Measuring the unmet need for caesarean sections in sub-Saharan Africa and South Asia

Francesca Louisa Cavallaro

Thesis submitted in accordance with the requirements for the degree of Doctor of Philosophy of the University of London

April 2015

Department of Infectious Disease Epidemiology
Faculty of Epidemiology and Population Health
LONDON SCHOOL OF HYGIENE & TROPICAL MEDICINE

Funded by the Economic and Social Research Council (ESRC)
Research group affiliation: MARCH Centre for Maternal, Reproductive and Child Health

I, Francesca Louisa Cavallaro, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed: ………………………………… Date: ……………….

Abstract

Background. Caesarean sections are critical interventions in obstetric care. The unmet need for caesareans is an important indicator for monitoring emergency obstetric care coverage: several methods have been proposed, however there is no consensus on how to measure the unmet need for caesareans in sub-Saharan Africa and South Asia.

Methods. First, trends in the caesarean rate by wealth were analysed in 26 countries in sub-Saharan Africa and South Asia using Demographic and Health Surveys, in order to identify groups with rates below 1% and 2%. Second, a global online survey was conducted on obstetricians' opinions of the optimal caesarean rate. Third, linked hospital and population-based data were used to validate the Unmet Obstetric Need (UON) indicator in central Ghana, which measures the unmet need for surgery for absolute maternal indications (AMIs), and to investigate novel approaches using hospital data.

Results. The caesarean rate was extremely low among poor women in most sub-Saharan African and South Asian countries. The median optimal caesarean rate reported by obstetricians worldwide was 20%, and there was a large variation in responses (IQR: 15-30%). The 1.4% threshold for the UON indicator was found not to be valid in Ghana. For most complications – including AMIs, among which caesarean rates were close to 100% – women were equally likely to have their need for caesareans met regardless of their educational level.

Conclusion. The optimal caesarean rate remains unknown, and thus cannot be used as a benchmark for measuring the unmet need. The UON indicator does not produce valid estimates of AMI-related mortality avertable with caesareans, however caesarean rates below 1% probably indicate a critical unmet need for life-saving surgery. Comparing caesarean rates in hospitals by education is useful for determining whether population-based differences in the caesarean rate are partly explained by differential access to care within facilities.

Acknowledgments

I have received help from many people throughout the last three years. I am very grateful to my supervisor, Carine Ronsmans, for her advice and patience – especially in reading endless drafts over the last few months – and for teaching me never to lose sight of the big picture even in the smallest details. Jenny Cresswell has been a fantastic co-supervisor, and I am indebted to her for being so generous with her time and guidance. Many thanks to John Bradley for his assistance with my statistical queries. I am thankful to Lisa Hurt for all her help understanding the ObaapaVitA data and for her enthusiasm about the findings.

I am grateful to the members of the Countdown to 2015 Equity Working Group, particularly Cesar Victora and Aluisio Barros, for their insights on presenting and interpreting caesarean rates from DHS surveys. Many thanks to Hannah Blencowe and Onikepe Owolabi for pre-testing the online survey, to the MSc students who piloted it, and to Anna, Bruna, Thomas, Renee, Filipe and Elizabet for translating it. I am thankful to Hannah Knight for sharing her insights on disseminating online surveys, as well as the national obstetrics societies and individuals who helped circulate it among their networks. Caitlin Shannon gave me invaluable insight for interpreting my findings in the context of central Ghana. I am deeply grateful to the ESRC for funding my postgraduate studies.

I feel lucky to have been part of such a supportive community of PhD students and the MARCH group at LSHTM. In particular, I am incredibly grateful to the best officemates ever: (in order of appearance) Clara, Susie, Rachel and Marina, as well as all the others who have shared our desk space – thanks for making LG21 such a happy place. I would also like to thank Veronique Filippi, Oona Campbell, Christopher Grollman, Catriona Towriss, Anton Camacho and Corinne Armstrong for their advice and encouragement. I have been blessed with wonderful friends who have supported me from near and far, not least Laure, Juliette, Nina, Zuzana and Angie. Many thanks to my family for all their love and support.

In loving memory of my grandfathers, Armando Cavallaro and David Denison.

Table of contents

List of tables

List of figures

List of acronyms

AMI	Absolute maternal indication
CI	Confidence interval
DHS	Demographic and Health Surveys
ICD-10	International Classification of Diseases, version 10
IQR	Interquartile range
MTCT	Mother-to-child transmission of HIV
NHIS	Ghana National Health Insurance Scheme
OR	Odds ratio
PRMR	Pregnancy-related mortality ratio
RCT	Randomised controlled trial
RR	Risk ratio
UON	Unmet Obstetric Need
VPM	Verbal post-mortem
WHO	World Health Organisation

Chapter 1. Conceptualising the unmet need for caesarean sections

This thesis aims to improve our understanding of the burden of poor maternal and perinatal outcomes by examining different methods for measuring the unmet need for caesarean sections in sub-Saharan Africa and South Asia.

Caesarean sections are a critical, and sometimes life-saving, intervention in emergency obstetric care. However, access to caesareans is inequitable: in many low- and middle-income countries, some women who need a caesarean do not receive one. The magnitude of this unmet need for caesareans is unknown.

Measuring the unmet need for caesareans is key to understanding which women do not have access to this intervention, and ultimately to reducing the burden of maternal and perinatal deaths. However, there is no consensus on how to measure the unmet need for caesareans in sub-Saharan Africa and South Asia. This thesis contributes to addressing this knowledge gap by examining existing and novel approaches to assessing the unmet need for caesareans.

1.1. Introduction

Caesarean sections are a surgical procedure in which the fetus is delivered through an incision in the mother's abdomen and uterus. Caesareans are often performed in cases where vaginal delivery would threaten the mother's or fetus' health, though some are also performed without medical indication. Globally, an estimated 18.5 million caesarean deliveries occur each year, representing approximately 14% of all births [1]. National caesarean rates vary greatly between countries, from 1.4% in Niger in 2012 to 52.3% in Brazil in 2010 [2, 3]. Caesarean rates have been rising since the 1990s in most middle-income countries [4], though the regional rate for Africa remained at 3.5% in the early 2000s [5]. National caesarean rates further mask wide differentials within countries, including by wealth and urban-rural residence [4, 6].

Caesareans are a critical component of emergency obstetric care, and can be a life-saving intervention during childbirth [7]. However, they entail risks as well as benefits, and therefore are not recommended for all deliveries [8]. The World Health Organisation (WHO) recommends that the population-based caesarean rate should be between 5-15% [7], but these thresholds are not based on empirical evidence. The difficulty in setting minimum and maximum benchmarks for caesarean rates has raised a debate over whether they should be used as an indicator of access to emergency obstetric care [9, 10], and if not, how to monitor coverage of this critical intervention. Several alternative approaches have been used in the literature in an attempt to measure the unmet need for caesareans, though the validity of these methods has often not been established.

The main objective of this thesis is to examine existing approaches, and explore novel approaches, to measuring the unmet need for caesarean sections in sub-Saharan Africa and South Asia. Concerns about unnecessary caesareans have been much discussed in the literature in the context of rising caesarean rates worldwide [11-14], however the excessive use of caesareans is not the focus of this work.

1.2. Defining the need for caesarean sections

Measuring the unmet need for caesareans requires first defining what constitutes a need for caesareans, and second determining how many women with a need for caesarean receive one. The issue of how to conceptualise the need for caesareans is central to assessing the unmet need, and can be defined at two levels: for the population as a whole, and among subgroups of deliveries.

The population-level need for caesareans can be defined as the percentage of all deliveries requiring a caesarean. The most common approach used to identify the population-level need relies on the concept of the optimal caesarean rate, which refers to the percentage of caesarean deliveries which minimises adverse maternal and perinatal outcomes at the population level [15]. This concept will be explained in detail below (section 1.3).

In subgroups of women, the percentage of deliveries requiring a caesarean depends on the relative risks and benefits of caesareans in different groups of deliveries (such as breech presentations, or women with previous caesarean). Caesareans may be used to treat a wide range of obstetric complications, including antepartum haemorrhage, prolonged or obstructed labour, eclampsia and intrapartum fetal distress [7]. Postpartum complications cannot be treated by caesarean, and other interventions may be favoured in the event of fetal death in some settings (namely, destructive deliveries). Caesareans allow for the rapid delivery of a fetus without passage through the birth canal. They are hence useful to treat complications where the fetus needs to be delivered urgently (such as eclampsia or fetal distress); or where vaginal delivery is either impossible (for example, in cases of obstructed labour) or would lead to severe morbidity or mortality. Planned or elective caesareans (scheduled in advance) can be used to treat conditions identified before labour that may lead to complications during delivery, such as placenta praevia, while emergency caesareans (time-sensitive) are performed after the onset of complications requiring urgent treatment. As with any surgical operation, there are also risks associated with caesarean delivery for the mother, including wound infection, endometritis, and damage to the bladder or ureter [16-18], which must be weighed against potential benefits [8].

The need for caesareans is seldom explicitly defined in the literature. In this thesis, I define a need for caesareans as deliveries where the expected health benefits of a caesarean to the woman and her baby outweigh the potential risks. This risk-benefit evaluation is likely to be context-dependent, since the safety of caesareans and of available alternative treatments varies across settings. In addition, maternal outcomes must be weighed against fetal/neonatal outcomes, as caesareans for fetal indications have implications for the mother and vice versa. Evidence relating to the risks and benefits of caesareans is required in order to operationalise this definition, and identifying complications that represent a need for caesarean entails a qualitative judgment of what level of risk is acceptable for a certain expected benefit. An unmet need for caesareans, accordingly, is defined as occurring when a woman with a need for caesarean does not receive one.

1.3. Measuring the unmet need for caesareans at the population level

The main approach that has been used to quantify the unmet need for caesareans has rested on the concept of the optimal caesarean rate, or the caesarean rate which minimises poor outcomes for mothers and babies at the population level [15]. The optimal caesarean rate is an estimated measure of the population-based need for caesareans, usually represented as an optimal range with a minimum and maximum threshold. If the thresholds are valid, the population-based unmet need for caesareans can be calculated as the deficit between the observed rate and the lower estimate of the optimal rate, in a given population. The most commonly cited recommendation for optimal caesarean rates is the WHO guideline of 5-15%, which has been used as a basis for calculating the unmet need for caesareans and the number of excess caesareans [1, 19-22]. A number of ecological studies have attempted to validate these thresholds by analysing the relationship between population-based caesarean rates and measures of maternal and perinatal mortality (see below).

Two other approaches have been used to measure the unmet need at the population level: the Unmet Obstetric Need indicator, which represents the deficit in life-saving surgery for a defined group of “absolute” maternal indications; and the identification of groups of women with less than 1% or 2% caesarean rates by stratifying the caesarean rate according to wealth or residence.

1.3.1. Optimal caesarean rates

The WHO guidelines for “acceptable” caesarean rates

The first WHO guidelines for the optimal caesarean rate were published in 1985 in response to rising caesarean rates in high-income countries. This much-cited recommendation states “there is no justification for any region to have a higher rate than 10-15%,” on the basis that “countries with some of the lowest perinatal mortality rates in the world” had caesarean rates below 10% [23]. The outcomes that this caesarean rate sought to minimise are not stated explicitly, though the previous statement implies that only perinatal – and not maternal – mortality was considered (perhaps because countries with rates above 10-15% generally had low maternal mortality at the time). No further details are given of the evidence base considered in adopting this guideline.

In 1997, the revised Guidelines for Monitoring the Availability and Use of Obstetric Services were published, in which the first mention of a minimum "acceptable level" was made: "as a proportion of all births in the population, Caesarean sections account for no less than 5% nor more than 15%" [24]. Contrary to the previous guidelines, these state that the benchmarks aim to minimise maternal mortality ("if national or regional data show that less than 5 per cent of births are by Caesarean section, this means that some women with life-threatening complications are not receiving necessary care" [24]), though implicitly takes into account perinatal outcomes, stating that the lower threshold may be below 5% if maternal indications only are considered.

The 5% lower limit was based on two cited studies, which do not provide evidence supporting this benchmark. In the first, Nordberg assumes caesareans are "justified" in 5% of births based on two other studies using benchmarks of 3% and 10%, both of which appear to be arbitrary [25]. The second cited article was a report published by UNICEF detailing the availability of emergency obstetric care in three districts in India [26]: I could not locate its full text version, but a peer-reviewed article by the same author was later published presenting findings on indicators of the availability of emergency obstetric care in 10 districts in India [27]. Nirupam recognises the limited evidence supporting the 5% threshold and states "it is generally agreed that [the exact percentage of births likely to require a caesarean] is not less than 5%" [27]. The 15% upper limit was based on a comparison of caesarean rates in 14 high-income countries in the 1980s [28], which found higher caesarean rates in Brazil (32%) and the USA (19%) than in other countries. The 1997 guidelines summarise the selection of the lower and upper limits as follows:

> In setting acceptable levels for Caesarean sections, it seems appropriate to have both a minimum and maximum. Five percent of all births in the population is a relatively conservative lower limit. For the upper limit, 15 percent seems reasonable. It is slightly higher than the level in most developed countries, but less than the level in those countries known to have problems with excessive use of this procedure. [24]

The definition of “excessive use” of caesareans is not specified. The lower threshold of the optimal caesarean rate recommended by the WHO therefore appears to be based on weak evidence.

