 to 2010, stunting from 48 to 44% and wasting from 4 to 3%. The access to clean water and improved sanitation was prioritized. *Umuganda* is a homegrown initiative aiming at improving environmental cleanliness and health practices through a community work organized once a month and that included discussions about health-related issues. These efforts to improve hygiene may have contributed to the decrease in diarrhoea morbidity in children before the age of five years from 23% in 1990 to 13% in 2010 (13, 140, 158). Improving the participation of women in the societal and political structures came into focus (160). The proportion of women parliamentarians increased from 18% before the 1994 genocide to 56% in 2008 and 64% in 2013, which was the highest female representation in parliament all over the world (161).

Several homegrown approaches to address poverty and reduce social inequities were developed or strengthened over the past decade. *Ubudehe* is a traditional practice that involves community members in a process of solving problems occurring in a community with special emphasis to pro-poor support. One Cow per Poor Family Programme *or Girinka,* which is part of *Ubudehe* approach, aims at providing support to poor people in order to improve their nutrition and income by providing one cow per poor household (158, 162). Poor people and other vulnerable groups have also been assisted by the national social protection system. This targeted support consists of cash transfer to facilitate the access to education and health services, access

to microcredit for investment, direct cash transfer to individuals living in extreme poverty and unable to work, and other programmes alleviating poverty (14). Since the mid-2000s decentralisation of governance in the public sector, including the health system was strengthened to empower local governments and other lower level institutions (12, 163). The decentralisation was expected to increase accountability, ownership and decision-making power at these levels, which may have contributed to improved service delivery. *Imihigo* refers to a traditional practice, also known as performance-based contracts, where individuals or community groups vowed to achieve certain goals by improving their performance. Since the last decade this practice has involved mayors and other authorities that publicly pledged and strived to improve social and health indicators in their districts (163).

Zero tolerance against corruption was strengthened. Intersectoral collaboration, involving all ministries and various partners, was emphasized and aligned with the overarching Vision 2020 strategy. In 2007 a Joint Action Development Forum was established, including various stakeholders from civil society, non-governmental organizations, local government authorities and other development partners, and scaled up in all districts. This forum worked as a consultative body with its main focus on the development of a district. The joint actions of these stakeholders have contributed to reduce child mortality (158).

Social inequities in mortality

Children born to women who haven't received any formal education have frequently an increased risk of dying before age five in low- and middle-income settings (44, 46, 164, 165). This association was also present in our analysis of Rwanda Demographic and Health survey data covering two decades (1990–2010), even though mortality risks were decreasing over time. There was no significant difference in neonatal mortality across mothers' educational levels in recent years (2005–2010). This was also the case for perinatal mortality in the hospital-based study. Evidence shows that women's education increases their capacity to address various social challenges including health problems, which is beneficial to their own health and to that of their offspring (4, 166). From 1970 to 2009 increased maternal education was linked to the prevention of more than a half of child deaths around the world (165). The government of Rwanda recently adopted the policy of a 12-year free basic education, which may contribute to further decrease of child mortality in the future (167). In addition, gender-related disparities in the access to education were given more attention, which resulted in 98% female enrolment to primary school in 2012 (168).

Our analyses have shown that in 2005–2010 children before the age of 5 years living in poor or rich households had comparable survival chances,

which was in contrast to findings commonly reported from other studies (3, 164). In the hospital-based case-control study we also found that there were no significant gaps in perinatal mortality across different household wealth groups. Increased coverage in life-saving interventions in Rwanda over the last decade together with targeted support to the poor (14, 123) may explain the improved perinatal and child survival noted in our studies. Similar trends were observed in Vietnam, where high coverage in health interventions combined with efforts to support socially deprived groups contributed to reduced inequities in neonatal mortality (46). A decreasing social divide in neonatal mortality was recently reported from many other low- and middle-income countries (128).

In low- and middle-income countries a gap in U5M between rural and urban areas is common (4). In Rwanda this gap has decreased over time, especially in 2005–2010, when no significant differences in mortality were found between rural and urban areas. The decline in social divide in child survival between these areas may reflect an effective national coverage in interventions and programmes, which have been scaled up since late 1990s (14, 108, 121). For example, when the community health insurance system, also called Mutuelle de santé, was scaled up in the whole country in the middle of the 2000s, approximately one million of the poorest people, mostly living in rural areas, got free access to this insurance (13, 17, 158). This contributed to reduced financial barriers to the utilisation of healthcare (169). Barriers to the access of healthcare were also reduced by the task-shifting strategy, which allowed a large number of trained community health workers to participate in services delivery, especially in rural areas (108). The *Ubudehe* approach mainly targeted poor and other disadvantaged groups (14, 123) and may have further contributed to tackle health-related inequities that could be reflected in the improved child survival regardless of rural or urban residency. However, our hospital-based study indicated excess perinatal deaths among women living in rural areas, as also shown in previous studies conducted elsewhere (48, 49). This may be related to lower access to adequate healthcare in rural areas as highlighted by some authors (170). In Rwanda, financial and distance constraints were reported as main factors limiting the accessibility to health facilities, especially in rural areas, which may partly explain the rural/urban divide in perinatal survival (13). This highlights the need to improve quality of care during pregnancy and the perinatal period, especially for women living in rural areas.

In the hospital-based study, we also found that the health insurance status was a key determinant of perinatal survival with increased mortality risks among babies born to women having no insurance. Studies conducted in Rwanda and other countries recognise that the possession of health insurance increases access to healthcare (169, 171), which may contribute to improved health outcomes (172). However, other social factors, including educational level and socioeconomic status of the household may also influence healthcare utilisation (173). These social determinants were significantly

associated with the type of insurance the pregnant women had. Community health insurance was most common for women with limited resources or for those having low educational levels, while state insurance or other insurance systems were more frequent for rich women or those having secondary or higher educational levels. This may partly explain the differences in perinatal survival between holders of community health insurance scheme and those using other health insurance systems. Thus, improved education and universal health coverage as well as poverty reduction seem to be key strategies for addressing social divide in perinatal survival.

Quality of care, perinatal and neonatal survival

There are well-known quality-of-care factors that contribute to perinatal mortality. Some of these factors are related to delays experienced by women or their babies in getting access to adequate care (50, 51). Such delays were identified in more than three quarters of the deaths reviewed through perinatal audit, as reported in paper III. Using a three-delay model, we found that the most frequent contributors to mortality were related to the first phase of delay (delay in decision-making to seek care), followed by the third phase of delay (delay in receiving adequate care), while the phase two delay (delay in reaching health facility) was less common. However, this order of frequency was not consistent across the different groups of perinatal deaths. Phase one delay was predominant among macerated stillbirths and phase three delay among fresh stillbirths and early neonatal deaths.

The plausible reason for the predominance of phase one delay was that most women were not aware of pregnancy and labour dangers signs and their severity, especially poor foetal movements, preterm labour or rupture of membranes. These women decided to seek care when it was too late, as reflected by a high number of macerated stillbirths, which all occurred before admission. The lack of knowledge about danger signs could be aggravated by the reliance on medicines provided by traditional healers, as shown by our results. Such a misuse of traditional medicines was associated with negative effects on mother and foetus such as increased risk of uterine rupture and intrapartum-related neonatal deaths (174, 175). Other contributors to phase one delay were related to social conditions such as women living without partners, unintended pregnancy and lack of communication between women and care providers. These factors have also been reported in other studies conducted in low- and middle-income countries (51, 176, 177).

Our findings suggest that the main contributing factors to phase two delay included limited financial means, lack of insurance or transport, long distance between home and health facility and other social reasons. We have also demonstrated that having no insurance during pregnancy increased the risk of perinatal death (Paper II). Transport problems were less common

since most women enrolled in our study on perinatal audit lived in urban areas, where transportation means and good roads were available. In a study on neonatal mortality in Uganda and another on stillbirths and neonatal deaths in India, relatively few difficulties to reach health facilities were also mentioned by care seekers (52, 176). However, in many low- and middle-income countries, lack of transport, long distances and poor roads, limited financial resources and lack of health insurance have been major challenges faced by patients when seeking care (55, 178-180).