The 5% threshold was upheld as the minimum “acceptable level” for population-based caesarean rates in the 2009 guidelines on Monitoring Emergency Obstetric Care [7]. The lack of evidence on which this optimal range is based is acknowledged in the guidelines:

> Earlier editions of this handbook set a minimum (5%) and a maximum (15%) acceptable level for caesarean section. Although WHO has recommended since 1985 that the rate not exceed 10-15% […], there is no empirical evidence for an optimum percentage or range of percentages, despite a growing body of research that shows a negative effect of high rates […] The technical consultation for these guidelines noted the difficulty of establishing a lower or upper limit for the proportion of caesarean sections. [7]

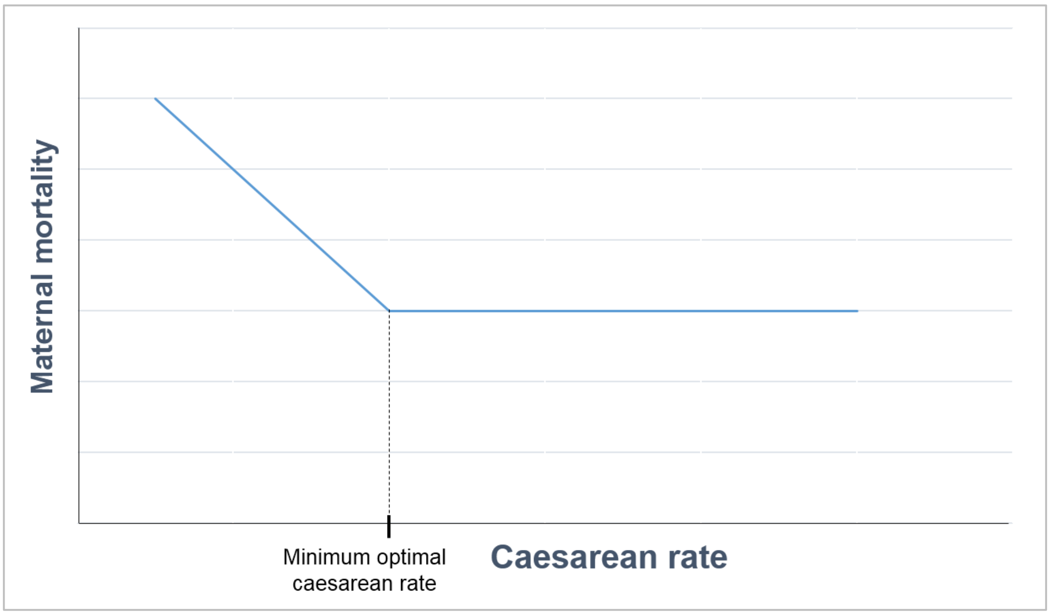
A notable difference from the 1997 guidelines is that the selection of the upper and lower limits refer to minimising morbidity as well as mortality (maternal and perinatal), mentioning that “a lower limit of 5% is reasonable for both maternal and fetal reasons” and that high rates carry risks for maternal and neonatal mortality and morbidity [7]. The WHO maintains its recommended range for caesarean rates despite the limited available evidence, stating:

> Both very low and very high rates of caesarean section can be dangerous, but the optimum rate is unknown. Pending further research, users of this handbook might want to continue to use a range of 5–15% or set their own standards. [7]

Validation of the minimum optimal caesarean rate

Since the publication of the most recent WHO guidelines, a number of ecological studies have explored the variation in mortality of mothers or babies according to caesarean rates, in order to examine the validity of the 5-15% recommendation. Validating the minimum optimal caesarean rate would require identifying the lowest caesarean rate beyond which there are no further mortality declines for mothers and babies. Maternal and perinatal mortality are predicted to be most affected by the caesarean rate (less so infant mortality), since a larger proportion of these deaths are intrapartum-related, and they are the most suited to validating the optimal caesarean rate. In order to identify this threshold in practice, the ideal scenario would be to observe a relationship whereby maternal mortality, for example, declines with the caesarean rate until a clear threshold after which it plateaus or increases again; this point would correspond to the minimum optimal caesarean rate for maternal mortality at the population level. Figure 1.1 illustrates this conceptual definition of the minimum optimal caesarean rate.

Figure 1.1 Conceptual definition of minimum optimal caesarean rate for maternal mortality



Several conceptual and methodological problems remain, however, with identifying the minimum optimal caesarean rate based on ecological analyses. First, the optimal caesarean rate may vary according to context. Populations with a higher prevalence of delivery complications (such as obstructed labour due to immature or small pelvis) may require a higher population-based caesarean rate [29], though the magnitude of these risk differences between populations is unknown. Countries with different caesarean rates are also likely to differ in other ways, and the association between caesarean rates and maternal or perinatal mortality may be partly confounded by other factors, such as per capita income, education, and health system development. Moreover, access to and quality of intrapartum care is likely to modify the relationship between the caesarean rate and maternal mortality: for instance, better monitoring during labour can lead to interventions that avoid the need for a caesarean, while unsafe caesareans may contribute to higher maternal mortality. Historically, certain high-income countries have achieved low maternal mortality with low caesarean rates, such as the Netherlands in 1968, when maternal mortality was around 20 per 100,000 with just below 2% caesareans [30]. Yet caesarean rates around 2% are associated with much higher levels of maternal mortality in sub-Saharan Africa, where many facilities are not equipped to provide emergency obstetric care [31] and the quality of delivery care is thought to be poor [32, 33]. A higher caesarean rate may thus be necessary to achieve low maternal mortality in these settings. Controlling for variations in quality of care is difficult, but at a minimum ecological analyses should validate the minimum optimal caesarean rate separately for high- and low-income countries.

Second, there are methodological issues regarding how to determine what the minimum optimal caesarean rate is. Ecological associations reveal a much less linear association between the caesarean rate and maternal mortality, with more variation in the data, than the conceptual relationship outlined in Figure 1.1 (see below). Curved regression models (such as exponential functions) indicating a gradual deceleration in mortality with rising caesarean rates, may prove to fit the data better than two linear segments. This lack of a clear threshold effect would hinder the identification of a minimum optimal caesarean rate.

Notwithstanding these limitations of ecological studies in identifying the optimal caesarean rate, if the threshold for reported minimum optimal caesarean rates was similar across ecological studies for the same outcome, this would give us confidence in this estimate. In addition, even without consensus in the minimum optimal rate, reviewing the ecological evidence may nonetheless validate the fact that maternal or perinatal mortality is universally high at very low caesarean rates.

I reviewed the ecological evidence relating to the association between caesarean rates and mortality in order to compare the reported minimum optimal caesarean rates across studies, and with different methodological approaches. I searched Medline for ecological studies of the association between population-based caesarean rates and maternal, perinatal, stillbirth and neonatal mortality rates published after 2000 (including time-series of caesarean rates and mortality in a single country). I did not include studies of the infant mortality rate, since this outcome is not expected to be substantially affected by the caesarean rate.

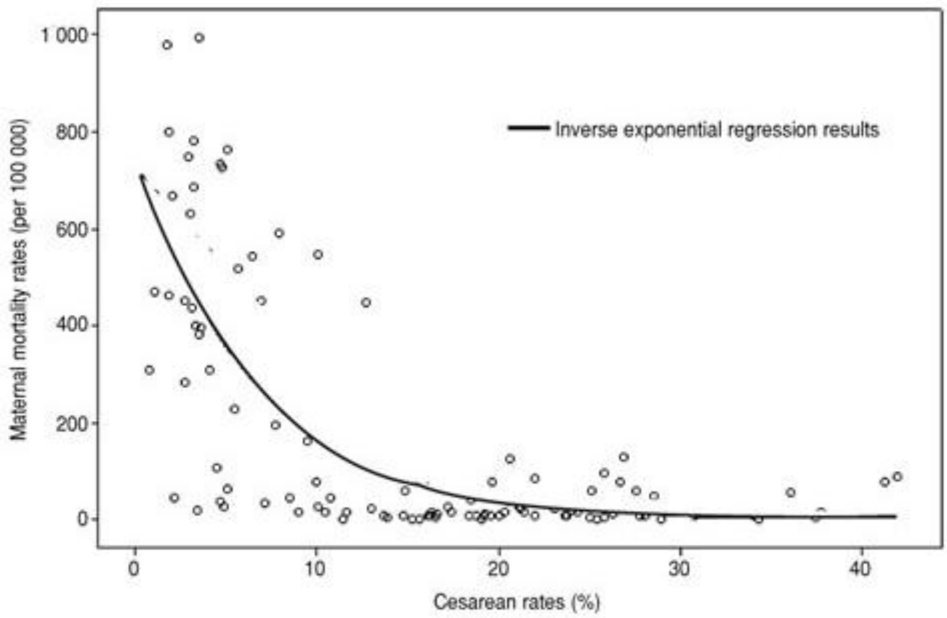
Table 1.1 (on page 24) describes the nine studies identified. Seven cross-sectional studies were truly ecological in that they compared the caesarean rate and mortality rates between countries [5, 21, 29, 34-36], or between sites in West Africa [37]. One time series study analysed annual changes in caesarean rates and mortality in one country (Iceland) [38], and another compared caesarean and mortality rates over time and across different areas (where each country had multiple data points for different years) [39]. Eight of the nine studies looked at variations in maternal mortality, while three looked at neonatal or early neonatal mortality, one at stillbirths and one at perinatal mortality. Two studies stratified the analyses according to country income or development level [29, 35].

The evidence base has not identified a clear minimum optimal caesarean rate for maternal mortality, and studies report a range of different thresholds. Maternal mortality was negatively associated with caesarean rates throughout the range of caesarean rates in West Africa (0.2-2.7%) [37] and the Arab region (1.4-16.0%) [21], with no reported threshold. The two studies stratifying results according to country income or development found no association among high-income, middle-income, or developed countries, but reported that maternal mortality ceases to decline after 10% in developing countries and 15-20% in low-income countries [29, 35]. In a study of high-income countries, the threshold was found to be 15% [39], while it ranged between 9% and 15% among studies not using any stratification [5, 34, 36]. These studies suggest that the minimum optimal caesarean rate for maternal mortality may be higher than the WHO 5% lower limit.

Across studies, the relationship between caesarean rates and maternal mortality was modelled using inverse exponential functions or piecewise simple linear regression (where “natural” breakpoints in the trend are identified and the relationship is modelled as a linear function between these breakpoints). The reported thresholds identified based on visual inspection of curved regression lines tended to be higher (15% to 15-20%) [5, 29, 36, 39] than those ascertained by piecewise regression (9% to 10%) [34, 35]. Most authors did not report how they selected their models or the relative fit of piecewise linear regression compared with curved functions, and did not adjust for any potential national-level confounders (with two exceptions [29, 39]). Figure 1.2 presents maternal mortality and caesarean rates from a study of 112 high-, middle- and low-income countries [36]. Volpe modelled this relationship as an inverse exponential function, and states that the curve “lost inclination” beyond 10-15% caesareans. Yet when plotting the data, it appears that there is a wide range of maternal mortality ratios for a given national caesarean rate among countries with rates below 15%, and neither type of model (inverse exponential or piecewise linear regression) would succeed in explaining all this variation. No potential confounders were adjusted for, further questioning the validity of this estimate of the minimum optimal caesarean rate. As a result, ecological studies have not identified a clear threshold caesarean rate beyond which maternal mortality ceases to decline.

Nonetheless, maternal mortality appears to be universally high (above 300 per 100,000 births) with caesarean rates below 1%; a few countries achieved mortality below 200 per 100,000 below 2% caesareans, though most still experienced high maternal mortality. Moreover, regardless of the model, predicted mortality ratios tended to be above 600 per 100,000 around 1% caesareans and at least 500 per 100,000 at 2% caesareans.

Figure 1.2 Maternal mortality ratio as a function of caesarean rates, by country for 112 countries (2000-2009) - Reproduced from Volpe, 2011 [36]



Fewer studies looked at perinatal or neonatal mortality. In Iceland, the perinatal mortality rate did not change with an increase in the national caesarean rate from 12% to 17% between 1987 and 2006 [38] (though this timeframe is quite short, an observable change in perinatal mortality would still be expected in 20 years since changes in the caesarean rate would affect perinatal mortality relatively rapidly in a context of high quality of care). One study found no association between early neonatal mortality and the caesarean rate in middle- or high-income countries, but found that early neonatal mortality declines up to 15-20% caesareans in low-income countries [29]. Similarly, the stillbirth rate was found to decrease up to 13% caesareans in developing countries, with no association in developed countries [35]. Decreases in neonatal mortality were observed up to 15% caesarean rate before plateauing above 15% across countries worldwide [34], while it declined up to 10% in high-income countries [39]. As with maternal mortality, only two studies adjusted for confounders [29, 39], though most models predict high neonatal mortality and stillbirth rates (over 30 per 1,000 births) below 1% and 2% caesareans.

Among studies including mortality for both mothers and babies, there was no consistent trend as to which minimum optimal caesarean rate was higher. One study reported the same threshold for both maternal and early neonatal mortality in low-income countries (15-20% caesareans) [29]. In two global cross-country studies, the threshold was higher for stillbirths (13%) and neonatal mortality (15%) than for maternal mortality (10% and 9%, respectively) [34, 35], though it was lower for neonatal than maternal mortality in high-income countries (10%, compared with 15% for maternal mortality) [39].

Ecological studies report a range of different thresholds determined by questionable methods and most do not adjust for any potential confounders: therefore, the ecological evidence base does not identify a clear minimum caesarean rate necessary to achieve low maternal and neonatal mortality, and as a result, does not validate the optimal caesarean rate. However, it does highlight that maternal and perinatal mortality is almost universally high at levels of caesarean rates below 1% and, with some exceptions, below 2%, suggesting that caesarean rates below these thresholds indicate that women and babies are dying because of lack of access to caesareans.

Few other data sources exist to validate the minimum optimal caesarean rate, one of which may be clinicians' opinions of the optimal caesarean rate. No studies were identified which explored the extent of variation in reported optimal rates between obstetric providers (a survey of South African obstetricians reported the mean “ideal” caesarean rate, but did not explore agreement between respondents [40]).

Table 1.1 Ecological studies of the association between population-level caesarean rates and maternal, neonatal and infant mortality

Study reference	Unit of analysis	Setting	Outcome of interest	Association with outcome	Factors adjusted for	Range of caesarean rates
Althabe [29]	Country	119 high-, medium- and low-income countries	Maternal mortality	Maternal mortality decreases until 15-20% caesareans in low-income countries (p<0.0001). No significant association in high- and middle-income countries.	Gross national income; proportion of skilled attendance deliveries; proportion of literate population.	0.4-40
			Early neonatal mortality	Early neonatal mortality decreases until 15-20% caesareans in low-income countries (p<0.0001). No significant association in high- and middle-income countries.		
Betran [5]	Country	126 countries	Maternal mortality	Maternal mortality declines with increasing caesarean rates below 15% caesareans. Maternal mortality increases with increasing caesarean rates above 15% caesareans.	None	0.4-40.5
McClure [35]	Country	188 countries high-, middle- and low-income countries (unclear how many included in caesarean analysis)	Maternal mortality	Maternal mortality decreases with increasing caesarean rate below 10% caesareans for all countries (p<0.0001). No significant association above 10% caesareans for all countries (p=0.81). Similar association for developing countries, but no association in developed countries (p=0.22).	None	1-37 (1-36 for developing countries, 10-37 for developed countries)
			Stillbirths	Stillbirths decrease with increasing caesarean rate below 13% caesareans for all countries (p<0.0001). No significant association above 13% caesareans for all countries (p=0.77). Similar association for developing countries, but no association in developed countries (p=0.27).		
Volpe [36]	Country	193 countries	Maternal mortality	Maternal mortality declines exponentially with increasing caesarean rate (p<0.001); deceleration in curve between 10-15%.	None	0.4-41.9

Study reference	Unit of analysis	Setting	Outcome of interest	Association with outcome	Factors adjusted for	Range of caesarean rates
				Maternal mortality increases with caesarean rate when including only countries with caesarean rate >15% (p=0.08).		
Zizza [34]	Country	142 high-, medium- and low-income countries	Maternal mortality	Maternal mortality decreases with rising caesarean rate below 9% caesareans (p<0.001). No significant association above 9% caesareans.	None	0.4-42.3
			Neonatal mortality	Neonatal mortality decreases with rising caesarean rate below 15% caesareans (p<0.001). Neonatal mortality increases with rising caesarean rate above 15% caesareans (p=0.04).		
Jurdi [21]	Country	18 countries in the Arab region	Maternal mortality	Maternal mortality decreases with rising caesarean rate (r=-0.579, p<0.05).	None	1.4-16.0
Ronsmans [37]	Urban and rural study sites	16 sites in 8 West African countries	Maternal mortality	Maternal mortality decreases with rising caesarean rate (r=-0.59; r^2=0.34).	None	0.2-2.7
Ye [39]	Country and year	19 high-income countries, with repeated observations between 1980 and 2010	Maternal mortality	Maternal mortality decreases with rising caesarean rate below 15% caesareans. No significant association above 15% caesareans.	Human Development Index; Gross Domestic Product	6.2-32.8
			Neonatal mortality	Neonatal mortality decreases with rising caesarean rate below 10% caesareans. No significant association above 10% caesareans.		
Jonsdottir [38]	Year	Years between 1987-2006 in Iceland (national data)	Perinatal mortality	No significant change in perinatal mortality with increase in national caesarean rate.	None	11.9-16.7%

1.3.2. The Unmet Obstetric Need approach

Due to the difficulty of establishing a minimum optimal caesarean rate necessary to achieve optimal maternal and infant outcomes, researchers have instead tried to identify an absolute minimum threshold for conditions threatening the mother's life, to measure the population-level unmet need for life-saving surgery. The concept of absolute maternal indications (AMIs) was proposed by the Unmet Obstetric Need (UON) Network, and refers to obstetric complications for which, without receiving surgery, a woman is thought to be very likely to die [30]. Surgery can be used to treat a range of life-threatening obstetric conditions [7], and surgical interventions are generally better documented than less invasive treatments; therefore the UON indicator focused on obstetric surgery for both relevance and practicality reasons.

The UON indicator focuses on these life-threatening conditions because they are believed to occur in a constant percentage of deliveries across populations, and because they can be used to calculate a direct estimate of the number of maternal deaths from these conditions avertable by surgery, thus providing a clear interpretation for the indicator. AMIs for obstetric surgery consist of the following complications [30]:

- Severe antepartum haemorrhage caused by major placenta praevia or abruptio placentae (severe bleeding before delivery caused by an abnormal implantation of the placenta near the cervical os or detachment of the placenta from the uterine wall)
- Incoercible postpartum haemorrhage (unstoppable bleeding after delivery)
- Major cephalopelvic disproportion (where the fetal head is larger than the mother's pelvis, making vaginal delivery impossible)
- Uterine rupture (a catastrophic complication of obstructed labour, where the uterine wall tears)
- Transverse lie (where the baby's long axis lies across the long axis of the mother, making vaginal delivery impossible)
- Brow presentation (where the fetus' forehead is the presenting part; the diameter of the fetal head at this angle is usually larger than the mother's pelvis, making vaginal delivery impossible)

These complications were included as AMIs on the basis of clinical experience, but have not been validated with epidemiological data. Nonetheless, these are extremely severe complications thought to represent a critical need for obstetric surgery. Surgeries used to treat AMIs include primarily caesareans, as well as hysterectomy, laparotomy for uterine tear repair, internal version, symphysiotomy, and destructive deliveries (craniotomy and embryotomy).

The UON Network estimates that 1.4% (95% confidence interval (CI): 1.27-1.52) of deliveries will develop an AMI, on the basis of the observed percentage of surgeries for AMIs in urban settings thought to have good access to care (a detailed explanation of the evidence used for determining this benchmark is provided in chapter 5) [41]. The UON indicator is then calculated as the difference between the proportion of deliveries expected to develop an AMI, minus the observed proportion of deliveries receiving surgery for an AMI:

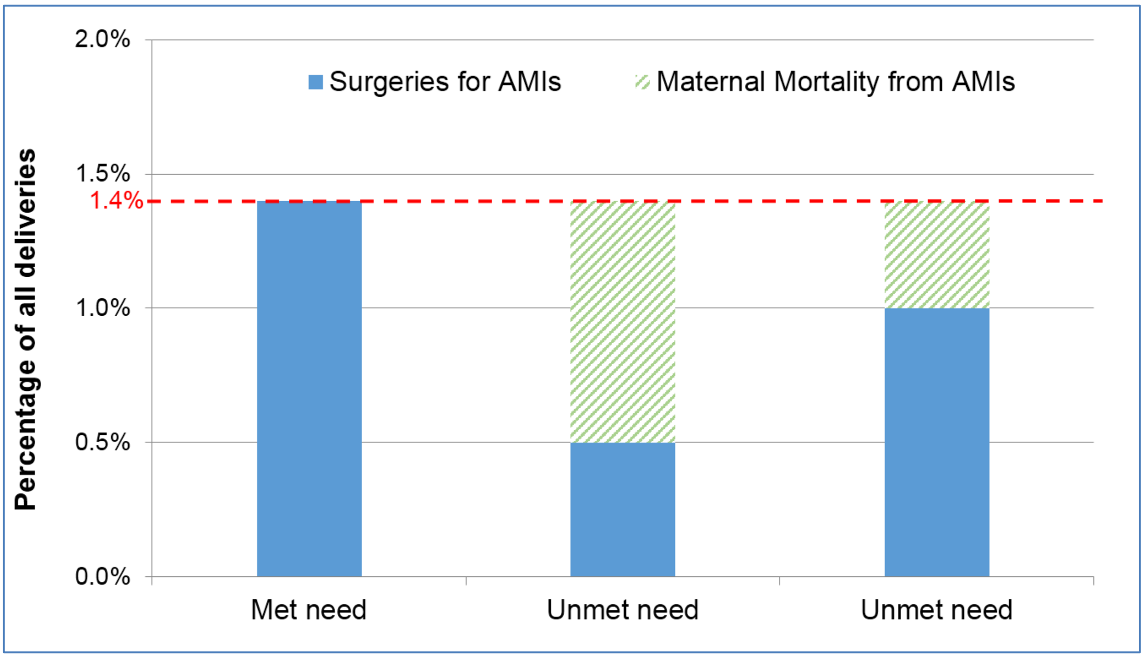
Unmet Obstetric Need

= Expected percentage of deliveries with AMIs (total need = 1.4%)

– Observed percentage of deliveries with surgery for AMIs (met need)

The assumption that women who develop an AMI will die if they do not receive surgery allows for making inferences about maternal mortality based on the expected AMI prevalence of 1.4%; for example, an observed percentage of surgery for AMIs of 1.4% suggests that there is no excess mortality from AMIs due to lack of access to surgery in this population (Figure 1.3 below was created to illustrate this concept). Conversely, if only 0.5% of deliveries actually receive surgery for an AMI, there is thought to be an unmet need for obstetric surgery and we would expect a mortality ratio of at least 0.9% (or 900 per 100,000 deliveries) for AMI-related causes.

Figure 1.3 Relationship between met need for obstetric surgery for AMIs and maternal mortality from AMI-related causes



Not all pregnancy-related deaths are caused by AMIs: indeed, a substantial proportion of deaths in pregnant or postpartum women are due to conditions which cannot necessarily be treated with surgery. A recent systematic review of global causes of maternal deaths identified hypertensive disorders and sepsis as the second and third most frequent causes of deaths (accounting for one quarter of all maternal deaths combined) [42], conditions in which obstetric surgery is not always useful to avert deaths, particularly in the case of sepsis. As a result, the level of all-cause maternal mortality will be higher than the estimated mortality from AMIs alone.

The UON indicator has been used to measure the unmet need for obstetric surgery in several low- and middle-income countries, though not all studies use the 1.4% threshold. The expected prevalence of AMIs used in these studies ranged between 1% in Haiti and Morocco [41], and 2% in Tanzania [43, 44]; some of these benchmarks contributed to calculating the 1.4% prevalence estimated by the UON, though some of these studies conducted after publication of this estimate continued to use different benchmarks, for unclear reasons.

The UON Network reported results from studies in eight countries (Benin, Burkina Faso, Haiti, Mali, Morocco, Niger, Pakistan, and Tanzania), where the percentage of deliveries receiving surgery for AMIs ranged from 0.23% in Niger to 1.03% in Benin, suggesting substantial unmet need for obstetric surgery in most of these settings [41].

Sub-national studies found that the regional percentage of surgery for AMIs varied between 0.3-0.8% in Mali in 2001 [45], 0.16-0.62% across wards in Morocco in 1995 [46] and 0.8-1.1% in three districts in north-east Tanzania in 2000-02 [43]. Another study in south-east Tanzania in the same time period found a percentage of surgery for AMIs of 1.8% for Mtwara region as a whole, and above 2% in several sub-divisions [44], suggesting potential misclassification of surgeries for AMIs. Most studies demonstrated larger unmet need among rural than urban women [43-45, 47].

The UON indicator builds on a number of assumptions which merit verification. First, it has not been demonstrated that groups with less than 1.4% surgery for AMIs suffer from excess mortality from these causes and the validity of this threshold is uncertain. Second, there is debate over whether other complications, such as eclampsia, should be included among AMIs, though many women with eclampsia survive without surgery [48]. Extra-uterine pregnancies and previous caesarean have also been included as AMIs in some studies in low-income countries [41]. Third, calculating the indicator usually relies on data from hospital records, where information is assumed to be valid, despite issues of missing information on indications and of misclassification related to surgeries performed for AMIs. In particular, cephalopelvic disproportion is a subjective diagnosis thought to have low specificity [49], implying that caesareans for other dystocic complications may be included as surgeries for AMIs, thus overestimating the met need. A previous study in Bangladesh found that groups with lower rates of surgery for AMIs did not suffer from excess mortality from AMIs, suggesting the indicator is not valid, and reported of misclassification of surgeries for major cephalopelvic disproportion [50]. The UON indicator has not been validated in sub-Saharan Africa, and the extent of misclassification in these settings is unknown.

1.3.3. Thresholds for the absolute minimum caesarean rate

One disadvantage of the UON indicator is that it requires data collection from hospitals, which is cumbersome and time-intensive. If the assumption that at least 1.4% of deliveries require surgery to ensure the mother's survival is valid, it implies that all-cause population-based caesarean rates below 1.4% (including, but not limited to, caesareans for AMIs) represent an unmet need for life-saving caesareans. Due to the uncertainty around the estimated prevalence of AMIs, two thresholds (1% and 2%) have been used as benchmarks for the absolute minimum caesarean rate at the population level. Although the minimum caesarean rate necessary to prevent all deaths avertable with caesareans is likely to be higher, rates below these extremely low thresholds suggest almost certainly that some women are dying from lack of access to surgery (as supported by the ecological evidence reviewed above).

Ronsmans et al. analysed differentials in caesarean rates across wealth quintiles in 42 countries in sub-Saharan Africa, south and south-east Asia, and Latin America and the Caribbean [6]. Using data from Demographic and Health Surveys conducted between 1990 and 2004 they found extremely low caesarean rates among the poor in the majority of countries, including 20 countries in which the poorest 20% had rates below 1%. Caesarean rates were below 1% for 80% of the population in six sub-Saharan countries (Chad, Madagascar, Niger, Ethiopia, Burkina Faso, and Mali). Stanton and Holtz examined urban-rural differences in caesarean rates in 36 developing countries [4]. Their results showed that urban rates were above 2% in all study countries, while the caesarean rate in rural areas was below 1% or 2% in several sub-Saharan African countries. These studies suggest that there is an unmet need for life-saving surgery in sub-Saharan Africa, particularly among the rural and the poor.

In summary, while recommendations for optimal caesarean rates suggest a minimum threshold of 5%, ecological studies have not identified a single minimum optimal caesarean rate necessary to achieve low maternal or perinatal mortality, though all reported thresholds were above 5%. Efforts to measure the unmet need at the population level have instead focused on identifying an absolute minimum threshold below which women are considered to be dying because of lack of access to surgery for life-threatening complications. The UON indicator proposes that groups with less than 1.4% deliveries receiving surgery for AMIs suffer from excess mortality from these causes; however, this indicator has not been validated. On the basis of work by the UON Network, population-based caesarean rates below 1% and 2% (for all indications) have also been suggested as indicating an unmet need for life-saving obstetric surgery, a suggestion supported by the high maternal and perinatal mortality observed in countries with very low caesarean rates.

1.4. Measuring the unmet need for caesareans among subgroups of deliveries

Defining the need for caesareans among subgroups of deliveries requires identifying conditions for which the benefits of receiving a caesarean outweigh the risks for mothers and babies. As outlined above, vaginal delivery would inevitably lead to severe morbidity or mortality for AMIs; these conditions constitute an absolute need for caesareans, and caesarean rates below 100% in these groups represent a clear unmet need. For other conditions, some – but not all – deliveries require a caesarean to avert poor outcomes, and these conditions do not necessarily represent an absolute need for caesareans for all cases (I will refer to this as a “relative need for caesareans” in this chapter). It is unclear how to measure the unmet need for these conditions: the minimum optimal caesarean rate – though lower than 100% – cannot be calculated from the magnitude of relative risk associated with caesarean delivery, and therefore the benchmark for calculating the unmet need is unknown in these groups.

The evidence on the risks and benefits of caesareans comes from several sources: clinical experience, randomised controlled trials, and observational studies. This section will review the available evidence relating to the benefits and risks of caesareans for specific obstetric conditions, with the aim of identifying conditions which constitute an absolute or relative need for caesareans. It will end by presenting an approach stratifying the caesarean rate according to groups of deliveries with different risk factors for caesareans (the Robson classification).

1.4.1. Clinical experience

Most of the evidence relating to the need for caesareans is clinical. Absolute maternal indications (AMIs), described previously (section 1.3.2), are considered to represent an absolute need for caesareans in order to save the mother’s life; these were identified on the basis of clinical experience that vaginal delivery with these conditions is either impossible, or threatens the life of the mother and the baby.

For most conditions, the decision to perform a caesarean is made on a case-by-case basis by clinicians. The risk-benefit evaluation takes into account multiple complex factors, and there are no standard algorithms for this clinical decision-making. For example, the assessment of whether a woman with pre-eclampsia needs a caesarean will depend on many factors at repeated time points, including – but not limited to – the severity of hypertension, whether she is in labour, whether induction of labour has succeeded, the pace of progression of labour, as well as the presence and severity of fetal distress. Most obstetric conditions do not represent a clear indication for caesareans in and of themselves, and the combinations of clinical criteria considered to require a caesarean has not been defined in a standardised way.

1.4.2. Evidence from randomised controlled trials

Randomised controlled trials (RCT) can help inform the need for caesareans by identifying conditions for which planned caesareans lower the overall mortality and morbidity risks for the mother and baby, compared with planned vaginal delivery. If a composite indicator of risk were constructed for maternal and perinatal outcomes, conditions associated with a very large relative risk for vaginal delivery compared with caesarean would represent an absolute need for caesareans, while those associated with a somewhat higher relative risk would represent a relative need for caesareans.

I searched the Cochrane Library for systematic reviews of the effectiveness of caesareans in averting poor maternal and/or perinatal outcomes, and identified two groups of deliveries for which RCTs assessed the benefits of caesarean delivery: breech presentation and women with HIV infection.