The suboptimal care received by mothers or their offspring at health facilities is recognised as a major contributor to poor perinatal outcome (55, 56, 181). A systematic review on maternal and perinatal mortality in low-resources settings has recently shown that suboptimal quality of care by healthcare providers was the most common factor contributing to death. These factors were followed by delays in patients seeking care or reaching the health facility, mainly due to lack of transport (51). Substandard care includes delays in patient referral (176), inadequate antenatal care, delay of diagnosis or treatment (7, 174, 182, 183), insufficient foetal and labour monitoring (55, 56, 177, 181), inadequate neonatal resuscitation and other emergency neonatal care (5, 54). Most of these inadequacies in healthcare provision at health facilities were also identified by our study on perinatal audit. This study also indicated that half of the perinatal deaths could have been averted if these delays had been prevented. Most of these potentially avoidable deaths included fresh stillbirths and early neonatal deaths, reflecting an insufficient care during the intrapartum period (149). In other settings, the proportion of perinatal deaths, which could be prevented, ranged from 14 to 75% (55, 184-186). This variation across different settings may partly be explained by different definitions and methods employed in these studies, the level of mortality and quality of care in each setting. There is also a variation in cut-off of gestational age (22 or 28 weeks) when defining cases of perinatal deaths (181, 182). Others have used a weight definition (at least 1500 g or 2000 g, respectively) (56, 185). Estimates on potentially avoidable deaths could also be influenced by opinions from the expert panel that performs the perinatal audit (56, 91).

The Helping Babies Breathe programme was conceived for the prevention of intrapartum-related neonatal deaths, which constitute a high number of perinatal deaths. It has been evaluated in some low- and middle-income countries (9, 95). Our results showed that healthcare workers from three urban hospitals significantly improved their knowledge in neonatal resuscitation after the HBB course and retained it 3 months later. However, their practical skills decreased over time after the training. Other studies have also found a rapid deterioration of acquired skills and, to a lesser extent, knowledge, in the months following the training in newborn resuscitation (187-191). While earlier findings showed that practical abilities could be even lost within 3 months, most studies have indicated a longer period for

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knowledge decline (188, 190, 192, 193). Nevertheless, the retention of both knowledge and skills remains a broader concern (188, 194). Thus, it was recommended by many authors to provide refresher courses at regular intervals and make instructional videos available in order to improve retention (190, 194). All trainees in the HBB programme also recommended such refresher courses that would be beneficial for maintaining their knowledge and skills. However, these refresher courses may not be sufficient without creating a conducive work environment and motivating healthcare workers that are key strategies for improved performance (195).

Although the HBB approach seems to improve knowledge and practical skills, this effect is still controversial. While the implementation of this programme in the United Republic of Tanzania was significantly associated with improved knowledge and practical skills of healthcare providers as well as reduction of fresh stillbirths and improved neonatal survival (9), a similar approach known as Neonatal Resuscitation Programme emphasizing basic newborn resuscitation did not show any differences in mortality reduction (196). A recent evaluation of the HBB programme in India also indicated that training in this programme was followed by a decline in stillbirths but not in neonatal mortality (95). Thus, the effectiveness of the HBB programme in terms of neonatal survival still needs to be reassessed in different settings.

Implications and recommendations

The rates of child mortality in Rwanda were exceedingly high during time of the genocide, highlighting the need to prevent social conflicts and genocide, which are devastating for people and the fabric of society (2, 64, 197, 198). These mortality rates markedly decreased in the aftermath of the genocide when the country received a strong support from the international community. However, a new peak of mortality occurred a couple of years later, at the time when this support was reduced, underscoring the need to have a wise transition from emergency aid to other forms of developmental assistance that would enable a country to recover from a deep social crisis to develop capacities to effectively cope with post-conflict challenges. The decrease of mortality observed immediately after the genocide also followed the removal of health services user fees that fostered health services utilisation during that critical period. Strengthening financing mechanisms such as community health insurance scheme that was scaled up recently all over the country have contributed to better health coverage and ensured that households are protected against catastrophic health expenditures (169). Major health and social reforms implemented over the last decade seems to have been crucial for accelerating the decline in child mortality. For further reduction these reforms should be sustained and particular attention should be given to strategies, which facilitate the implementation of effective interventions and programmes that could lead to positive changes. Such strategies include good governance and leadership, strong partnership with various stakeholders and long-term vision guiding the progress (158).

While increased coverage of health interventions is critical for improved child survival, this coverage needs to be combined with targeted interventions in order to address the gap in survival between different social segments (64). An increasing body of literature suggests that childhood mortality is lower in countries, which have made substantial investments in social protection to socially deprived groups (199). In Rwanda, the reduction of under-five mortality concurred with improved equity in survival, reflecting the efforts made to strengthen supportive policies to underserved groups. Direct or indirect support was provided to individuals or households living in extreme poverty and other vulnerable groups; community health insurance was primarily developed to help low-income families to increase their access to healthcare; community health workers contributed to improved health services delivery, reducing rural/urban disparities in health coverage; many

other initiatives were undertaken to improve key determinants of social inequities in health such as education and poverty. Such efforts are needed for further reduction of social inequities in health at national and subnational levels and among population groups, especially during the perinatal and early childhood period.

However, to ensure a sustainable reduction of mortality, special attention should be given to quality improvement of health services across the continuum of care for mother, newborn and child. Optimizing these services requires that due consideration is given to competence and motivation of the health workforce as well as availability of infrastructure and equipment (195). Optimization of care also entails scale-up of evidence-based approaches such as perinatal audit and Helping Babies Breathe, which have shown a positive impact on perinatal and neonatal survival (9, 95). The Helping Babies Breathe programme is currently being scaled up in Rwanda, which may contribute to a reduced number of intrapartum-related stillbirths and neonatal deaths (200).

Availability of high-quality health and demographic information is crucial for guiding policy formation and health interventions in a country, where Demographic and Health Survey data still are the main sources of health statistics. Thus, research is needed to assess, for example, the quality of perinatal care through a nationwide perinatal audit study, which was beyond the scope of this thesis. It would also be relevant to analyse contextual factors that may hamper or foster the implementation of evidence-based knowledge for better survival. The success in reducing mortality in Rwanda was made possible through heavy investments, especially in the health sector. However, the sustainability of this achievement may be a challenge since the country is still dependent on external financial support, which may be decreased or suspended in the future.

Conclusion

This thesis has shed light on Rwandan trends in under-five mortality and equity in child survival during the last two decades. It has also revealed barriers to perinatal and neonatal survival as well as shown a positive effect of Helping Babies Breathe programme on knowledge and practical skills of health workers in neonatal resuscitation. The trends of mortality in children younger than five years of age were influenced by major social developments, which occurred in the country during the recent years. The highest mortality peak occurred during the 1994 genocide and was followed by another peak in 1997. This second peak occurred when the international emergency aid provided to the country after the genocide was removed. The health care user fee that was abolished during genocide was also reintroduced after the suspension of the international support, which may partly explain this second peak of mortality. The mortality remained high until late 1990s when broader health and social reforms were scaled up. These reforms were followed by an impressive decrease in child mortality. However, neonatal mortality showed a relatively slow decline as compared to infant and under-five mortality.

The successful reduction of child mortality concurred with improved equity in survival between rural and urban areas and household wealth groups, while children born to women with no formal education still had excess mortality. The improved equity in survival was mainly attributable to increased health coverage and investments in other sectors with main focus on pro-poor support. These efforts may also explain the minimal differences in perinatal mortality in relation to maternal educational levels and household wealth groups at hospitals in the capital of Rwanda. However, the risk of perinatal death was increased for women living in rural areas or for those not covered by a health insurance.

The most common factors, which contributed to perinatal mortality included delays in care-seeking during pregnancy and labour, followed by inadequate care by healthcare providers. The delays in reaching formal health institutions were not frequent. Half of the perinatal deaths were considered potentially avoidable and most of them were fresh stillbirths and early neonatal deaths, reflecting suboptimal care mainly during intrapartum period (5). Therefore, educating healthcare personnel in the handling of deliveries and neonates at birth seems to be a key strategy for preventing such deaths. After Helping Babies Breathe training, healthcare workers from three

urban hospitals in Rwanda significantly improved their knowledge in neonatal resuscitation. This knowledge was sustained within at least 3 months following the training while their practical performance deteriorated over the same period, suggesting the need of effective re-training strategies for retention.

Summary in Kinyarwanda

Nyuma ya genocide yo mu 1994 n'isenyuka ry'urwego rw'ubuvuzi ryayiku-rikiye, leta y'u Rwanda yatangije amavugurura mu nzego zose z'igihugu harimo n'urw'ubuvuzi hagamijwe kugabanya umubare w'impfu z'abana n'ubusumbane mu bantu nkuko bisabwa mu ntego z'ikinyagihumbi. Icyari kigamijwe muri ubu bushakashatsi twakoze ni ukumenya uko impfu z'abana batarengeje imyaka itanu zagiye zigabanuka cyangwa se ziyongera uko imyaka yagiye ihita, ndetse niba hari ubusumbane bwagaragaye muri izo mpfu hashingiye ku mibereho y'abaturage. Twari tugamije kandi kumenya inzitizi zibangamira igabanuka ry'impfu z'abana bataravuka n'izabatarengeje icyumweru bavutse. Indi mpamvu yari iyo gusuzuma niba uburyo bushya bita *Helping Babies Breathe*, mu magambo ahinnye HBB, bushobora gufa-sha kongera ubumenyi n'ubushobozi bw'abaganga, ababyaza n'abaforomo mu kuzanzamura umwana uvutse ntabashe guhumeka.