Caesarean for breech presentation

Breech presentation occurs when the fetus' buttocks or feet are the first body part to enter the birth canal. Three trials of planned caesarean for singleton breech presentation at term were included in the Cochrane review [51]. The meta-analysis found reduced perinatal or neonatal mortality or serious neonatal morbidity in the planned caesarean group, compared with planned vaginal birth (risk ratio (RR)=0.33, 95% CI: 0.19-0.56). Contrary to countries with low perinatal mortality, serious neonatal morbidity was not reduced with caesarean delivery in countries with high perinatal mortality (RR=0.08, 95% CI: 0.02-0.32 in countries with low perinatal mortality, compared with RR=0.92, 95% CI: 0.42-1.99 in countries with high perinatal mortality) [52], but the risk ratio for perinatal or neonatal death was similar in both groups of countries. It is important to note that 45% of women assigned to planned vaginal birth had an emergency intrapartum caesarean delivery, suggesting that the increased fetal risk in the planned vaginal group may be partly explained by the higher risks of emergency intrapartum caesareans compared with planned caesareans.

Planned caesarean for breech presentation was associated with an increase in maternal morbidity at three months (RR=1.29, 95% CI 1.03-1.61) [51]. Specifically, they were more likely to experience abdominal pain (RR=1.89, 95% CI 1.29-1.79), but less likely to have urinary incontinence (RR=0.62, 95% CI 0.41-0.93) or perineal pain (RR=0.32, 95% CI 0.18-0.58) [51]. None of the adverse neonatal outcomes studied were higher among the group assigned to caesarean delivery, suggesting there were no risks to the infant.

The authors argue that improved perinatal outcomes at the expense of maternal morbidity is important information for individual decision-making, but do not make a general recommendation for routine caesareans among breech deliveries. Not all breech deliveries require a caesarean to avert poor perinatal outcomes (since vaginal breech delivery can be performed safely in some cases), and breech presentation thus represents a relative – rather than absolute – need for caesarean.

Caesarean for maternal HIV infection

One RCT of planned caesarean for prevention of mother-to-child transmission (MTCT) of HIV-1 was identified [53]. Planned caesarean was found to be efficacious for preventing MTCT among women not taking antiretrovirals or taking zidovudine only (odds ratio (OR)=0.2, 95% CI 0-0.8), but its effect was unclear among HIV-1-infected women with low viral loads. There were no data available regarding maternal or perinatal mortality or morbidity according to mode of delivery in this trial. The authors recommended that mode of delivery be decided on an individual basis for women with low viral loads, but they argue that “the benefit of elective caesarean section generally outweighs the risk of postpartum maternal morbidity” in women with high viral loads [53]. Women with high HIV viral load probably represent a relative need for caesareans (despite missing information on morbidity or mortality) since MTCT does not occur in 100% of vaginal deliveries.

While the evidence from RCTs has shown that breech delivery and high HIV viral load represent a relative need for caesareans, it is unclear how to measure the unmet need for caesareans in these groups because the relative risk cannot be used to determine the minimum optimal caesarean rate. Other systematic reviews identified insufficient data from RCTs to assess the effect of caesarean delivery on maternal and perinatal outcomes in the event of previous caesarean (compared with planned vaginal birth [54] and induction of labour [55]), singleton preterm labour [56], twin pregnancy [57], maternal hepatitis C infection [58], or of caesareans for non-medical reasons at term [59]. No RCTs of emergency caesareans for antepartum or intrapartum complications have been conducted, because the clinical benefit is believed to be obvious, therefore making RCTs unethical.

The evidence base from RCTs is therefore very limited: few obstetric conditions have been studied, and these trials cannot be used to determine the optimal caesarean rate in groups with a relative need for caesareans.

1.4.3. Evidence from observational studies

Risks and benefits of caesareans for specific complications

There are important limitations of using observational studies to assess which complications would benefit from a caesarean: since women who deliver by caesarean are likely to have more severe complications (leading to performing the caesarean), their outcomes are likely to be worse than women who deliver vaginally irrespective of the mode of delivery. The confounders which would need to be controlled for in order to achieve comparability between groups (other than type of obstetric complication) are unknown, and likely to be multiple and complex. Therefore evidence from observational studies is not appropriate for assessing the need for caesareans for specific complications.

As an example, Hall and colleagues compared the risk of neonatal morbidity between antepartum caesarean and trial of labour among women with severe pre-eclampsia before 34 weeks gestation [60]. Babies exposed to labour had a lower risk of sepsis (RR=0.56, 95% CI 0.33-0.93) and receiving intensive care (RR=0.4, 95% CI 0.27-0.58) [60]. However, the higher morbidity among babies born by antepartum caesarean is likely caused by selection bias: in the study hospital, antepartum caesareans were only performed in the case of complications such as fetal distress or breech presentation, and the caesarean group thus had a higher prevalence of obstetric complications affecting neonatal morbidity at baseline. These findings are not useful for determining whether early-onset pre-eclampsia constitutes a need for caesarean.

Intrinsic risks associated with caesarean sections

The risk associated with caesareans has two components: an intrinsic risk, which occurs for all caesareans, and a risk that is dependent on the complication (for example, HIV-infected women receiving a caesarean were almost six times more likely to develop postpartum sepsis than HIV-negative women delivering by caesarean [61]). Assessing the complication-specific risk is subject to the same issue of selection bias outlined above. However, several large observational studies have attempted to quantify the intrinsic risks related to caesarean delivery by comparing caesareans with no medical indication to vaginal deliveries: since these caesareans do not have a clinical indication, women with caesareans are not thought to be at higher risk of obstetric complications than women delivering vaginally, and any observed increase in morbidity or mortality can be attributed to the caesarean itself.

The WHO Global Survey on Maternal and Perinatal Health was a large facility-based survey of mode of delivery and birth outcomes in 24 countries in Africa, Asia and the Americas [8]. This study found that the odds of severe maternal morbidity or mortality (including death, admission to intensive care, blood transfusion and hysterectomy) were 6 times higher (OR=5.93, 95% CI 3.88-9.05) for antepartum caesareans without indications (n=1,735), and 14 times higher (OR=14.29, 95% CI: 10.91-18.72) for intrapartum caesareans without indications (n=950), compared with spontaneous vaginal delivery (n=205,551) and adjusting for a wide range of socio-economic and obstetric factors. The odds of severe perinatal outcome (including perinatal death and intensive care stay of over 7 days) were 2.5 times higher for intrapartum caesarean without indications (OR=2.48, 95% CI: 1.66-3.69), but were no different between babies born by antepartum caesarean without indications and spontaneous vaginal delivery.

The odds ratio of severe maternal morbidity associated with caesareans without indications was considerably larger in Africa (OR=71.29, 95% CI: 32.06-158.55 for antepartum caesarean without indications, compared with spontaneous vaginal delivery) than in Asia or the Americas (OR=2.14, 95% CI: 1.04-4.43 in Asia, and OR=1.94, 95% CI: 0.77-4.9 in the Americas), though the estimates for Africa are based on small numbers for antepartum and intrapartum caesareans (n=63 and n=202, respectively). This geographical difference suggests that the magnitude of risk associated with caesareans varies according to setting, and therefore, that identifying conditions with a need for caesareans is also context-specific.

Evidence from high-income countries corroborates findings of increased maternal and neonatal morbidity with caesareans without medical indication. A retrospective study using data from the Swedish birth registry found that women undergoing caesareans without medical indication were more likely to experience haemorrhage (OR=2.5, 95% CI: 2.1-3.0) and infection (OR=2.6, 95% CI: 1.8-3.8) compared with spontaneous vaginal delivery (n=5,877 caesareans and n=13,774 vaginal deliveries) [62]. This study also found an increase in neonatal respiratory morbidity after caesareans without medical indication (OR=2.7, 95% CI: 1.8-3.9). A similar study of deliveries in Canada between 1991 and 2005 found that women who underwent a low-risk planned caesarean (defined as a planned caesarean for breech delivery, without antepartum complications) had 3 times the odds of severe maternal morbidity as healthy women with planned vaginal delivery (OR=3.1, 95% CI 3.0-3.3, based on n=46,766 low-risk elective caesareans and n=2,292,420 planned vaginal deliveries in healthy women) [63].

Observational studies have therefore provided evidence that there is a non-negligible intrinsic risk associated with caesarean delivery. Though the relative risk for caesareans without medical indication is not directly relevant to measuring the unmet need for caesareans, it does indicate that the benefits of performing a caesarean in a subgroup of deliveries must be at least as large as these risks in order for these complications to require a caesarean.

In summary, there is very little robust epidemiological evidence which can help measure the unmet need for caesareans in subgroups of deliveries. Clinical experience suggests that absolute maternal indications need a caesarean in all cases; caesarean rates below 100% in these groups is thought to represent a clear unmet need for caesareans. Systematic reviews of RCTs suggest that breech deliveries and women with high HIV viral load represent a relative need for caesareans, but the optimal caesarean rate in these groups cannot be deduced based on the relative risk, and therefore it is not possible to measure the unmet need for these complications. For other conditions, there is no epidemiological evidence on the risks and benefits of caesareans, and the need for caesarean is generally assessed at the individual level based on clinical experience. Therefore, it is not possible to establish a clear minimum threshold of need for caesareans in subgroups of deliveries other than absolute maternal indications.

1.4.4. Robson classification

I have argued above that identifying the need for caesareans epidemiologically is not possible for most obstetric conditions; some effort has instead been made to analyse caesarean rates in groups of women with different demographic and reproductive risk factors for caesareans. In the context of rising caesarean rates in the UK, Robson proposed a woman-based classification of caesareans, with the aim of enabling maternity units to understand which groups of deliveries drive trends in their institutional caesarean rate [64]. This classification was conceived as a tool for reviewing clinical management to achieve appropriate caesarean rates, given the case-mix of a specific facility. I will explore whether this classification may also be useful for monitoring unmet need within facilities in sub-Saharan Africa and South Asia.

The Robson classification is based on six obstetric parameters: parity, single/multiple pregnancy, fetal presentation, gestational age, onset of labour, and previous caesarean [64]. The classification includes 10 groups of deliveries based on combinations of the six parameters (described in Table 1.2), which were "created to reflect as much as possible the groups of women who are most relevant in clinical practice" [64] and thus drawn on the basis of clinical experience, rather than epidemiological data.

Table 1.2 Robson classification of caesarean sections

Category number	Category description
1	Nulliparous, singleton cephalic, ≥ 37 weeks, in spontaneous labour
2	Nulliparous, singleton cephalic, ≥ 37 weeks, induced or caesarean before labour
3	Multiparous (excluding previous caesarean), singleton cephalic, ≥ 37 weeks, in spontaneous labour
4	Multiparous (excluding previous caesarean), singleton cephalic, ≥ 37 weeks, induced or caesarean before labour
5	Previous caesarean, singleton cephalic, ≥ 37 weeks
6	All nulliparous breeches
7	All multiparous breeches (including previous caesarean)
8	All multiple pregnancies (including previous caesarean)
9	All singleton transverse or oblique lies (including previous caesarean)
10	All singleton cephalic, ≤ 36 weeks (including previous caesarean)

The Robson classification assigns all deliveries in a facility, and reports the caesarean rate as well as the percentage of all caesareans performed in each group. A decade after proposing the classification, Robson provided some guidelines for interpreting these rates [65]. He suggests that the caesarean rate among transverse and oblique lies (group 9) should be 100% (consistent with their definition as absolute maternal indications); therefore caesarean rates below 100% suggest an unmet need. Optimal caesarean rates in other categories are based on Robson's experience as an obstetrician, though they have not been validated (epidemiologically or by clinical consensus). He mentions the caesarean rate is "usually" around 25-30% among singleton nulliparas who do not go into spontaneous labour (group 2), 4-6% among singleton multiparas without spontaneous labour (group 4), and 60% among multiple pregnancies (group 8) [65]. He further argues that a rate of 50-60% among singleton deliveries with previous caesarean is "satisfactory provided there is satisfactory perinatal outcome” [65] (though “satisfactory perinatal outcomes” are not defined). The evidence that these percentages are based on is unclear, and they should not be used as benchmarks for the minimum caesarean rate in these groups. Though the ranking of these categories in terms of need for caesarean is not explicit, singleton transverse and oblique lies (group 9) have the highest need for caesarean (close to 100%) and singleton cephalic multiparas in spontaneous labour, with no previous caesarean (group 3), are considered to have the lowest need for caesarean.

A recent systematic review [66] of studies applying the Robson classification identified 73 studies in 31 countries, primarily cross-sectional studies and time trend analyses in high-income countries including Ireland [65], Belgium [67], Sweden [68], the USA [69, 70], Oman [71], Singapore [72], and Chile [73]. The authors of the systematic review note “the interpretation of the results of the classification is the weakest point of its use” [66]. One of the advantages of the classification (as reported by its users) is that it can be used as an intervention to reduce caesareans [66], by analysing excess caesareans in different categories. For example, in Tanzania, Litorp et al. found that the caesarean rate in the lowest risk group (multipara without previous caesarean, with term singleton cephalic delivery and in spontaneous labour, group 3) rose to 33% with no improvement in maternal or perinatal outcomes. The authors suggest that this rate is high and implies some of these interventions are performed on “questionable” indications [74], though the basis for this interpretation is unclear. There is no consensus on what the minimum caesarean rates should be among most Robson categories in order to measure the unmet need, except for transverse and oblique lies.

1.5. Proportion of emergency caesareans and caesareans for specific indications

In the literature, clinical information on caesareans (such as indications for caesareans) has been examined as a means of assessing excess caesareans, but less attention has been paid to its ability to inform estimates of the unmet need for caesareans.

Many different classifications of caesareans have been used in the literature; these have been summarised in a systematic review conducted by the WHO [75]. Torloni et al. identified three main types of classifications. The first two examine caesareans by degree of urgency, which emphasise “when” (or how fast) a caesarean should be performed; and by clinical indication, which assess “why” the caesarean was performed. The third classification examines “who” receives a caesarean (such as the Robson classification, described above), and will not be further developed here [75].

Information on emergency status and indications may be useful to calculate the unmet need for caesareans if there were clear benchmarks for the percentage of all deliveried which should receive an emergency caesarean or a caesarean for a specific indication. However, I will argue in this section that there are no such validated benchmarks, therefore this information is not useful for measuring the unmet need for caesareans.

1.5.1. Proportion of emergency caesareans

The simplest urgency-based classification categorises caesareans as elective (planned in advance), or emergency (performed rapidly after the decision is made). More complex classifications are used in certain clinical settings [75], such as the Royal College of Obstetricians and Gynaecologists’ classification (“immediate threat to the life of the mother or fetus”, “maternal or fetal compromise, but not immediately life-threatening”, “no maternal or fetal compromise, but needs early delivery” and “delivery timed to suit woman or staff”) [76].

There is no known threshold of the percentage of caesareans that should be emergencies, or the percentage of all deliveries requiring an emergency caesarean, and therefore information on emergency status is not useful for measuring the unmet need. Very high proportions of elective caesareans within a facility may indicate excess caesareans in some settings, though even in areas of Brazil with a population-based caesarean rate of 45%, only one third of caesareans were recorded as elective [77]. Even if such a minimum threshold were known, not all emergency procedures are necessary. Indeed, emergency caesareans may be overutilised if the severity threshold of complications for performing a caesarean is too low; caesareans performed in response to prolonged labour in particular may be performed before the appropriate duration of labour has been reached (as defined by partograph assessment) [78].