Mu bushakashatsi twakoze ku nshuro ya mbere, twifashishije imibare ya-garagajwe n'ubushakashatsi bwakozwe mu gihugu hose ku birebana n'ubuzima n'imibereho y'abaturage mu mwaka wa 2000, 2005 na 2010. Muri ubu bushakashatsi twagaragaje uko impfu z'abana zagiye zigabanuka cyangwa ziyongera hagati y'umwaka wa 1990 na 2010, ndetse niba igaba-nuka ry'umubare w'impfu ryarajyanye n'igabanuka ry'ubusumbane hagati y'izi mpfu hashingiye ku mibereho y'abaturage. Ubushakashatsi twakoze ku nshuro ya kabiri, iya gatatu n'iya kane bukaba bwo bwarabereye mu bitaro bitatu byo mu mujyi wa Kigali. Ku birebana n'ubushakashatsi twakoze ku nshuro ya kabiri, twagaragaje niba hari ubusumbane hagati y'impfu z'abana bataravuka n'izabatarengeje icyumweru bavutse bitewe n'imibereho y'imiryango bakomokamo. Ku nshuro ya gatatu, ubushakashatsi twakoze bwagaragaje zimwe mu mpamvu zifitanye isano n'impfu z'abana bataravuka n'izabatarengeje icyumweru bavutse. Ubu bushakashatsi bwagaragaje kandi umubare w'impfu zishobora kwirindwa mu gihe haba hanogejwe ubuvuzi buhabwa abagore batwite n'abana batarengeje icyumweru bavutse. Ku nshuro ya kane, ubushakashatsi bwagaragaje niba HBB ishobora kongera ubumenyi n'ubushobozi bw'abaganga, ababyaza n'abaforomo mu gufasha umwana wananiwe guhumeka akimara kuvuka.

Imyanzuro yavuye mu bushakashatsi twakoze igaragaza ko umubare mu-nini w'impfu z'abana batarengeje imyaka itanu wagaragaye mu gihe cya genocide yo mu 1994, aho mu bana 1000 bavutse ari bazima 238 muri bo bitabye Imana. Uyu mubare waje kugabanuka ugera ku mpfu 65 mu bana

1000 bavutse ari bazima mu mpera za 2010. Uku kugabanuka k'umubare w'impfu z'abana kukaba kwarakurikiwe n'igabanuka ry'ubusumbane bw'izi mpfu hagati y'ibyaro n'imijyi, hagati y'ababyeyi bize n'abatarize no hagati y'abakire n'abakene. Gusa ubushakashatsi bukaba bwaragaragaje ko umubare munini w'impfu z'abana wari ukiboneka mu babyeyi batigeze biga. Ubushakashatsi kandi bwerekanye ko umubare w'impfu z'abana batarengeje ukwezi bavutse wagiye ugabanuka buhoro ugereranije n'impfu z'abana batarengeje umwaka cyangwa imyaka itanu. Ku birebana n'impfu z'abana bapfira mu nda n'izabatarengeje icyumweru bavutse, umubare munini w'izi mpfu ukaba waragaragaye mu babyeyi badafite ubwishingizi mu kwivuza cyangwa baturuka mu byaro. Gusa nta busumbane bukabije bwagaragaye mu mibare y'izi mpfu hagati y'ababyeyi bize n'abatarize cyangwa hagati y'abakire n'abakene. Imwe mu mpamvu z'ibanze zifitanye isano n'impfu z'abana bataravuka n'izabatarengeje icyumweru bavutse ikaba yari ishingiye ku bumenyi buke ku birebana n'ibimenyetso mpuruza umugore utwite ashobora kugira. Iyi ikaba ari nayo yakunze kuba intandaro yo gutinda kujya kwivuza. Indi mpamvu y'ingenzi ifitanye isano n'izi mpfu ikaba yari ishingiye ku buvuzi budahagije bwahawe bamwe mu bagore batwite cyane cyane mu gihe babaga bari kunda cyangwa babyara. Byagaragaye kandi ko icya kabiri cy'izi mpfu zashoboraga kuba zakwirindwa iyo bamwe mu bagore batwite baza kuba barabonye ubuvuzi bukwiye mu gihe gikwiye. Ubushakashatsi bukaba bwarerekanye kandi ko nyuma yo guhugura abaganga, ababyaza n'abaforomo ku birebana no gufasha umwana uvutse ntabashe guhumeka hakoreshejwe HBB, ubumenyi n'ubushobozi bwabo bwiyongereye. Ubu bumenyi bungutse bukaba butarigeze bugabanuka mu gihe cy'amezi atatu yakurikiye amahugurwa mu gihe ubushobozi bwabo bwo bwasubiye inyuma.

Muri rusange, ubushakashatsi twakoze bwerekanye ko hakenewe gukomeza guteza imbere ubuvuzi no guharanira ko ubuvuzi bukwiye bwagera kuri bose mu rwego rwo kugabanya umubare w'impfu z'abana, zaba izibera mu ngo cyangwa mu mavuriro.

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References

1. United Nations. United Nations Millennium Declaration: resolution adopted by the General Assembly. A/res/52/2. 2000. Available from: http://www.un.org/millennium/declaration/ares552e.pdf (accessed June 3, 2015).
2. UN Inter-agency Group for Child Mortality Estimation. Level and trends in child mortality: report 2014. 2014. Available from: http://www.unicef.org/media/files/Levels_and_Trends_in_Child_Mortality_20 14.pdf (accessed April 23, 2015).
3. Houweling TA, Kunst AE. Socio-economic inequalities in childhood mortality in low- and middle-income countries: a review of the international evidence. Br Med Bull. 2009;93:7-26.
4. Macassa G, Hallqvist J, Lynch JW. Inequalities in child mortality in sub-Saharan Africa: A social epidemiologic framework. Afr J Health Sci. 2011;18:14-26.
5. World Health Organization. Neonatal and perinatal mortality. Country, regional and global estimates. 2006. Available from: http://whqlibdoc.who.int/publications/2006/9241563206_eng.pdf (accessed February 23, 2014).
6. Dunn PM, McIlwaine G. Perinatal audit: A report produced for the European Association of Perinatal Medicine. 1996. Available from: http://www.amazon.com/Perinatal-Audit-Produced-European-Association/dp/1850709335 (accessed November 5, 2014).
7. Pattinson R, Kerber K, Waiswa P, Day LT, Mussell F, Asiruddin SK, et al. Perinatal mortality audit: counting, accountability, and overcoming challenges in scaling up in low- and middle-income countries. International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics. 2009;107 Suppl 1:S113-21, S21-2.
8. Singhal N, Lockyer J, Fidler H, Keenan W, Little G, Bucher S, et al. Helping Babies Breathe: Global neonatal resuscitation program development and formative educational evaluation. Resuscitation. 2012;83(1):90-6.
9. Msemo G, Massawe A, Mmbando D, Rusibamayila N, Manji K, Kidanto HL, et al. Newborn mortality and fresh stillbirth rates in Tanzania after helping babies breathe training. Pediatrics. 2013;131(2):e353-60.
10. Vossius C, Lotto E, Lyanga S, Mduma E, Msemo G, Perlman J, et al. Cost-effectiveness of the "helping babies breathe" program in a missionary hospital in rural Tanzania. PloS one. 2014;9(7):e102080.
11. World Health Organization. Everybody business : strengthening health systems to improve health outcomes : WHO's framework for action. 2007. Available from: http://www.who.int/healthsystems/strategy/everybodys_business.pdf (accessed January 25, 2014).

12. National Institute of Statistics of Rwanda, Ministry of Health, Macro International Inc. Rwanda service provision assessment survey 2007. 2008. Available from: http://www.populationmedia.org/wp-content/uploads/2009/03/rwanda-hiv-mch-spa-2007.pdf (accessed February 3, 2014).

13. National Institute of Statistics of Rwanda, Ministry of Health, and ICF International. Rwanda demographic and health survey 2010. 2012. Available from: http://www.statistics.gov.rw/system/files/user_uploads/files/books/DHS%202010%20Rwanda%20version%202.pdf (accessed March 23, 2014).

14. Republic of Rwanda Ministry of Local Government. National social protection strategy. 2011. Available from: http://www.ilo.org/gimi/gess/ShowRessource.action?ressource.ressourceId=23208 (accessed February 12, 2014).

15. Bucagu M, Kagubare JM, Basinga P, Ngabo F, Timmons BK, Lee AC. Impact of health systems strengthening on coverage of maternal health services in Rwanda, 2000-2010: a systematic review. Reprod Health Matters. 2012;20(39):50-61.

16. Farmer PE, Nutt CT, Wagner CM, Sekabaraga C, Nuthulaganti T, Weigel JL, et al. Reduced premature mortality in Rwanda: lessons from success. BMJ. 2013;346:f65.

17. Binagwaho A, Farmer PE, Nsanzimana S, Karema C, Gasana M, de Dieu Ngirabega J, et al. Rwanda 20 years on: investing in life. Lancet. 2014;384(9940):371-5.

18. Abbott P, Rwirahira J. Millennium development goals–progress report: Rwanda country report 2010. 2010. Available from: http://www.abdn.ac.uk/sustainable-international-development/documents/UNDP%20final%20PA%2030%20October%202010_1.pdf (accessed February 2, 2014).

19. National Institute of Statistics of Rwanda. Rwanda Demographic and Health Survey 2014/2015: key findings. 2015. Available from: http://www.statistics.gov.rw/publications/demographic-and-health-survey-dhs-20142015-key-findings (accessed July 8, 2015).

20. United Nations Children's Fund. Committing to child survival: a promise renewed. Progress report 2014. 2014. Available from: http://www.apromiserenewed.org/APR_2014_web_15Sept14.pdf (accessed July 15, 2015).

21. Hill K, You D, Inoue M, Oestergaard MZ, Technical Advisory Group of United Nations Inter-agency Group for Child Mortality E. Child mortality estimation: accelerated progress in reducing global child mortality, 1990-2010. PLoS medicine. 2012;9(8):e1001303.

22. Rajaratnam JK, Marcus JR, Flaxman AD, Wang H, Levin-Rector A, Dwyer L, et al. Neonatal, postneonatal, childhood, and under-5 mortality for 187 countries, 1970-2010: a systematic analysis of progress towards Millennium Development Goal 4. Lancet. 2010;375(9730):1988-2008.

23. Lozano R, Wang H, Foreman KJ, Rajaratnam JK, Naghavi M, Marcus JR, et al. Progress towards Millennium Development Goals 4 and 5 on maternal and child mortality: an updated systematic analysis. Lancet. 2011;378(9797):1139-65.

24. Oestergaard MZ, Inoue M, Yoshida S, Mahanani WR, Gore FM, Cousens S, et al. Neonatal mortality levels for 193 countries in 2009 with trends since 1990:

a systematic analysis of progress, projections, and priorities. PLoS medicine. 2011;8(8):e1001080.

25. Liu L, Oza S, Hogan D, Perin J, Rudan I, Lawn JE, et al. Global, regional, and national causes of child mortality in 2000–13, with projections to inform post-2015 priorities: an updated systematic analysis. Lancet. 2015;385:430-40.

26. Wang H, Liddell CA, Coates MM, Mooney MD, Levitz CE, Schumacher AE, et al. Global, regional, and national levels of neonatal, infant, and under-5 mortality during 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 2014;384(9947):957-79.

27. Froen JF, Cacciatore J, McClure EM, Kuti O, Jokhio AH, Islam M, et al. Stillbirths: why they matter. Lancet. 2011;377(9774):1353-66.

28. Lawn JE, Blencowe H, Pattinson R, Cousens S, Kumar R, Ibiebele I, et al. Stillbirths: Where? When? Why? How to make the data count? Lancet. 2011;377(9775):1448-63.

29. Froen JF, Gordijn SJ, Abdel-Aleem H, Bergsjo P, Betran A, Duke CW, et al. Making stillbirths count, making numbers talk - issues in data collection for stillbirths. BMC pregnancy and childbirth. 2009;9:58.

30. Cousens S, Blencowe H, Stanton C, Chou D, Ahmed S, Steinhardt L, et al. National, regional, and worldwide estimates of stillbirth rates in 2009 with trends since 1995: a systematic analysis. Lancet. 2011;377(9774):1319-30.

31. Lawn JE, Blencowe H, Oza S, You D, Lee AC, Waiswa P, et al. Every Newborn: progress, priorities, and potential beyond survival. Lancet. 2014;384(9938):189-205.

32. Mosley WH, Chen LC. An analytical framework for the study of child survival in developing countries. 1984. Bulletin of the World Health Organization. 2003;81(2):140-5.

33. Bryce J, Requejo JH, Moulton LH, Ram M, Black RE, Population Health I, et al. A common evaluation framework for the African Health Initiative. BMC health services research. 2013;13 Suppl 2:S10.

34. Solar O, Irwin A. A conceptual framework for action on the social determinants of health. Social determinants of health discussion paper 2 (Policy and practice). 2010. Available from: http://www.who.int/sdhconference/resources/Conceptualframeworkforactionon SDH_eng.pdf (accessed February 24, 2015).

35. Whitehead M. The concepts and principles of equity and health. International journal of health services : planning, administration, evaluation. 1992;22(3):429-45.

36. Marmot M, Friel S, Bell R, Houweling TA, Taylor S, Commission on Social Determinants of H. Closing the gap in a generation: health equity through action on the social determinants of health. Lancet. 2008;372(9650):1661-9.

37. Macassa G, Ghilagaber G, Bernhardt E, Diderichsen F, Burstrom B. Inequalities in child mortality in Mozambique: differentials by parental socio-economic position. Soc Sci Med. 2003;57(12):2255-64.

38. Malqvist M, Hoa DT, Thomsen S. Causes and determinants of inequity in maternal and child health in Vietnam. BMC public health. 2012;12:641.

39. Goland E, Hoa DT, Malqvist M. Inequity in maternal health care utilization in Vietnam. International journal for equity in health. 2012;11:24.

40. Valle ED, Potter JE, Fernandez L. Religious Affiliation, Ethnicity, and Child Mortality in Chiapas, Mexico. Journal for the scientific study of religion. 2009;48(3):588-603.

41. Cau BM, Sevoyan A, Agadjanian V. Religious affiliation and under-five mortality in Mozambique. Journal of biosocial science. 2013;45(3):415-29.

42. Antai D, Ghilagaber G, Wedren S, Macassa G, Moradi T. Inequities in under-five mortality in Nigeria: differentials by religious affiliation of the mother. Journal of religion and health. 2009;48(3):290-304.
43. Rahman S, Salameh K, Bener A, El Ansari W. Socioeconomic associations of improved maternal, neonatal, and perinatal survival in Qatar. Int J Womens Health. 2010;2:311-8.
44. Perez W, Pena R, Persson LA, Kallestal C. Tracking progress towards equitable child survival in a Nicaraguan community: neonatal mortality challenges to meet the MDG 4. BMC public health. 2011;11:455.
45. Malqvist M, Nga NT, Eriksson L, Wallin L, Hoa DP, Persson LA. Ethnic inequity in neonatal survival: a case-referent study in northern Vietnam. Acta Paediatr. 2010;100(3):340-6.
46. Hoa DP, Nga NT, Malqvist M, Persson LA. Persistent neonatal mortality despite improved under-five survival: a retrospective cohort study in northern Vietnam. Acta Paediatr. 2008;97(2):166-70.
47. Andargie G, Berhane Y, Worku A, Kebede Y. Predictors of perinatal mortality in rural population of Northwest Ethiopia: a prospective longitudinal study. BMC public health. 2013;13:168.
48. Nankabirwa V, Tumwine JK, Tylleskar T, Nankunda J, Sommerfelt H. Perinatal mortality in eastern Uganda: a community based prospective cohort study. PloS one. 2011;6(5):e19674.
49. Tromp M, Eskes M, Reitsma JB, Erwich JJ, Brouwers HA, Rijninks-van Driel GC, et al. Regional perinatal mortality differences in the Netherlands; care is the question. BMC public health. 2009;9:102.
50. Thaddeus S, Maine D. Too far to walk: maternal mortality in context. Soc Sci Med. 1994;38(8):1091-110.
51. Merali HS, Lipsitz S, Hevelone N, Gawande AA, Lashoher A, Agrawal P, et al. Audit-identified avoidable factors in maternal and perinatal deaths in low resource settings: a systematic review. BMC pregnancy and childbirth. 2014;14:280.
52. Waiswa P, Kallander K, Peterson S, Tomson G, Pariyo GW. Using the three delays model to understand why newborn babies die in eastern Uganda. Tropical medicine & international health : TM & IH. 2010;15(8):964-72.
53. Osman H, Campbell OM, Sinno D, Zarwi R, Nassar AH. Facility-based audit of maternal mortality in Lebanon: a feasibility study. Acta obstetricia et gynecologica Scandinavica. 2009;88(12):1338-44.
54. Nakibuuka VK, Okong P, Waiswa P, Byaruhanga RN. Perinatal death audits in a peri-urban hospital in Kampala, Uganda. African health sciences. 2012;12(4):435-42.
55. Mbaruku G, van Roosmalen J, Kimondo I, Bilango F, Bergstrom S. Perinatal audit using the 3-delays model in western Tanzania. International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics. 2009;106(1):85-8.
56. Kidanto HL, Mogren I, van Roosmalen J, Thomas AN, Massawe SN, Nystrom L, et al. Introduction of a qualitative perinatal audit at Muhimbili National Hospital, Dar es Salaam, Tanzania. BMC pregnancy and childbirth. 2009;9:45.
57. Kallander K, Hildenwall H, Waiswa P, Galiwango E, Peterson S, Pariyo G. Delayed care seeking for fatal pneumonia in children aged under five years in Uganda: a case-series study. Bulletin of the World Health Organization. 2008;86(5):332-8.
58. Gabrysch S, Campbell OM. Still too far to walk: literature review of the determinants of delivery service use. BMC pregnancy and childbirth. 2009;9:34.