1.5.2. Percentage of caesareans for clinical indications

Classifications of clinical indications (“why” a caesarean was performed) abound in the literature: Torloni et al. identified 12 classifications with sufficient explanation to be reproducible [75], though many more have been used. These classifications are used to measure the percentage of caesareans performed for each indication. The categories included vary widely: dystocic complications (including obstructed labour, cephalopelvic disproportion, and prolonged labour) tend to be the most common indication for caesarean [19, 79-84], though the percentage of caesareans performed for this indication varies substantially (between 2% in a private facility in Bangladesh to 59% in an urban government facility in Guinea, according to one study [85]). Other common indications for caesarean include malpresentation, fetal distress, and pre-eclampsia or eclampsia [19, 79, 80, 83].

Information on indications is not useful to identify the unmet need within health facilities: as with the urgency of caesareans, there is no benchmark for the minimum caesarean rate for each indication. If the prevalence of various complications and the minimum optimal rate for each complication were known, the percentage of all deliveries requiring a caesarean for each indication could be ascertained, though these have not been validated [86, 87]. Some researchers have made inferences on the excess of caesareans based on indications data. For instance, maternal requests account for 20% of caesareans in South-East China, all of which are considered unnecessary interventions [88], and the 33% of caesareans performed for "other" indications in Bangladesh, in a facility where half of deliveries were by caesarean, was interpreted by the authors as suggesting unnecessary interventions [85].

Several important limitations of indications data are worth noting, particularly the lack of standardised terminology [75, 85]. Obstructed labour and cephalopelvic disproportion are often poorly defined and used interchangeably with prolonged labour, as suggested by the inverse association between the percentage of caesareans for "failure to progress" and for "obstructed labour" across facilities [85]. A quality assurance audit in Tanzania found that only two thirds of women undergoing caesarean for "prolonged labour" had a prolonged labour based on partograph assessment [78], further suggesting that the severity of indications may be misclassified. Another limitation is that caesareans often have multiple indications: most classifications do not include hierarchical rules for assigning a single indication in these cases [75], in part because such a hierarchy between indications is not obvious (except for extremely severe indications, such as uterine rupture).

In summary, information on the urgency of or indications for caesareans are not useful for assessing the unmet need for caesareans, because there are no benchmarks for interpreting the proportion of deliveries that require an emergency caesarean, or a caesarean for a specific indication. However, comparing the percentage of emergency caesareans or caesareans performed for various indications across groups of women with different population-based caesarean rates may help understand how access to care affects the case-mix of hospital deliveries across groups. This has not been explored, in part because it requires both population-based data on caesareans and maternal socio-economic characteristics, as well as clinical data from hospital records.

Table 1.3 summarises the strengths and weaknesses of the different approaches to measuring the unmet need for caesareans discussed in this chapter.

Table 1.3 Summary of different types of information on caesarean sections and their relevance for measuring the unmet need for or unnecessary caesareans

Name	Approach	Indicator	Data requirements	Interpretation	Usefulness for measuring unmet need	Usefulness for measuring unnecessary caesareans
Deliveries in health facilities						
Emergency vs. elective caesareans	Classify all caesareans into emergency (time-sensitive) and elective (planned); emergency caesareans can be specified as antepartum or intrapartum.	• Percentage of emergency and non-emergency caesareans Numerator: number of emergency or elective caesareans; denominator: total number of caesareans or of deliveries	• Emergency or elective status (clinical records); OR • Timing of decision / caesarean relative to labour (clinical records)	All emergency antepartum caesareans are interpreted to fill a need for obstetric surgery, though a proportion of emergency intrapartum and elective caesareans may be “unnecessary” interventions. The interpretation of the indicators is unclear due to lack of benchmarks.	• Not useful for measuring unmet need, though socio-economic stratification may be useful to identify whether groups with low caesarean rates have high proportions of emergency caesareans	• High proportions of elective caesareans may reflect unnecessary caesareans • However, no benchmarks for interpreting indicator and percentage likely to be affected by case mix • Informative at facility level, but not population level
Clinical indications for caesarean	All caesareans are classified according to their indication	• Percentage of caesareans performed for each indication Numerator: number of caesareans with indication; denominator: total number of caesareans or deliveries	• Indication for caesarean (clinical records)	Unclear how to assess unmet need. A high proportion of caesareans for maternal request or “other” may reflect unnecessary caesareans, though benchmark is unknown.	• Not useful for measuring unmet need, though socio-economic stratification may be useful to identify whether groups with low caesarean rates have high proportions of caesareans for more severe complications	• High proportions of caesareans for “maternal request” or “other” may reflect unnecessary caesareans • However, misclassification of indications is common and multiple indications may be recorded • Informative at facility level, but not population level

Name	Approach	Indicator	Data requirements	Interpretation	Usefulness for measuring unmet need	Usefulness for measuring unnecessary caesareans
Robson classification of deliveries	Deliveries in health facilities are grouped into 10 categories based on six obstetric parameters (multiple pregnancy, parity, induced labour, previous caesarean, gestational age and fetal presentation). Caesarean rates are calculated in each category.	• Caesarean rate in each Robson category Numerator: number of caesareans in Robson category; denominator: number of deliveries in Robson category	• Six obstetric characteristics (multiple pregnancy, parity, induced labour, previous caesarean, gestational age and fetal presentation) (clinical records)	Caesarean rate among singleton, term, cephalic multipara with no previous caesarean and spontaneous labour (group 3) should be "no higher than 3%". Caesarean rate of 50-60% is "satisfactory" among singleton cephalic deliveries with previous caesarean (group 5). Caesarean rate should be 100% among transverse and oblique lies (group 9). Benchmarks not validated (except group 9).	• Caesarean rates below 100% among transverse or oblique lies represent unmet need for caesareans in this group • Informative at facility level, but not population level	• May be useful to identify excess caesareans among low-risk categories, but benchmarks have not been validated • Unclear how need for caesareans is predicted to vary across categories (no explicit ranking of need) • Categories drafted from clinical experience, rather than based on epidemiological evidence • Informative at facility level, but not population level
All deliveries in population						

Name	Approach	Indicator	Data requirements	Interpretation	Usefulness for measuring unmet need	Usefulness for measuring unnecessary caesareans
Unmet obstetric need	Calculate expected number of absolute maternal indications (AMIs) in population based on rate of 1.4%, and compare it to number of surgeries performed for these indications. AMIs include severe antepartum haemorrhage, incoercible postpartum haemorrhage, major cephalopelvic disproportion, transverse lies and brow presentations.	• Number of deliveries with unmet obstetric need [Expected number of deliveries with AMIs] – [major obstetric interventions for AMIs] • Percentage of unmet obstetric need Numerator: Number of major deliveries with unmet obstetric need; Denominator: number of deliveries with AMIs	• Expected number of births in population (based on birth rate and population size) • Number of major obstetric interventions for AMIs (clinical records from facilities equipped to perform surgery)	The unmet need for surgery represents the number of women likely to have died from AMIs because of lack of access to obstetric surgery. The percentage of unmet obstetric need represents the percentage of women with AMIs who do not receive surgery.	• Estimates unmet need for maternal life-saving surgery for AMIs at the population level • However, misclassification of indication for surgery may overestimate met need (particularly for "major cephalopelvic disproportion"), and does not capture unmet need related to maternal deaths from non-AMI causes, maternal morbidity or adverse perinatal outcomes • The assumptions underlying this approach have not been validated.	• Not useful for measuring unnecessary caesareans

Name	Approach	Indicator	Data requirements	Interpretation	Usefulness for measuring unmet need	Usefulness for measuring unnecessary caesareans
Absolute minimum threshold for the caesarean rate	The absolute minimum threshold applies to all population-based caesarean rates, but is often more useful to rates stratified across subgroups of deliveries. Stratify deliveries according to maternal characteristics (e.g. socioeconomic status (SES), residence or region) and calculate caesarean rate in each group	• Caesarean rates stratified by socioeconomic status Numerator: number of caesareans in SES category; denominator: number of deliveries in SES category • Percent population with caesarean rate below 1% / 2% Numerator: number of deliveries with cumulative caesarean rate below threshold; denominator: total number of deliveries	• Socioeconomic status of women and mode of delivery for all deliveries (population-based survey data)	The need for caesareans is assumed to be equal across groups, and groups with caesarean rate below 1-2% are interpreted to have avoidable maternal deaths as a result of unmet need for surgery (based on Unmet Obstetric Need approach).	• Estimates unmet need at population level on the basis of caesarean rates below 1%, 2% and 5% • However, these thresholds have not been validated and the sample size of caesareans may be small in certain groups • Achieving a caesarean rate above 1% in a subgroup does not imply the need for life-saving caesareans has been met	• May be useful to measure unnecessary caesareans, but benchmarks for maximum caesarean rates are unknown

1.6. Rationale for the thesis

Caesareans are a critical, and sometimes life-saving, procedure. However, they also have risks, and therefore surgical deliveries should only be performed where the expected benefit outweighs the potential risks. There is limited epidemiological data that can help identify groups of women with a clear need for caesareans (that is, where the benefits clearly outweigh the risks); nonetheless there is little doubt that, in many countries in sub-Saharan Africa and South Asia, some women are not receiving caesareans that they need.

Caesarean sections are an emergency obstetric care intervention and measures relating to caesareans are therefore process, rather than outcome, indicators. Coverage is defined as the proportion of people in need of an intervention who actually receive it [89]. High-quality and timely measurement of the coverage of interventions thought to improve maternal and perinatal health is important to monitor the effectiveness of these interventions and to track progress towards international health goals [90]: for instance, the proportion of births with skilled attendance is a key process indicator for Millennium Development Goal 5 (reduction of maternal mortality). Process indicators are particularly valuable for assessing progress in maternal morbidity and mortality, which may be slow to respond to changes in intervention coverage and difficult to measure precisely. Measuring the unmet need for caesareans – that is, the reverse of coverage – is important because these operations can avert a substantial burden of adverse maternal and perinatal outcomes, and identifying women with an unmet need is necessary for devising interventions to improve access to quality care, and ultimately to reduce maternal and perinatal mortality. In this thesis, I focus on sub-Saharan Africa and South Asia since these two regions account for 85% of maternal deaths [91] and 73% of intrapartum-related neonatal deaths [92] worldwide, and therefore are likely to have the largest burden of unmet need for caesareans.

A large literature exists on caesareans in low- and middle-income countries, but there is little consensus on how to measure the unmet need for caesareans in these settings. The WHO recommendation that at least 5% of all births should be by caesarean is not evidence-based, and thus its use as a benchmark for calculating the unmet need is uncertain. The percentage of deliveries with surgery for AMIs below 1.4% has been suggested as evidence of an unmet need for life-saving surgery, as well as rates below 100% in one Robson category (transverse and oblique lies), though this indicator has not been validated. Population-based caesarean rates below 1% or 2% have likewise not been validated as indicators of unmet need for life-saving surgery; however the review of ecological evidence presented in section 1.3.1 revealed that no countries with caesarean rates below these thresholds have achieved low maternal mortality. Caesarean rates below 1% and 2% are likely to indicate that women are dying because of lack of access to caesareans, and therefore suggest an unmet need for life-saving surgery. There are no other validated benchmarks for assessing the unmet need in other Robson categories, and information on urgency and indication appears not to be useful for measuring the unmet need for caesareans.

In this thesis I will contribute to the debate on the unmet need for caesareans in a number of ways. First, I will examine caesarean rates according to household wealth in countries of sub-Saharan Africa and South Asia, as well as the proportion of the population with caesarean rates below 1% and 2%, in order to describe socio-economic differentials in caesarean rates and understand the magnitude of unmet need for life-saving caesareans in these regions. Second, I will examine the variation in obstetricians' opinions of the optimal caesarean rate, at the population level and for specific groups of deliveries, to determine whether obstetricians agree on an optimal rate across various groups of women. Third, I will use population-based demographic and socio-economic data from Ghana, linked to hospital information on deliveries, to validate the UON indicator and to investigate what we can learn about access to care and the unmet need for caesareans from hospital data. Specifically, caesarean rates among groups with different obstetric complications (including absolute maternal indications) have not been compared, for all deliveries or stratified according to maternal socio-economic status: these approaches may be useful to determine whether the caesarean rate varies based on the predicted level of need for caesareans among different complications, and to investigate whether women of low socio-economic status are less likely to receive a caesarean once they reach a hospital.

1.7. Thesis objectives

The overall objective of this PhD is to examine existing and novel methods of measuring the unmet need for caesarean sections in sub-Saharan Africa and South Asia, in order to determine whether available information can help identify groups with an unmet need for caesareans.

The specific objectives of this thesis are:

Objective 1. To examine socio-economic variation in caesarean rates and the proportion of the population with caesarean rates below a critical life-saving threshold in sub-Saharan Africa and South Asia

1.1. Examine changes in national caesarean rates over time
1.2. Describe caesarean rates by wealth quintile
1.3. Examine the proportion of the population with a caesarean rate below 1% and below 2%

Objective 2. To describe opinions of the optimal caesarean rate among doctors who perform caesarean sections worldwide

2.1. Determine the extent of variation in opinions of the optimal caesarean rate, for all deliveries and among specified categories of deliveries
2.2. Assess whether reported optimal rates vary according to the national caesarean rate in respondents' country of practice

Objective 3. To examine existing and novel approaches to measuring the unmet need for caesarean sections in Ghana

3.1. Describe the socio-demographic determinants of facility deliveries, caesarean sections and pregnancy-related deaths in central Ghana
3.2. Validate the Unmet Obstetric Need approach for measuring the unmet need for obstetric surgery
3.3. Examine the variation in caesarean rates for different complications, for all deliveries and by maternal education

1.8. Thesis outline

Chapter 1 has provided the introduction and background to the research questions addressed in this thesis. It has examined approaches to measuring the population-based unmet need for caesareans, and described the available evidence for assessing the need for caesareans among subgroups of women. Lastly, I have described the usefulness of clinical data on caesareans for assessing the unmet need.

Because the study design and data sources used to address each objective differ, there is no overall methods chapter, and detailed methods for each study are presented in individual results chapters (chapters 2-6) in order to avoid repetition.

Chapter 2 addresses objective 1 of this thesis, and examines trends in caesarean rates by socio-economic status and over time in sub-Saharan Africa and South Asia. This chapter consists of an article published in the *Bulletin of the WHO* in 2013 detailing the distribution of caesareans across wealth quintiles, followed by additional analyses on caesarean rates according to maternal education. Chapter 2 examines whether socio-economic stratification of caesarean rates can help identify groups with an unmet need for caesareans, using the 1% and 2% benchmarks.

In Chapter 3, I address objective 2 by presenting findings from a large survey of obstetric care providers' opinions of the optimal caesarean rate. I explore the extent of variation in reported optimal rates, at the population level and for individual complications, and determine whether this variation is partly explained by the national caesarean rate in respondents' country of practice.

Objective 3 of this thesis is addressed in chapters 4, 5 and 6. Chapter 4 provides a detailed description of the study population and data sources used in these three chapters. It further examines risk factors for facility deliveries, caesareans and pregnancy-related deaths in the study population. These methods and descriptive analyses provide relevant information for interpreting the results presented in chapters 5 and 6.