59. Finlayson K, Downe S. Why do women not use antenatal services in low- and middle-income countries? A meta-synthesis of qualitative studies. PLoS medicine. 2013;10(1):e1001373.

60. Upadhyay RP, Rai SK, Krishnan A. Using three delays model to understand the social factors responsible for neonatal deaths in rural Haryana, India. Journal of tropical pediatrics. 2013;59(2):100-5.

61. Abouchadi S, Alaoui AB, Meski FZ, Bezad R, De Brouwere V. Preventable maternal mortality in Morocco: the role of hospitals. Tropical medicine & international health : TM & IH. 2013;18(4):444-50.

62. Pacagnella RC, Cecatti JG, Parpinelli MA, Sousa MH, Haddad SM, Costa ML, et al. Delays in receiving obstetric care and poor maternal outcomes: results from a national multicentre cross-sectional study. BMC pregnancy and childbirth. 2014;14:159.

63. Saleh WF, Ragab WS, Aboulgheit SS. Audit of maternal mortality ratio and causes of maternal deaths in the largest maternity hospital in Cairo, Egypt (Kasr Al Aini) in 2008 and 2009: lessons learned. African journal of reproductive health. 2013;17(3):105-9.

64. Bell R, Donkin A, Marmot M. Tackling structural and social issues to reduce inequities in children's outcomes in low- to middle-income countries. 2013. Available from: http://www.unicef-irc.org/publications/pdf/marmot_layout5.pdf (accessed July 13, 2015).

65. United Nations. Universal declaration of human rights. 1948. Available from: http://www.unhcr.org/refworld/docid/3ae6b3712c.html (accessed July 2, 2015).

66. United Nations. Convention on the rights of the child. 1989. Available from: http://www.unicef.org/malaysia/1959-Declaration-of-the-Rights-of-the-Child.pdf (accessed July 2, 2015).

67. Eastwood R, Lipton M. Rural-urban dimensions of inequality change. 2000. Available from: https://www.google.rw/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CB0QFjAAahUKEwi93K255vDGAhUFPhQKHTl5BqM&url=http%3A%2F%2Fwww.wider.unu.edu%2Fpublications%2Fworking-papers%2Fprevious%2Fen_GB%2Fwp-200%2F_files%2F82530864860178662%2Fdefault%2Fwp200.pdf&ei=KqGwVb2fAYX8ULnymZgK&usg=AFQjCNF5SMMlXg2g2jBBmNUSfcyrKVw_mQ&sig2=o7DtkrKtKCFLj4HU76EeEg (accessed July 3, 2015).

68. Ooi GL, Phua KH. Urbanization and slum formation. Journal of urban health : bulletin of the New York Academy of Medicine. 2007;84(3 Suppl):i27-34.

69. Gibson M, Petticrew M, Bambra C, Sowden AJ, Wright KE, Whitehead M. Housing and health inequalities: a synthesis of systematic reviews of interventions aimed at different pathways linking housing and health. Health & place. 2011;17(1):175-84.

70. Gwatkin DR, Rutstein S, Johnson K, Suliman E, Wagstaff A, Amouzou A. Socio-economic differences in health, nutrition, and population within developing countries: an overview. Nigerian journal of clinical practice. 2007;10(4):272-82.

71. United Nations Children's Fund. The state of the world's children: children in an urban world. 2012. Available from: http://www.unicef.org/sowc/files/SOWC_2012-Main_Report_EN_21Dec2011.pdf (accessed June 15, 2015).

72. World Health Organization Regional Office for South East Asia. Tackling social and economic determinants of health through women's empowerment: the SEWA case study. 2008. Available from: http://www.who.int/social_determinants/resources/isa_sewa_ind.pdf (accessed July 21, 2015).

73. Artazcoz L, Benach J, Borrell C, Cortes I. Social inequalities in the impact of flexible employment on different domains of psychosocial health. Journal of epidemiology and community health. 2005;59(9):761-7.

74. Kim IH, Muntaner C, Khang YH, Paek D, Cho SI. The relationship between nonstandard working and mental health in a representative sample of the South Korean population. Soc Sci Med. 2006;63(3):566-74.

75. Robertson L, Mushati P, Eaton JW, Dumba L, Mavise G, Makoni J, et al. Effects of unconditional and conditional cash transfers on child health and development in Zimbabwe: a cluster-randomised trial. Lancet. 2013;381(9874):1283-92.

76. Gwatkin DR, A W, Yazbeck AS, eds. Reaching the poor with health, nutrition, and population services. 2005. Available from: https://openknowledge.worldbank.org/handle/10986/7393 (accessed July 22, 2015).

77. Lykens K, Singh KP, Ndukwe E, Bae S. Social, economic, and political factors in progress towards improving child survival in developing nations. Journal of health care for the poor and underserved. 2009;20(4 Suppl):137-48.

78. CSDH Social Exclusion Knowledge Network. Understanding and tackling social exclusion: final report of the Social Exclusion Knowledge Network of the Commission on Social Determinants of Health. 2008. Available from: http://www.who.int/social_determinants/knowledge_networks/final_reports/sekn_final%20report_042008.pdf (accessed May 9, 2015).

79. World Health Organization. The world health report 2000. Health systems : improving performance. 2000. Available from: http://www.ctc-health.org.cn/file/whr00_en.pdf (accessed May 14, 2015).

80. Don de Savigny, Adam T, eds. Systems Thinking for Health Systems Strengthening. Geneva: Alliance for Health Policy and Systems Research, WHO; 2009. http://www.who.int/alliance-hpsr/resources/9789241563895/en/ (accessed June 27, 2015).

81. Dickson KE, Simen-Kapeu A, Kinney MV, Huicho L, Vesel L, Lackritz E, et al. Every Newborn: health-systems bottlenecks and strategies to accelerate scale-up in countries. Lancet. 2014;384(9941):438-54.

82. Finegood DT, Karanfil O, Matteson CL. Getting from analysis to action: framing obesity research, policy and practice with a solution-oriented complex systems lens. HealthcarePapers. 2008;9(1):36-41; discussion 62-7.

83. Sambo LG, Kirigia JM. Investing in health systems for universal health coverage in Africa. BMC international health and human rights. 2014;14:28.

84. Shiell A. The danger in conservative framing of a complex, systems-level issue. HealthcarePapers. 2008;9(1):42-5; discussion 62-7.

85. Lazarus J, France T. A new era for the WHO health system building blocks? Available from: http://hsg-whobb.iniscommunication.com/?utm_content=buffera6c3f&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer (accessed July 20, 2015).

86. Mancey-Jones M, Brugha RF. Using perinatal audit to promote change: a review. Health policy and planning. 1997;12(3):183-92.

87. Council of Europe. The development and implementation of quality improvement systems (QIS) in health care – recommendation no. R (97) 17 and explanatory memorandum. 1998. Available from: https://book.coe.int/eur/en/health-and-society-ethics/607-the-development-and-implementation-of-quality-improvement-systems-qis-in-health-care-recommendation-no-r-97-17-and-explanatory-memorandum.html (accessed July 20, 2015).

88. Ashton CM, Kuykendall DH, Johnson ML, Wray NP. An empirical assessment of the validity of explicit and implicit process-of-care criteria for quality assessment. Medical care. 1999;37(8):798-808.

89. Goldman RL. The reliability of peer assessments of quality of care. Jama. 1992;267(7):958-60.

90. van Diem MT, Timmer A, Bergman KA, Bouman K, van Egmond N, Stant DA, et al. The implementation of unit-based perinatal mortality audit in perinatal cooperation units in the northern region of the Netherlands. BMC health services research. 2012;12:195.

91. El Amin S, Langhoff-Roos J, Bodker B, Bakr AA, Ashmeig AL, Ibrahim SA, et al. Introducing qualitative perinatal audit in a tertiary hospital in Sudan. Health policy and planning. 2002;17(3):296-303.

92. World Health Organization. Every newborn. An action plan to end preventable deaths. 2014. Available from: http://apps.who.int/iris/bitstream/10665/127938/1/9789241507448_eng.pdf?ua=1 (accessed July 2, 2015).

93. Wall SN, Lee AC, Carlo W, Goldenberg R, Niermeyer S, Darmstadt GL, et al. Reducing intrapartum-related neonatal deaths in low- and middle-income countries-what works? Seminars in perinatology. 2010;34(6):395-407.

94. American Academy of Paediatrics. Helping Babies Breathe: a new global program to boost newborn survival rates. 2010. Available from: http://aapnews.aappublications.org/content/31/8/1.1.full.pdf (accessed July 6, 2015).

95. Goudar SS, Somannavar MS, Clark R, Lockyer JM, Revankar AP, Fidler HM, et al. Stillbirth and newborn mortality in India after helping babies breathe training. Pediatrics. 2013;131(2):e344-52.

96. World Bank. Gross Domestic Product per capita: data by country. Available from: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD?page=4 (accessed July 21, 2015).

97. Republic of Rwanda. Rwanda vision 2020: revised version. 2012. Available from: http://www.minecofin.gov.rw/fileadmin/templates/documents/NDPR/Vision_2020_.pdf (accessed July 3, 2015).

98. Repulic of Rwanda Ministry of Agriculture and Animal Resources. One cow per poor family program or "Girinka". Available from: http://www.minagri.gov.rw/index.php?id=28&L=1 (accessed July 2014, 2014).

99. National Institute of Statistics of Rwanda. Statistical year book 2012. 2012. Available from: http://statistics.gov.rw/publications/statistical-yearbook-2012 (accessed December 23, 2014).

100. United Nations. The millennium development goals report 2010. 2010. Available from: http://www.un.org/millenniumgoals/pdf/MDG%20Report%202010%20En%20r15%20-low%20res%2020100615%20-.pdf (accessed July 2, 2015).

101. Republic of Rwanda Ministry of Health. Health sector policy. 2014. Available from: http://www.moh.gov.rw/fileadmin/templates/policies/Health_Sector_Policy_2014.pdf (accessed July 9, 2015).
102. Republic of Rwanda Ministry of Health Rwanda Biomedical Center. Annual report July 2011–June 2012. 2012. Available from: http://www.rbc.gov.rw/IMG/pdf/rbc_annual_report_final_march2013.pdf (accessed July 8, 2015).
103. Republic of Rwanda Ministry of Health. Rwanda health systems strengthening framework and consolidated strategic plan 2009−2012. 2010. Available from: ftp://www.gavifund.org/MannionDaniels/HSFP%20review%20May%202012/Rwanda_Resubmission/Attachment%201/Annex%201d%20Rwanda_Health%20System%20Stregthening%20%20Strategy.pdf (accessed December 30, 2014).
104. Republic of Rwanda Ministry of Health. Rwanda health statistics booklet 2011. 2012. Available from: http://www.moh.gov.rw/fileadmin/templates/HMIS_Docs/MOH_Annual_booklet-2011.pdf (accessed February 14, 2015).
105. Republic of Rwanda Ministry of Health. Annual report 2008. 2009. Available from: http://www.moh.gov.rw/fileadmin/templates/MOH-Reports/Final-MoH-annual-report-2008.pdf (accessed January 25, 2015).
106. Republic of Rwanda Ministry of Health. Annual report 2005. 2005. Available from: www.moh.gov.rw/fileadmin/templates/MOH-Reports/2005-Annual-Report.pdf (accessed June 26, 2015).
107. Republic of Rwanda Ministry of Health. Strategic plan for the acceleration of child survival 2008-2012. 2008. Available from: http://www.basics.org/documents/National-Child-Survival-Strategy.pdf (accessed July 12, 2015).
108. Republic of Rwanda Ministry of Health. Annual report 2011–2012. 2012. Available from: http://www.moh.gov.rw/fileadmin/templates/MOH-Reports/MoH-Annual-Report-July-2011-June-2012.pdf (accessed June 12, 2015).
109. Kerber KJ, de Graft-Johnson JE, Bhutta ZA, Okong P, Starrs A, Lawn JE. Continuum of care for maternal, newborn, and child health: from slogan to service delivery. Lancet. 2007;370(9595):1358-69.
110. Republic of Rwanda Ministry of Health. Maternal, neonatal and child health national strategy July 2013–June 2018. Available from: http://rbc.gov.rw/IMG/pdf/maternal_newborn_and_child_health_national_strategy_july_2013-_june_2018.pdf (accessed July 13, 2015).
111. Republic of Rwanda Ministry of Health. Comprehensive multi-year plan 2013–2017. 2012. Available from: ftp://iff-immunisation.org/MannionDaniels/HSFP%20review%20May%202012/Rwanda_Resubmission/Attachment%201/Annex%201c%20Rwanda%20Vaccine%20Preventable%20Disease%20Strategic%20plan%20(cMYP).doc (accessed March 13, 2015).
112. Republic of Rwanda Ministry of Health. National annual report on HIV and AIDS July 2011–June 2012. 2012. Available from: http://rbc.gov.rw/IMG/pdf/national_annual_report_on_hiv_aids_july_2011_june_2012-2.pdf (accessed March 26, 2015).

113. Bergh AM, Sayinzoga F, Mukarugwiro B, Zoungrana J, Abayisenga G, Karera C, et al. Evaluation of Kangaroo Mother Care services in Rwanda. 2012. Available from: http://www.mchip.net/sites/default/files/Rwanda%20KMC%20Evaluation%20 Report_0.pdf (accessed May 25, 2015).

114. USAID. President's malaria initiative–Malaria operational plan (MOP)– Rwanda FY 2011. 2010. Available from: http://www.pmi.gov/countries/mops/fy11/rwanda_mop-fy11.pdf (accessed April 12, 2015).

115. World Health Organization. World health statistics 2009. 2009. Available from: http://www.who.int/gho/publications/world_health_statistics/EN_WHS09_Full .pdf (accessed February 24, 2015).

116. Republic of Rwanda Ministry of Health. National community health policy. 2008.

117. Republic of Rwanda Ministry of Health. Annual report July 2009–June 2010. 2010. Available from: http://globalhealthscholar.yale.edu/sites/323_85679_Final%20MoH%20annual %20report%2027%2001%202011%20(2).pdf (accessed March 27, 2015).

118. World Health Organization. Assisting community health workers in Rwanda. Ministry of Health's RapidSMS and mUbuzima. 2013. Available from: http://apps.who.int/iris/bitstream/10665/92814/1/WHO_RHR_13.15_eng.pdf (accessed November 28, 2014).

119. Leslie M F, Ravishankar N, Squires J, Williamson R T, Brinkerhoff D. Rwanda health governance report assessment. 2010. Available from: http://apps.who.int/medicinedocs/documents/s18413en/s18413en.pdf (accessed July 22, 2015).

120. Pandit-Rajani T, Sharma S, Muramutsa F. Fostering public-private partnerships to improve access to family planning in Rwanda. 2010. Available from: http://www.healthpolicyinitiative.com/Publications/Documents/1266_1_Rwan da_PPP_FINAL_acc.pdf (accessed April 23, 2015).

121. Republic of Rwanda Ministry of Health. Key indicators. 2012. Available from: http://www.moh.gov.rw/index.php?id=3 (accessed February 23, 2015).

122. Rusa L, Ngirabega Jde D, Janssen W, Van Bastelaere S, Porignon D, Vandenbulcke W. Performance-based financing for better quality of services in Rwandan health centres: 3-year experience. Tropical medicine & international health : TM & IH. 2009;14(7):830-7.

123. Republic of Rwanda. Economic Development and Poverty Reduction Strategy 2008−2012. 2007. Available from: http://www.statistics.gov.rw/publications/economic-development-poverty-reduction-strategy-2008-2012 (Accessed July 2, 2015).

124. Transparency International. Corruption perceptions index 2012. 2013. Available from: http://www.transparency.org/cpi2012/results (accessed June 14, 2015).

125. United Nations Children's Fund, World Health Organization. Countdown to 2015. Fulfilling the health agenda for women and children: the 2014 report. 2014. Available from: http://www.countdown2015mnch.org/documents/2014Report/The2014report/C ountdown_The_2014_Report_final.pdf (accessed July 23, 2015).