In chapter 5, I validate the Unmet Obstetric Need approach to measuring the unmet need for obstetric surgery, by examining whether the percentage of deliveries with surgery for or pregnancy-related death from absolute maternal indications consistently represents 1.4% across educational groups. Chapter 6 examines the usefulness of hospital information on caesareans for measuring the unmet need within facilities, including existing approaches to presenting data on indications for caesarean sections. I further examine the variation in caesarean rates across obstetric complications, and analyse whether indications and hospital-based caesarean rates vary according to maternal education.

The final chapter synthesises the main findings from these studies and presents a discussion of the results. I conclude by discussing the policy implications for how to measure the unmet need for caesareans and recommendations future research.

1.9. Ethical approval

Ethical approval for this thesis was granted by the London School of Hygiene & Tropical Medicine Ethics Committee (ref: 6455, A437, 6429). Additional approval was provided by the Ghana Health Service for the secondary analysis of ObaapaVitA data (ref: 2012-05). Ethical approval forms can be found in **Appendix A: Ethical approval letters**.

Chapter 2. Trends in caesarean rates over time and by socio-economic status in sub-Saharan Africa and South Asia

Chapter 2 addresses the first objective of this thesis by presenting a descriptive analysis of temporal and socio-economic trends in caesarean rates in sub-Saharan Africa and South Asia. The main purpose of this analysis is to provide the most recent nationally representative estimates of caesarean rates in these two regions, in order to assess the extent of unmet need for caesareans among socio-economic subgroups of women.

This chapter begins with the article presenting the main findings from this analysis, which was published in the Bulletin of the WHO (December 2013). The paper presents caesarean rates over time in the 26 countries included in the analysis, as well as rates by relative wealth quintile and urban/rural residence. This is followed by an additional analysis on caesarean rates according to maternal education, in order to assess whether findings were consistent with caesarean rates across wealth quintiles.

This article resulted from a collaboration with the Countdown to 2015 Initiative, within which I downloaded and prepared the datasets used in the analysis, carried out the analyses, as well as was primarily responsible for writing the article. The version of the article presented in this chapter was edited to incorporate a longer methods section providing more details on the data source used for the analyses (Demographic and Health Surveys), as well as an expanded discussion of the strengths and limitations of the DHS data. For the sake of legibility, it also includes graphs disaggregated by region for all analyses, rather than the single graph of caesarean rates by quintile included in the published version of the article.

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT
www.lshtm.ac.uk

Registry
T: +44(0)20 7299 4646
F: +44(0)20 7299 4656
E: registry@lshtm.ac.uk

LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

COVER SHEET FOR EACH 'RESEARCH PAPER' INCLUDED IN A RESEARCH THESIS

Please be aware that one cover sheet must be completed for each 'Research Paper' included in a thesis.

1. For a 'research paper' already published

1.1. Where was the work published? Bulletin of the World Health Organisation

1.2. When was the work published? December 2013

1.2.1. If the work was published prior to registration for your research degree, give a brief rationale for its inclusion: N/A

1.3. Was the work subject to academic peer review? Yes

1.4. Have you retained the copyright for the work? **Yes ~~/ No~~**
If yes, please attach evidence of retention: The Bulletin of the WHO is an open access journal and I retained the copyright for this publication (see "Licence for publication" on http://www.who.int/bulletin/volumes/92/1/14-990114/en/).
If no, or if the work is being included in its published format, please attach evidence of permission from copyright holder (publisher or other author) to include work

2. For a 'research paper' prepared for publication but not yet published

2.1. Where is the work intended to be published?

2.2. Please list the paper's authors in the intended authorship order

2.3. Stage of publication – Not yet submitted / Submitted / Undergoing revision from peer reviewers' comments / In press

3. For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)

I am the first author on this paper. I was responsible for preparing the merged dataset from the original 86 survey datasets, constructing the variables used in the analysis and conducting the analysis. I was also primarily responsible for writing the article. My co-authors supported this work in an advisory capacity and in helping to edit the writing.

NAME IN FULL (Block Capitals) FRANCESCA CAVALLARO

STUDENT ID NO: 234864

CANDIDATE'S SIGNATURE ……………………………………………. Date …………..

SUPERVISOR/SENIOR AUTHOR'S SIGNATURE (3 above)

………………………………………………………………………………………………

2.1. Published article - Trends in Caesarean delivery by country and wealth quintile: analysis of 80 national datasets in southern Asia and sub-Saharan Africa

Article reference: Cavallaro FL, Cresswell JA, Franca GV, Victora CG, Barros AJ, Ronsmans C. Trends in caesarean delivery by country and wealth quintile: cross-sectional surveys in southern Asia and sub-Saharan Africa. Bull World Health Organ. 2013;91(12):914-22d. [93]

2.1.1. Abstract

Objective To examine temporal trends in caesarean delivery rates, by country and wealth quintile.

Methods Cross-sectional data were extracted from the results of 80 Demographic and Health Surveys conducted in 26 countries in South Asia or sub-Saharan Africa. Caesarean delivery rates were evaluated – as percentages of the deliveries that ended in live births – for each wealth quintile in each survey. The annual rates recorded for each country were then compared to see if they had increased over time.

Findings Caesarean delivery rates had risen over time in every study country but were consistently found to be < 5% in 18 of the countries and ≤ 10% in the other eight countries. Among the poorest 20% of the population, caesarean sections accounted for < 1% and < 2% of deliveries in 12 and 21 countries of the study countries, respectively. In each of 11 countries, the caesarean delivery rate in the poorer 40% of the population remained < 1%. In Chad, Ethiopia, Guinea, Madagascar, Mali, Mozambique, Niger and Nigeria, the rate remained < 1% in the poorer 80%. Compared with the 22 African study countries, the four South Asian study countries experienced a much greater rise in their caesarean delivery rates over time. However, the rates recorded among the poorest quintile in each of these countries consistently fell below 2%.

Conclusion The caesarean delivery rates among large sections of the population in sub-Saharan Africa are very low, probably because of poor access to such surgery.

2.1.2. Introduction

Caesarean sections, when adequately indicated, can prevent poor obstetric outcomes and be life-saving procedures for both the mother and the fetus [8]. However, at a time when the caesarean delivery rate – as a percentage of live births – has been rising globally [8], there is growing concern about unnecessary caesarean sections [94]. Unnecessary caesarean sections can increase the risk of maternal morbidity, neonatal death and neonatal admission to an intensive care unit [94]. At the same time, there is also concern that – in low-income countries in general and among the poorer sections of the populations in such countries in particular – caesarean sections are not always accessible, even when they are clearly indicated [6].

There is no consensus on the “optimal” rate of caesarean delivery at the population level. Although values between 5% and 15% of live births have been suggested, the basis on which these thresholds have been proposed is not clear [7]. Some historical studies indicate that low maternal mortalities can be achieved when the caesarean delivery rate is far below 15% of live births. In the Netherlands, for example, maternal mortality had fallen below 20 deaths per 100 000 live births by 1968, when caesarean sections were associated with less than 2% of live births [95, 96]. The results of some ecological studies indicate not only that no further reductions in mortality occur when caesarean delivery rates increase above 10%, but also that rates above 15% may be associated with additional mortality [5, 29]. The World Health Organization (WHO) has suggested that a caesarean delivery rate of 15% should be taken as a threshold that should not be exceeded – rather than a target to be achieved [7].

The lower threshold for an “acceptable” rate of caesarean delivery has received much less attention than the upper threshold. Extremely low rates are indications that access to surgical care is poor and that, in consequence, women, fetuses and neonates are dying unnecessarily. As 1 to 2% of all births are associated with conditions that absolutely require caesarean sections to save the mothers’ lives – such as obstructed labour and complete placenta praevia – caesarean delivery rates of less than 1% or less than 2% are thought to reflect a real deficit in access to life-saving obstetric care and to be associated with excess maternal mortality [48, 97-99]. Rates of at least 5% are thought to be necessary to save the greatest numbers of both mothers and neonates, although there is little evidence to support such a cut-off [7].

National rates of caesarean delivery can mask substantial within-country variation in the rates of such surgery. For example, urban rates are consistently found to be higher than rural rates [4] and the rates for the poorest sections of the population often fall well below the national mean. In a retrospective analysis of data from Demographic and Health Surveys (DHSs) conducted in 42 developing countries, caesarean delivery rates were often found to fall below 1% either in the poorest quintile of the population (20 countries) or in all but the richest quintile (six countries) [6]. Only in five countries included in this analysis did the rate of caesarean delivery in the poorest quintile exceed 5% of live births [6].

With Millennium Development Goals (MDGs) 4 and 5 nearing their target date of 2015, it is timely and necessary to assess recent progress in improving access to caesarean sections. In this paper we analyse trends in caesarean delivery rates in South Asia and sub-Saharan Africa over the past 15 years. We focused on countries in South Asia and sub-Saharan Africa because such countries account for 85% of all maternal deaths [91] and 73% of all intrapartum neonatal deaths globally [92]. We examined caesarean delivery rates over time and by wealth quintile and estimated, for each country, how many and which of the five wealth quintiles were experiencing caesarean delivery rates below 1%, 2% and 5%.

2.1.3. Methods

All of the data that we analysed – retrospectively – came from DHSs, and all of the datasets that we used were downloaded from the MEASURE DHS website [100]. The DHSs are nationally representative cross-sectional household surveys conducted by ICF International in low- and middle-income countries. Most surveys follow a two-stage sampling design, where geographical areas (“clusters”) are first selected, and households are selected from within these clusters [101]. The DHS use standardised questionnaires in order to enable comparisons between countries and over time. The core questionnaire is administered to all women aged 15-49 who usually live in the household and guests who stayed in the household the previous night. The interview includes questions on the respondent’s background and reproductive history, including a detailed birth history of all children born alive; extensive information is collected on children born within the five years preceding the interview, including data on delivery care [102].

A question on mode of delivery was first introduced in the Phase 2 model DHS questionnaire, asking for each birth in the preceding five years “Was [NAME] delivered by caesarian section?” [103]. Several modifications to the question have been made to minimise misreporting. The Phase 4 questionnaire introduced a skip pattern in 2001 so that this question would not be asked to women who reported delivering in their home or at an "other" location [104]. The question was amended in the Phase 6 questionnaire in 2011 to "Was [NAME] delivered by caesarean, that is, did they cut your belly open to take the baby out?" [105]. Multiple Indicator Cluster Surveys (MICS) were not used in this analysis since data on mode of delivery were not collected until MICS 4 (2009-2011), and no countries had more than one survey with available data on caesareans at the time this analysis was conducted.

The DHS also collect a wide range of socio-economic data. In this analysis, we stratified caesarean rates according to household wealth quintile since several reviews have found that it is consistently associated with the use of delivery care in low- and middle-income countries [106-108]. Household wealth quintile is calculated on the basis of ownership of household assets including car ownership, livestock, water source, and dwelling characteristics (such as floor and wall materials). Principal components analysis is used to calculate a weight for each asset. Individual asset scores are then calculated on the basis of these weights, and summed to obtain the total wealth index for each household. Households are ordered according to their wealth index, and grouped into five quintiles of equal size. Full details of the method for calculating household wealth indices are given in the DHS report [109]. Maternal educational attainment is also collected in the DHS, defined as the highest grade completed, was categorised into five groups: no education, incomplete primary, complete primary, incomplete secondary, and complete secondary or higher.

The data that we used came from the countries in South Asia or sub-Saharan Africa that were included in the "Countdown to 2015" initiative [110], although only data from the 26 countries where there had been at least two DHSs were analysed. The countries that we investigated were categorized into three regions – eastern and southern Africa, South Asia, and western and central Africa – according to the classification of the United Nations Children's Fund [111]. We merged all available surveys for each country and pooled the data for all deliveries associated with a live birth in the 5 years preceding each survey whenever possible. In a few surveys, data on deliveries were only collected for the 3 or 4 years preceding the survey. We investigated the mode of delivery for each singleton birth and for the neonate who was born last in each multiple birth.

Deliveries that had been recorded as caesareans even though they had occurred in locations where caesarean sections were implausible – such as homes, dispensaries and health posts – were recoded as vaginal deliveries [112]. The data on deliveries in higher-level facilities were excluded if information on mode of delivery was missing. However, the proportion of deliveries included in a survey that had missing information on mode of delivery never exceeded 3.3% – recorded in a survey in the United Republic of Tanzania in 1996 – and generally fell below 1%. The response rate in each of the surveys that we investigated was at least 90%.

We used three types of analysis. All analyses took account of sampling weights, in addition to clustering and stratification where appropriate. First, we calculated caesarean delivery rates by country and survey year. These rates were calculated as percentages of the deliveries that ended in live births – excluding, in multiple births, the deliveries of all but the last born neonates. We tested for time trends in these rates by using a binomial log–linear regression model [113] to calculate annual rates of increase – as crude risk ratios (RRs) per year. Since caesarean sections are no longer a rare outcome in several of the countries that we investigated, odds ratios obtained with logistic regression would have overestimated the RRs. For each study country, annual rates of increase in caesarean deliveries were calculated for all the women and for the women who fell in the two lowest wealth quintiles combined – that is, for the poorest 40% of the women in the country. We also calculated caesarean delivery rates by wealth quintile and survey year within each country.

Finally, we categorized each delivery according to whether the mother lived in a rural or urban area and whether her household's wealth index fell above the national median value – indicating that the mother was "richer" – or below it – indicating that the woman was "poorer". This allowed us to evaluate caesarean delivery rates separately for relatively poor and wealthy urban women and relatively poor and wealthy rural women. All of the data analyses were performed using Stata SE version 12 (StataCorp LP, College Station, United States of America).

2.1.4. Results

Data were available for 80 surveys, which had been conducted in four countries in South Asia, 11 countries in western and central Africa and 11 countries in eastern and southern Africa. The median number of surveys per country was three, with a range of two to four. In the surveys, data on births in the previous 5 years (n = 68), 4 years (*n* = 1) or 3 years (*n* = 11) had been collected. The total sample consisted of 686 789 deliveries – each of which had ended in a live birth – that had occurred between 1985 and 2011.

Table 2.1 and Figure 2.1 present the caesarean delivery rates recorded in the 3 to 5 years preceding each survey, by country and survey year, and the corresponding annual rates of increase. Statistically significant increases in caesarean delivery rates – varying from 2 to 19% per year – were observed in seven of the 11 study countries in western and central Africa, nine of the 11 study countries in eastern and southern Africa and all four of the study countries in South Asia. However, only 12 of the study countries – three in western and central Africa, five in eastern and southern Africa and the four in South Asia – showed evidence of an increase in caesarean delivery rates among the two lowest wealth quintiles. The crude RRs for the annual rates of increase in these 12 countries varied from 1.03 in Madagascar to 1.30 in Bangladesh. We were not able to calculate an annual rate of increase for the poorest 40% in Chad because caesarean deliveries had only been reported in one year in the surveys from Chad that we investigated.

Caesarean delivery rates were found to be very low in the sub-Saharan African study countries. In the most recent survey for each country, for example, 10 of the study countries in sub-Saharan Africa had national rates of less than 2% and only five countries – Ghana, Kenya, Lesotho, Rwanda and Uganda – had national rates of more than 5%. The corresponding rates recorded in the most recent survey in each of three of the study countries in South Asia were much higher. Nepal was the only South Asian study country in which the most recently recorded, national, caesarean delivery rate was less than 5%.