126. Bhutta ZA, Chopra M, Axelson H, Berman P, Boerma T, Bryce J, et al. Countdown to 2015 decade report (2000-10): taking stock of maternal, newborn, and child survival. Lancet. 2010;375(9730):2032-44.

127. Victora CG, Fenn B, Bryce J, Kirkwood BR. Co-coverage of preventive interventions and implications for child-survival strategies: evidence from national surveys. Lancet. 2005;366(9495):1460-6.
128. McKinnon B, Harper S, Kaufman JS, Bergevin Y. Socioeconomic inequality in neonatal mortality in countries of low and middle income: a multicountry analysis. The Lancet Global health. 2014;2(3):e165-73.
129. Victora CG, Wagstaff A, Schellenberg JA, Gwatkin D, Claeson M, Habicht JP. Applying an equity lens to child health and mortality: more of the same is not enough. Lancet. 2003;362(9379):233-41.
130. Victora CG, Barros AJ, Axelson H, Bhutta ZA, Chopra M, Franca GV, et al. How changes in coverage affect equity in maternal and child health interventions in 35 Countdown to 2015 countries: an analysis of national surveys. Lancet. 2012;380(9848):1149-56.
131. Chowdhury SR, Nayar KR. Multidimensional approach to child survival needed. Lancet. 2013;381(9864):374.
132. Barros AJ, Ronsmans C, Axelson H, Loaiza E, Bertoldi AD, Franca GV, et al. Equity in maternal, newborn, and child health interventions in Countdown to 2015: a retrospective review of survey data from 54 countries. Lancet. 2012;379(9822):1225-33.
133. Logie DE, Rowson M, Ndagije F. Innovations in Rwanda's health system: looking to the future. Lancet. 2008;372(9634):256-61.
134. ICF International. Demographic and Health Surveys. Available from: http://dhsprogram.com/What-We-Do/survey-search.cfm?pgtype=main&SrvyTp=country.%20Accessed%202013-20-09 (accessed July 7, 2015).
135. National Institute of Statistics of Rwanda, ORC Macro. Rwanda Demographic and health Survey 2005. 2006. Available from: http://dhsprogram.com/pubs/pdf/FR183/FR183.pdf (accessed July 4, 2015).
136. Rwanda National Office of Population, ORC Macro. Rwanda Demographic and Health Survey 2000. 2001. Available from: http://dhsprogram.com/pubs/pdf/FR125/FR125.pdf (accessed July 2, 2015).
137. MRC Unit for Maternal and Infant Health Care Strategies. Saving babies 2003–2005: fifth perinatal care survey of South Africa. Available from: http://bettercare.co.za/wp-content/uploads/2013/01/Saving-Babies-2003-2005.pdf (accessed July 20, 2015).
138. National Institute of Statistics of Rwanda, Ministry of Finance and Economic Planning. Fourth Rwanda Population and Housing Census 2012. Thematic report: population size, structure and distribution. 2014. Available from: http://statistics.gov.rw/sites/default/files/user_uploads/files/books/RPHC4_%20Population_Size.pdf (accessed July 4, 2015).
139. Rwanda Ministry of Finance and Economic Planning, National Census Service. Third Rwanda Population and Housing Census 2002. 2003. Available from: https://www.google.rw/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CB0QFjAAahUKEwiB9NzC2vbGAhXKWhQKHZpDAI4&url=http%3A%2F%2Fmicrodata.statistics.gov.rw%2Findex.php%2Fcatalog%2F9%2Fdownload%2F40&ei=9rmzVYGhNcq1UZqHgfAI&usg=AFQjCNHRTCNH3-yS8dreZ2A81QyTAP_-cw&sig2=uEu6E2kQzoxljeBNjE0kZQ (accessed July 5, 2015).
140. Rwanda National Office of the population, Macro International Inc. Rwanda Demographic and health Survey 1992. 1994. Available from: http://statistics.gov.rw/system/files/user_uploads/files/survey-reports/DHS_French%20_1992.pdf (accessed July 4, 2015).

141. National Institute of Statistics of Rwanda, Ministry of Finance and Economic Planning. Fourth Rwanda Population and Housing Census 2012. Thematic report: mortality. 2014. Available from: http://statistics.gov.rw/system/files/user_uploads/files/books/Mortality.pdf (accessed July 4, 2015).

142. World Bank. Gross Domestic Product per capita: sub-Saharan Africa. Available from: http://data.worldbank.org/indicator/NY.GNP.PCAP.CD/countries/ZF?display=graph (accessed July 23, 2015).

143. Bates D, Maechler M, Bolker B, et al. lme4: Linear mixed-effects models using Eigen and S4. R package version 0.999999-0. 2012. Available from: http://cran.r-project.org/package=lme4 (accessed July 2, 2015).

144. Therneau T. Coxme: Mixed effects Cox models. R package version 2.2-3. 2012. Available from: http://cran.r-project.org/package=coxme (accessed July 3, 2015).

145. ICF International. Available datasets. Available from: http://dhsprogram.com/data/available-datasets.cfm (accessed July 31, 2015).

146. Little G, Niermeyer S, Singhal N, Lawn J, Keenan W. Neonatal resuscitation: a global challenge. Pediatrics. 2010;126(5):e1259-60.

147. Curtis SL. Assessment of quality of data used for direct estimation of infant and child mortality in DHS-II surveys. Occasional papers No.3 1995. Available from: http://www.measuredhs.com/pubs/pdf/OP3/OP3.pdf (accessed 2 Feb 2014).

148. Sastry N. What explains rural-urban differentials in child mortality in Brazil? Soc Sci Med. 1997;44(7):989-1002.

149. Lawn J, Shibuya K, Stein C. No cry at birth: global estimates of intrapartum stillbirths and intrapartum-related neonatal deaths. Bulletin of the World Health Organization. 2005;83(6):409-17.

150. Lawn JE, Yakoob MY, Haws RA, Soomro T, Darmstadt GL, Bhutta ZA. 3.2 million stillbirths: epidemiology and overview of the evidence review. BMC pregnancy and childbirth. 2009;9 Suppl 1:S2.

151. Ersdal HL, Mduma E, Svensen E, Perlman J. Birth asphyxia: a major cause of early neonatal mortality in a Tanzanian rural hospital. Pediatrics. 2012;129(5):e1238-43.

152. Langhoff-Roos J, Larsen S, Basys V, Lindmark G, Badokynote M. Potentially avoidable perinatal deaths in Denmark, Sweden and Lithuania as classified by the Nordic-Baltic classification. British journal of obstetrics and gynaecology. 1998;105(11):1189-94.

153. Romina RP, Fiona S, Liesbet S. Rwanda's progress in health: leadership, performance, and insurance. 2011. Available from: http://www.developmentprogress.org/sites/developmentprogress.org/files/resource_report/rwanda_report_-_master_0.pdf (accessed January 19, 2014).

154. James C, Morris SS, Keith R, Taylor A. Impact on child mortality of removing user fees: simulation model. BMJ. 2005;331(7519):747-9.

155. Ponsar F, Van Herp M, Zachariah R, Gerard S, Philips M, Jouquet G. Abolishing user fees for children and pregnant women trebled uptake of malaria-related interventions in Kangaba, Mali. Health policy and planning. 2011;26 Suppl 2:ii72-83.

156. Lawn JE, Kinney MV, Black RE, Pitt C, Cousens S, Kerber K, et al. Newborn survival: a multi-country analysis of a decade of change. Health policy and planning. 2012;27 Suppl 3:iii6-28.

157. Kuruvilla S, Schweitzer J, Bishai D, Chowdhury S, Caramani D, Frost L, et al. Success factors for reducing maternal and child mortality. Bulletin of the World Health Organization. 2014;92(7):533-44B.

158. Ministry of Health Rwanda, PMNCH, WHO, World Bank, AHPSR, and participants in the Rwanda multistakeholder policy review. Success Factors for Women's and Children's Health: Rwanda. 2014. Available from: http://www.who.int/pmnch/knowledge/publications/rwanda_country_report.pdf?ua=1 (accessed July 13, 2015).

159. Bishai D, Cohen RL, Alfonso YN, Adam T, Kuruvilla S, Schweitzer J. Factors contributing to child mortality reductions in 142 low-and middle-income countries between 1990 and 2010. 2014. Available from: http://www.who.int/pmnch/knowledge/publications/bishai.pdf (accessed July 4, 2015).

160. World Health Organization. Success Factors for Women's and Children's Health: Multisector Pathways to Progress. Available from: http://www.who.int/pmnch/knowledge/publications/successfactors/en/index2.html (accessed July 4, 2015).

161. United Nations. Accountable governance: Women secure 64 per cent of seats in Rwandan parliamentary elections. 2014. Available from: http://www.rw.one.un.org/press-center/news/women-secure-64-cent-seats-rwandan-parliamentary-elections (accessed July 23, 2015).