Figure 2.1 Caesarean rates by country and DHS survey year in Eastern & Southern Africa

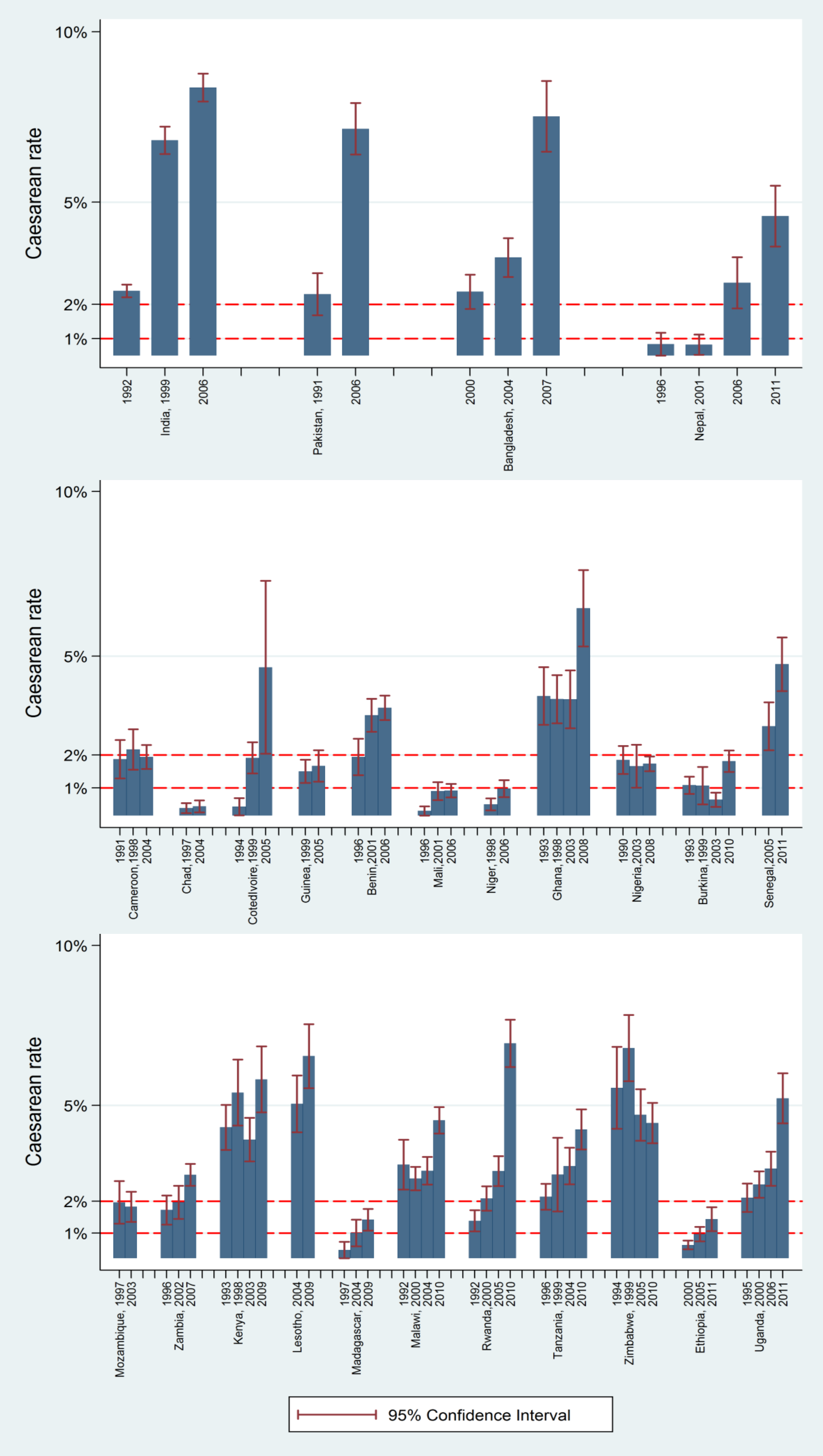


Table 2.1 Caesarean delivery rates and mean annual increases in such rates, by country and survey year, South Asia and sub-Saharan Africa

Country	Survey period								Annual increase[b] (95% CI) among:	
	Before 1997		1997–2001		2002–2006		2007–2011		All women	Women in poorest two quintiles
	Year	Rate[a] (%)	Year	Rate[a] (%)	Year	Rate[a] (%)	Year	Rate[a] (%)		
South Asia										
Bangladesh	–	–	2000	2.37	2004	3.38	2007	7.52	1.19 (1.16–1.22)	1.30 (1.19–1.42)
India	1992	2.40	1999	6.82	2006	8.37	-	-	1.09 (1.08–1.10)	1.09 (1.07–1.11)
Nepal	1996	0.83	2001	0.82	2006	2.63	2011	4.59	1.15 (1.12–1.17)	1.13 (1.05–1.21)
Pakistan	1991	2.30	–	–	2006	7.15	–	–	1.08 (1.06–1.10)	1.11 (1.05–1.17)
West and Central Africa										
Benin	1996	1.94	2001	3.20	2006	3.43	–	–	1.05 (1.03–1.07)	1.03 (0.99–1.08)
Burkina Faso	1993	1.08	1999	1.06	2003	0.64	2010	1.81	1.04 (1.02–1.06)	1.03 (0.98–1.09)
Cameroon	1991	1.87	1998	2.17	2004	1.94	–	–	1.00 (0.97–1.03)	0.94 (0.87–1.01)
Chad	–	–	1997	0.38	2004	0.44	–	–	0.99 (0.91–1.06)	–[c]
Côte d'Ivoire	1994	0.42	1999	1.91	2005	4.66	–	–	1.18 (1.12–1.23)	1.17 (1.09–1.26)
Ghana	1993	3.79	1998	3.69	2003	3.69	2008	6.46	1.04 (1.02–1.06)	1.06 (1.01–1.10)
Guinea	–	–	1999	1.50	2005	1.66	–	–	1.01 (0.96–1.06)	0.97 (0.84–1.09)
Mali	1996	0.30	2001	0.90	2006	0.91	–	–	1.07 (1.03–1.11)	1.08 (0.99–1.17)
Niger	–	–	1998	0.50	2006	0.97	–	–	1.07 (1.02–1.12)	1.11 (0.95–1.27)
Nigeria	1990	1.85	–	–	2003	1.66	2008	1.73	1.00 (0.98–1.01)	0.94 (0.91–0.97)
Senegal	–	–	–	–	2005	2.87	2011	4.75	1.05 (1.01–1.09)	1.11 (1.04–1.17)
Eastern and Southern Africa										
Ethiopia	–	–	2000	0.63	2005	0.97	2011	1.44	1.08 (1.05–1.11)	1.10 (0.99–1.21)
Kenya	1993	4.31	1998	5.40	2003	3.93	2009	5.81	1.02 (1.00–1.03)	1.00 (0.97–1.03)
Lesotho	–	–	–	–	2004	5.05	2009	6.54	1.06 (1.02–1.10)	1.02 (0.95–1.09)
Madagascar	–	–	1997	0.47	2004	1.01	2009	1.42	1.07 (1.03–1.12)	1.02 (0.91–1.13)
Malawi	1992	3.14	2000	2.71	2004	2.95	2010	4.53	1.03 (1.02–1.05)	1.03 (1.01–1.05)
Mozambique	–	–	1997	1.96	2003	1.83	–	–	1.00 (0.93–1.07)	0.85 (0.62–1.09)

Country	Survey period								Annual increase[b] (95% CI) among:	
	Before 1997		1997–2001		2002–2006		2007–2011		All women	Women in poorest two quintiles
	Year	Rate[a] (%)	Year	Rate[a] (%)	Year	Rate[a] (%)	Year	Rate[a] (%)		
Rwanda	1992	1.39	2000	2.09	2005	2.94	2010	6.94	1.11 (1.10–1.13)	1.12 (1.10–1.15)
Uganda	1995	2.11	2000	2.52	2006	3.02	2011	5.22	1.06 (1.05–1.08)	1.06 (1.03–1.09)
United Republic of Tanzania	1996	2.14	1999	2.83	2004	3.10	2010	4.25	1.05 (1.03–1.07)	1.05 (1.01–1.08)
Zambia	1996	1.73	–	–	2002	1.97	2007	2.82	1.04 (1.02–1.07)	1.07 (1.01–1.12)
Zimbabwe	1994	5.55	1999	6.79	2005	4.70	2010	4.44	0.98 (0.97–0.99)	0.95 (0.92–0.98)

[a] Caesarean delivery rates are expressed as percentages of the deliveries that ended in a live birth, excluding all but the last-born of the neonates delivered in each multiple birth. These rates take into account sampling weights.

[b] 95% confidence intervals are shown in parentheses. They take into account sampling clusters, strata and sampling weights.

[c] In the Demographic and Health Surveys that have been conducted in Chad, only two caesarean deliveries have ever been recorded among women in the lowest two percentiles for wealth, both of them in 1992.

Table 2.2 and Figure 2.2 present the caesarean delivery rates stratified by wealth quintile and survey. The rates were extremely low among the poorest quintile in every survey. In the most recent survey for each country, for example, the caesarean delivery rates among the poorest quintile were less than 1% in 12 of the study countries – all in sub-Saharan Africa – and they were less than 2% in all of the study countries except Lesotho, Malawi, Rwanda, Uganda and Zimbabwe. Caesarean delivery rates among the richest quintile were much higher in all of the study countries but exceeded 15% only in Bangladesh, India and Pakistan.

In the most recent survey for each of 17 of the study countries, caesarean delivery rates increased monotonically from the lowest quintile for wealth to the highest (Table 2.2). In the other nine study countries, the between-quintile variation in the rates was very small. In 10 of the study countries in sub-Saharan Africa – seven in western and central Africa and three in eastern and southern Africa – caesarean delivery rates of less than 1% had been recorded among the poorer 40% or 60% of women. In eight of these countries – Chad, Ethiopia, Guinea, Madagascar, Mali, Mozambique, Niger and Nigeria – the poorer 80% of women had caesarean delivery rates of less than 1%. The poorest quintile in three of the study countries in South Asia had caesarean delivery rates of more than 1%. In Nepal, however, the corresponding rate for the two lowest quintiles for wealth combined was less than 1%. In seven of the eight study countries that had national rates above 5%, the overall rate for the three lowest wealth quintiles combined was less than 5%.

Figure 2.2 Caesarean rates by wealth quintile and DHS survey year in Eastern & Southern Africa

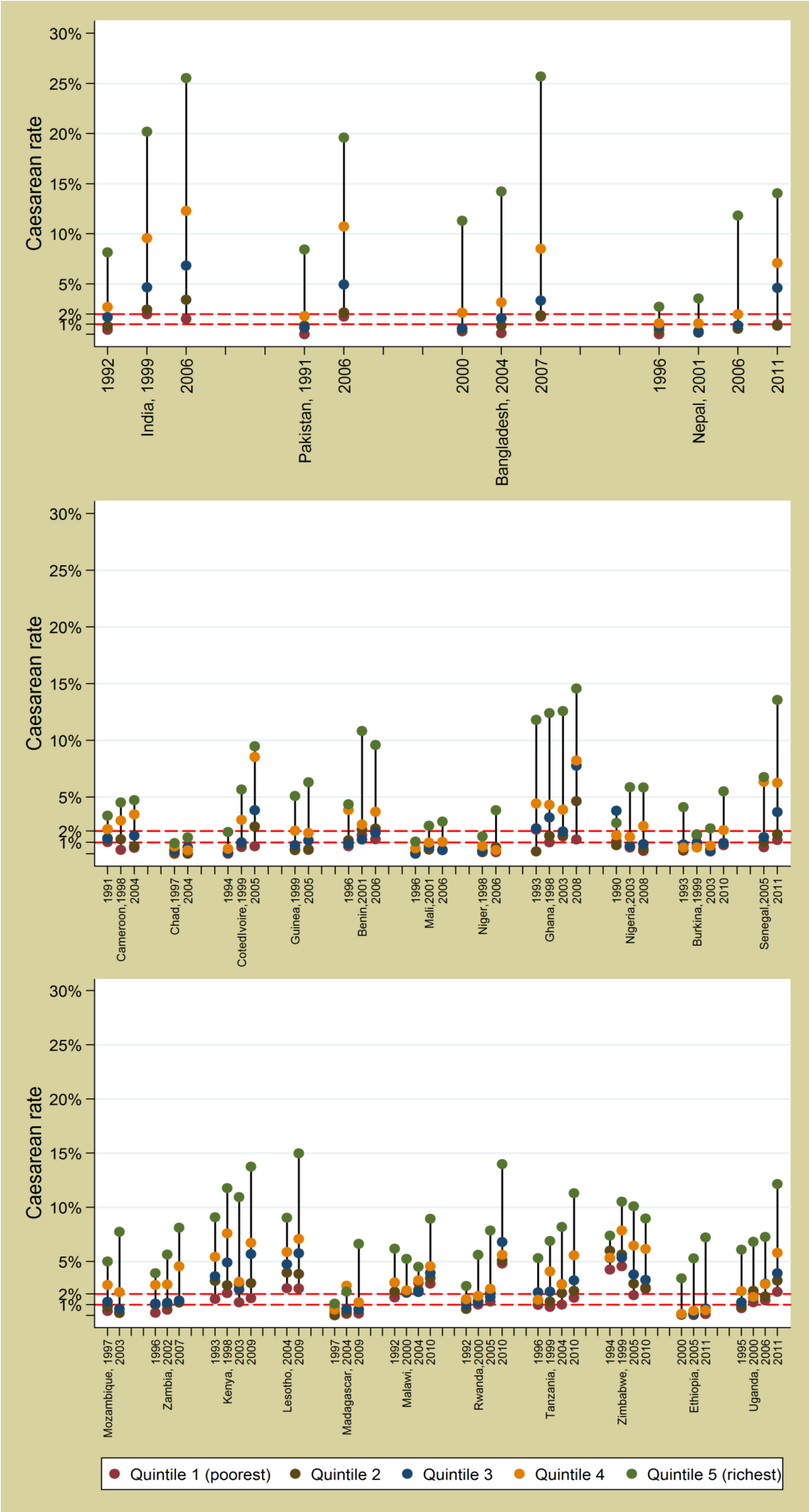


Table 2.2 Caesarean delivery rates by wealth quintile and survey year, South Asia and sub-Saharan Africa