162. Binagwaho A, Scott KW. Improving the world's health through the post-2015 development agenda: perspectives from Rwanda. International journal of health policy and management. 2015;4(4):203-5.

163. Brinkerhoff DW, Fort C, Stratton S. Good Governance and Health: Assessing Progress in Rwanda. 2009. Available from: http://www.intrahealth.org/~intrahea/files/media/good-governance-and-healthassessing-progress-in-rwanda/goodgovandhealth.pdf (accessed July 3, 2015).

164. Pena R, Wall S, Persson LA. The effect of poverty, social inequity, and maternal education on infant mortality in Nicaragua, 1988-1993. American journal of public health. 2000;90(1):64-9.

165. Gakidou E, Cowling K, Lozano R, Murray CJ. Increased educational attainment and its effect on child mortality in 175 countries between 1970 and 2009: a systematic analysis. Lancet. 2010;376(9745):959-74.

166. Lloyd CB. New lessons: the power of educating adolescent girls. 2009. Available from: http://www.ungei.org/resources/files/2009PGY_NewLessons.pdf (accessed July 30, 2015).

167. Republic of Rwanda Ministry of Education. Forward looking joint review of the education sector. 2012. Available from: http://www.mineduc.gov.rw/fileadmin/user_upload/Foward_looking_report_EDPRS1.pdf (accessed July 31, 2015).

168. United Nations Children's Fund. Education in Rwanda. . Available from: http://www.unicef.org/rwanda/education.html (accessed July 29, 2015).

169. Saksena P, Antunes AF, Xu K, Musango L, Carrin G. Mutual health insurance in Rwanda: evidence on access to care and financial risk protection. Health policy. 2011;99(3):203-9.

170. Houweling TA, Ronsmans C, Campbell OM, Kunst AE. Huge poor-rich inequalities in maternity care: an international comparative study of maternity and child care in developing countries. Bulletin of the World Health Organization. 2007;85(10):745-54.

171. Devoe JE, Baez A, Angier H, Krois L, Edlund C, Carney PA. Insurance + access not equal to health care: typology of barriers to health care access for low-income families. Annals of family medicine. 2007;5(6):511-8.
172. Lee AC, Lawn JE, Cousens S, Kumar V, Osrin D, Bhutta ZA, et al. Linking families and facilities for care at birth: what works to avert intrapartum-related deaths? International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics. 2009;107 Suppl 1:S65-85, S6-8.
173. Hong R, Ayad M, Ngabo F. Being insured improves safe delivery practices in Rwanda. Journal of community health. 2011;36(5):779-84.
174. Ezugwu EC, Onah HE, Ezegwui HU, Nnaji C. Stillbirth rate at an emerging tertiary health institution in Enugu, southeast Nigeria. International journal of gynaecology and obstetrics: the official organ of the International Federation of Gynaecology and Obstetrics. 2011;115(2):164-6.
175. Mukasa PK, Kabakyenga J, Senkungu JK, Ngonzi J, Kyalimpa M, Roosmalen VJ. Uterine rupture in a teaching hospital in Mbarara, western Uganda, unmatched case- control study. Reproductive health. 2013;10:29.
176. Bapat U, Alcock G, More NS, Das S, Joshi W, Osrin D. Stillbirths and newborn deaths in slum settlements in Mumbai, India: a prospective verbal autopsy study. BMC pregnancy and childbirth. 2012;12:39.
177. De Lange TE, Budde MP, Heard AR, Tucker G, Kennare R, Dekker GA. Avoidable risk factors in perinatal deaths: a perinatal audit in South Australia. The Australian & New Zealand journal of obstetrics & gynaecology. 2008;48(1):50-7.
178. Knight HE, Self A, Kennedy SH. Why are women dying when they reach hospital on time? A systematic review of the 'third delay'. PloS one. 2013;8(5):e63846.
179. Moyer CA, Mustafa A. Drivers and deterrents of facility delivery in sub-Saharan Africa: a systematic review. Reproductive health. 2013;10:40.
180. Say L, Raine R. A systematic review of inequalities in the use of maternal health care in developing countries: examining the scale of the problem and the importance of context. Bulletin of the World Health Organization. 2007;85(10):812-9.
181. Essén B, Bödker B, Sjöberg N.-O, Langhoff-Roos J, Greisen G et al. Are some perinatal deaths in immigrant groups linked to suboptimal perinatal care services? BJOG. 2002;109:677-82.
182. de Reu P, Van Diem M, Eskes M, Oosterbaan H, Smits L, Merkus H, et al. The Dutch Perinatal Audit Project: a feasibility study for nationwide perinatal audit in the Netherlands. Acta obstetricia et gynecologica Scandinavica. 2009;88(11):1201-8.
183. Esscher A, Binder-Finnema P, Bodker B, Hogberg U, Mulic-Lutvica A, Essen B. Suboptimal care and maternal mortality among foreign-born women in Sweden: maternal death audit with application of the 'migration three delays' model. BMC pregnancy and childbirth. 2014;14:141.
184. Farquhar C, Sadler L, Masson V. Beyond the numbers: reporting potentially avoidable perinatal deaths. BJOG. 2012;119(3):381-2.
185. Hinderaker SG, Olsen BE, Bergsjo PB, Gasheka P, Lie RT, Havnen J, et al. Avoidable stillbirths and neonatal deaths in rural Tanzania. BJOG. 2003;110(6):616-23.

186. Jansone M, Lazdane G. Audit of perinatal deaths in a tertiary level hospital in Latvia (1995-1999) using the Nordic-Baltic perinatal death classification: evidence of suboptimal care. The journal of maternal-fetal & neonatal medicine : the official journal of the European Association of Perinatal Medicine, the Federation of Asia and Oceania Perinatal Societies, the International Society of Perinatal Obstet. 2006;19(8):503-7.

187. Bould MD, Hayter MA, Campbell DM, Chandra DB, Joo HS, Naik VN. Cognitive aid for neonatal resuscitation: a prospective single-blinded randomized controlled trial. Br J Anaesth. 2009;103(4):570-5.

188. Kaczorowski J, Levitt C, Hammond M, Outerbridge E, Grad R, Rothman A, et al. Retention of neonatal resuscitation skills and knowledge: a randomized controlled trial. Fam Med. 1998;30(10):705-11.

189. Palese A, Trenti G, Sbrojavacca R. [Effectiveness of retraining after basic cardiopulmonary resuscitation courses: a literature review]. Assist Inferm Ric. 2003;22(2):68-75.

190. Skidmore MB, Urquhart H. Retention of skills in neonatal resuscitation. Paediatr Child Health. 2001;6(1):31-5.

191. Smith KK, Gilcreast D, Pierce K. Evaluation of staff's retention of ACLS and BLS skills. Resuscitation. 2008;78(1):59-65.

192. Carlo WA, Wright LL, Chomba E, McClure EM, Carlo ME, Bann CM, et al. Educational impact of the neonatal resuscitation program in low-risk delivery centers in a developing country. J Pediatr. 2009;154(4):504-8 e5.

193. Trevisanuto D, Ferrarese P, Cavicchioli P, Fasson A, Zanardo V, Zacchello F. Knowledge gained by pediatric residents after neonatal resuscitation program courses. Paediatr Anaesth. 2005;15(11):944-7.

194. Hamilton R. Nurses' knowledge and skill retention following cardiopulmonary resuscitation training: a review of the literature. J Adv Nurs. 2005;51(3):288-97.

195. Gilson L. Health policy and systems Research: a methodology reader. The abridged version. Geneva: WHO; 2012. Available from: http://www.who.int/alliance-hpsr/resources/alliancehpsr_reader.pdf?ua=1 (accessed July 2, 2015).

196. Carlo WA, Goudar SS, Jehan I, Chomba E, Tshefu A, Garces A, et al. Newborn-care training and perinatal mortality in developing countries. N Engl J Med. 2010;362(7):614-23.

197. Rieder M, Choonara I. Armed conflict and child health. Archives of disease in childhood. 2012;97(1):59-62.

198. Southall D. Armed conflict women and girls who are pregnant, infants and children; a neglected public health challenge. What can health professionals do? Early human development. 2011;87(11):735-42.

199. Wolfe I, Thompson M, Gill P, Tamburlini G, Blair M, van den Bruel A, et al. Health services for children in western Europe. Lancet. 2013;381(9873):1224-34.

200. Republic of Rwanda Ministry of Health. Annual report July 2012–June 2013 2013. Available from: http://www.moh.gov.rw/fileadmin/templates/Press_release/MoH_Annual_Report_July_2012-June_2013.pdf (accessed July 5, 2015).

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