Country and wealth quintile[a]	Caesarean delivery rate[b] (%) in:				Cumulative rate[c] (%)	Quintiles with cumulative rate of:[d]		
	1990–1996	1997–2001	2002–2006	2007–2011		< 1%	< 2%	< 5%
South Asia								
Bangladesh						None	1-2	1–4
1	–	0.26	0.08	1.75	1.75			
2	–	0.46	0.84	1.87	1.81			
3	–	0.58	1.58	3.34	2.28			
4	–	2.13	3.17	8.52	3.71			
5	–	11.31	14.23	25.69	7.52			
India						None	1	1–3
1	0.44	1.97	1.51	–	1.51			
2	0.79	2.43	3.43	–	2.41			
3	1.69	4.67	6.84	–	3.70			
4	2.70	9.57	12.30	–	5.51			
5	8.16	20.18	25.54	–	8.37			
Nepal						1-2	1-2	1–5
1	0.00	0.16	0.80	0.98	0.98			
2	0.42	0.27	0.54	0.85	0.92			
3	0.76	0.17	0.86	4.61	2.05			
4	1.07	1.07	1.97	7.09	3.07			
5	2.72	3.56	11.81	14.04	4.59			
Pakistan						None	1-2	1–4
1	0.00	–	1.75	–	1.75			
2	0.84	–	2.15	–	1.94			
3	0.63	–	4.96	–	2.87			
4	1.79	–	10.75	–	4.58			
5	8.43	–	19.61	–	7.15			
West and Central Africa								
Benin						None	1–3	1–5
1	0.66	1.65	1.28	–	1.28			
2	1.18	2.14	2.21	–	1.72			
3	0.86	1.25	1.85	–	1.76			
4	3.85	2.58	3.70	–	2.23			
5	4.37	10.82	9.59	–	3.43			
Burkina Faso						1–3	1–5	1–5
1	0.28	0.61	0.20	0.74	0.74			
2	0.28	1.63	0.43	0.95	0.85			
3	0.81	0.96	0.21	0.90	0.86			
4	0.54	0.55	0.70	2.07	1.16			
5	4.10	1.71	2.23	5.51	1.81			
Cameroon						1–3	1–5	1–5
1	1.03	0.34	0.52	–	0.52			
2	1.36	1.28	0.65	–	0.58			
3	1.32	2.91	1.60	–	0.89			
4	2.18	2.91	3.46	–	1.44			
5	3.36	4.52	4.72	–	1.94			
Chad						1–5	1–5	1–5
1	–	0.00	0.00	–	0.00			
2	–	0.13	0.00	–	0.00			
3	–	0.31	0.56	–	0.19			
4	–	0.64	0.29	–	0.22			
5	–	0.92	1.44	–	0.44			

Country and wealth quintile[a]	Caesarean delivery rate[b] (%) in:				Cumul-ative rate[c] (%)	Quintiles with cumulative rate of:[d]		
	1990–1996	1997–2001	2002–2006	2007–2011		< 1%	< 2%	< 5%
Côte d'Ivoire						1	1-2	1–5
1	0.00	0.59	0.66	–	0.66			
2	0.12	0.87	2.39	–	1.55			
3	0.12	1.01	3.83	–	2.24			
4	0.43	3.00	8.54	–	3.79			
5	1.92	5.66	9.47	–	4.66			
Ghana						None	1	1–3
1	2.12	1.00	1.53	1.24	1.24			
2	0.21	1.57	1.61	4.64	2.82			
3	2.23	3.20	1.96	7.77	4.22			
4	4.42	4.32	3.88	8.22	5.12			
5	11.80	12.40	12.58	14.57	6.46			
Guinea						1–4	1–5	1–5
1	–	0.40	0.33	–	0.33			
2	–	0.31	0.38	–	0.35			
3	–	0.75	1.15	–	0.60			
4	–	2.04	1.82	–	0.86			
5	–	5.10	6.29	–	1.66			
Mali						1–5	1–5	1–5
1	0.08	0.39	0.35	–	0.35			
2	0.00	0.36	0.32	–	0.33			
3	0.00	0.61	0.31	–	0.33			
4	0.48	0.98	1.04	–	0.50			
5	1.06	2.46	2.83	–	0.91			
Niger						1–5	1–5	1–5
1	–	0.13	0.14	–	0.14			
2	–	0.14	0.56	–	0.34			
3	–	0.27	0.34	–	0.34			
4	–	0.68	0.32	–	0.34			
5	–	1.52	3.84	–	0.97			
Nigeria						1–4	1–5	1–5
1	1.07	–	0.55	0.25	0.25			
2	0.76	–	0.68	0.40	0.32			
3	3.78	–	0.68	0.84	0.47			
4	1.62	–	1.48	2.43	0.89			
5	2.73	–	5.87	5.85	1.73			
Senegal						None	1-2	1–5
1	–	–	0.58	1.20	1.20			
2	–	–	1.02	1.71	1.45			
3	–	–	1.46	3.68	2.11			
4	–	–	6.34	6.25	3.07			
5	–	–	6.77	13.56	4.75			
Eastern and Southern Africa								
Ethiopia						1–4	1–5	1–5
1	–	0.06	0.03	0.13	0.13			
2	–	0.08	0.28	0.44	0.28			
3	–	0.13	0.15	0.64	0.40			
4	–	0.15	0.43	0.49	0.42			
5	–	3.42	5.28	7.21	1.44			
Kenya						None	1	1–4
1	1.52	2.07	1.21	1.59	1.59			
2	3.21	2.80	2.92	2.98	2.22			
3	3.62	4.90	2.42	5.69	3.22			

Country and wealth quintile[a]	Caesarean delivery rate[b] (%) in:				Cumulative rate[c] (%)	Quintiles with cumulative rate of:[d]		
	1990–1996	1997–2001	2002–2006	2007–2011		< 1%	< 2%	< 5%
4	5.41	7.59	3.11	6.70	3.98			
5	9.07	11.75	10.94	13.74	5.81			
Lesotho						None	None	1–4
1	–	–	2.51	2.50	2.50			
2	–	–	3.94	3.83	3.12			
3	–	–	4.74	5.75	3.92			
4	–	–	5.87	7.07	4.73			
5	–	–	9.04	14.97	6.54			
Madagascar						1–4	1–5	1–5
1	–	0.35	0.14	0.17	0.17			
2	–	0.00	0.32	0.53	0.34			
3	–	0.67	0.61	0.59	0.41			
4	–	0.54	2.76	1.20	0.57			
5	–	1.09	2.22	6.61	1.42			
Malawi						None	None	1–5
1	1.66	2.23	3.04	2.93	2.93			
2	2.20	2.09	2.35	3.45	3.19			
3	3.03	2.16	2.16	3.92	3.43			
4	3.05	2.32	3.23	4.53	3.68			
5	6.16	5.22	4.50	8.93	4.53			
Mozambique						1–4	1–5	1–5
1	–	0.41	0.28	–	0.28			
2	–	0.81	0.23	–	0.26			
3	–	1.27	0.59	–	0.37			
4	–	2.82	2.15	–	0.72			
5	–	4.98	7.73	–	1.83			
Rwanda						None	None	1-2
1	1.32	1.01	1.27	4.80	4.80			
2	0.60	1.30	2.13	5.08	4.93			
3	1.01	1.24	1.70	6.78	5.50			
4	1.50	1.80	2.48	5.61	5.53			
5	2.72	5.59	7.84	13.99	6.94			
Uganda						None	None	1–4
1	0.68	1.22	1.41	2.19	2.19			
2	0.83	2.27	1.76	3.21	2.69			
3	1.21	1.63	2.94	3.91	3.07			
4	2.26	1.71	2.89	5.79	3.66			
5	6.08	6.80	7.27	12.14	5.22			
United Republic of Tanzania						None	1-2	1–5
1	0.97	0.80	0.99	1.64	1.64			
2	1.38	1.28	2.06	2.28	1.98			
3	2.14	2.21	2.88	3.24	2.40			
4	1.46	4.07	2.87	5.57	3.09			
5	5.29	6.88	8.19	11.30	4.25			
Zambia						None	1–4	1–5
1	0.24	–	0.53	1.20	1.20			
2	1.01	–	1.01	1.22	1.21			
3	1.10	–	1.18	1.37	1.26			
4	2.82	–	2.86	4.53	1.99			
5	3.89	–	5.63	8.12	2.82			
Zimbabwe						None	None	1–5
1	4.24	4.54	1.87	2.46	2.46			
2	5.98	5.63	2.94	2.57	2.51			
3	5.31	5.35	3.80	3.30	2.75			

Country and wealth quintile[a]	Caesarean delivery rate[b] (%) in:				Cumul-ative rate[c] (%)	Quintiles with cumulative rate of:[d]		
	1990–1996	1997–2001	2002–2006	2007–2011		< 1%	< 2%	< 5%
4	5.34	7.85	6.47	6.15	3.61			
5	7.39	10.52	10.08	8.95	4.44			

[a] The wealth quintile to which each surveyed household belonged was categorized as 1, 2, 3, 4 or 5. Quintile 1 comprised the poorest 20% of households and Quintile 5 comprised the richest 20%.

[b] Caesarean delivery rates are expressed as percentages of deliveries that ended in a live birth, excluding all but the last-born of the neonates delivered in each multiple birth. They take into account sampling weights.

[c] The caesarean delivery rate – in this and any poorer quintiles – in the most recent survey included in the analysis.

[d] Values from the most recent survey included in the analysis.

In the most recent surveys, caesarean delivery rates were highest among the “urban richer” in all 26 study countries and lowest among the “rural poorer” in 18 of the study countries (Table 2.3 and Figure 2.3). In all four study countries in South Asia, the caesarean delivery rate was higher among the “rural richer” than among the “urban poorer”; the absolute difference ranged from 2.6% in Nepal (95% CI: −2.0 to 7.2) to 10.2% in Bangladesh (95% CI: 7.7 to 12.7). Of the study countries in sub-Saharan Africa, however, only Ghana and Kenya had markedly higher caesarean delivery rates in the “rural richer” than in the “urban poorer” – with absolute differences of 5.0% (95% CI: −0.3 to 10.3) and 6.7% (95% CI: 3.0 to 10.4), respectively. In six western African and two eastern African countries, the rural women – whether “richer” or “poorer” – had caesarean delivery rates of less than 2%.

Figure 2.3 Caesarean rates by residence and wealth in South Asia and sub-Saharan Africa (most recent survey)

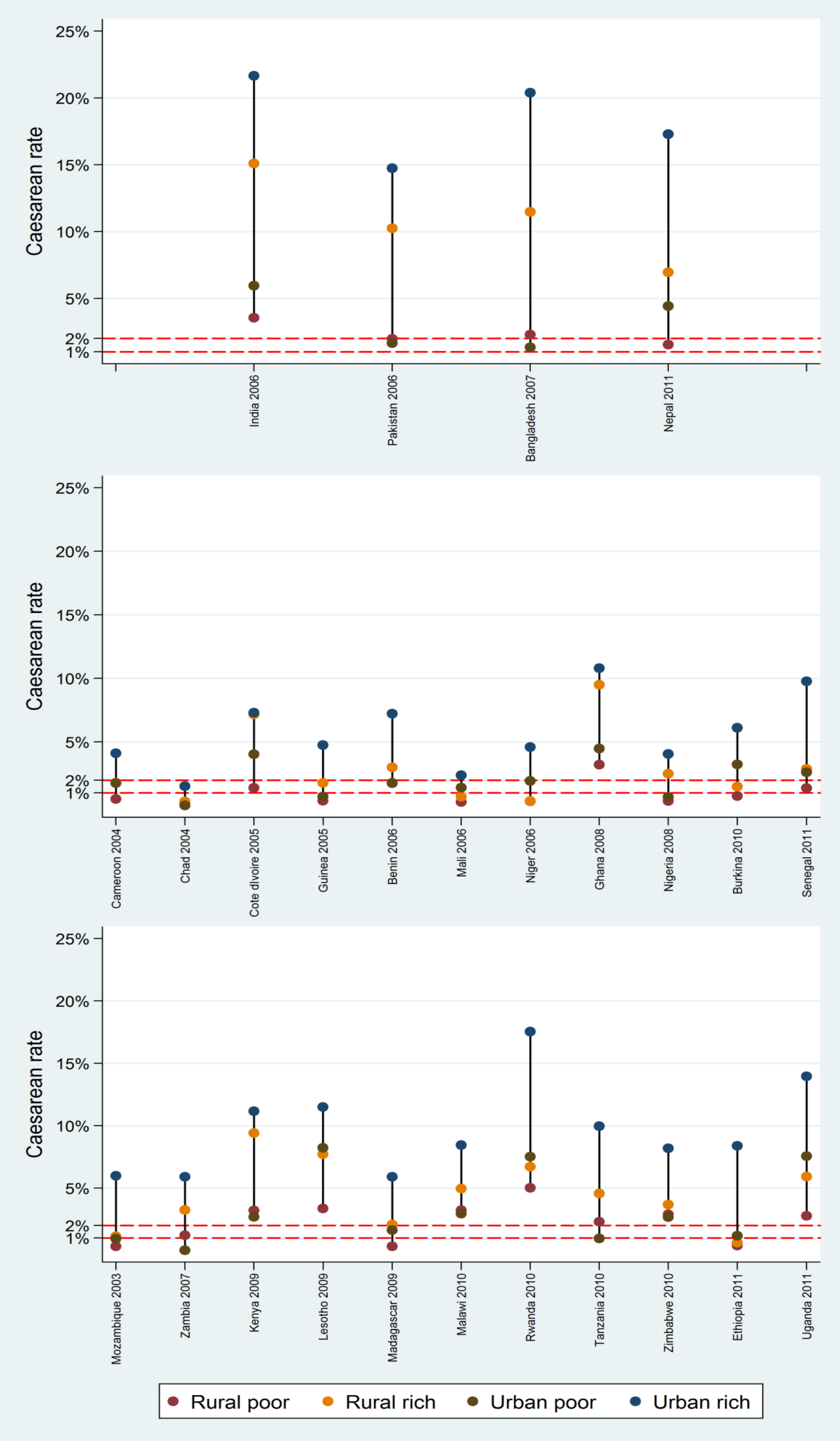


Table 2.3 Caesarean delivery rates among richer and poorer women in urban and rural areas, South Asia and sub-Saharan Africa

Country	Caesarean rate[a]				Absolute difference[b] (95% CI)	
	Rural poorer	Rural richer	Urban poorer	Urban richer		
South Asia						
Bangladesh	2.29	11.52	1.32	20.37	10.19	(7.73 to 12.65)
India	3.59	15.23	5.99	21.75	9.25	(7.44 to 11.05)
Nepal	1.51	7.03	4.40	17.24	2.63	(–1.97 to 7.23)
Pakistan	2.00	10.50	1.65	14.97	8.85	(6.53 to 11.18)
West and Central Africa						
Benin	1.76	3.00	1.78	7.23	1.22	(0.26 to 2.19)
Burkina Faso	0.76	1.48	3.23	6.11	–1.75	(–3.35 to –0.16)
Cameroon	0.51	1.79	1.75	4.11	0.04	(–1.46 to 1.53)
Chad	0.18	0.33	0.00	1.53	0.33	(–0.19 to 0.84)
Côte d'Ivoire	1.39	7.17	4.04	7.30	3.13	(–9.19 to 15.44)
Ghana	3.22	9.50	4.49	10.80	5.01	(–0.27 to 10.30)
Guinea	0.38	1.77	0.71	4.76	1.06	(–0.71 to 2.83)
Mali	0.27	0.69	1.41	2.39	–0.72	(–2.23 to 0.79)
Niger	0.34	0.37	1.93	4.60	–1.57	(–5.66 to 2.53)
Nigeria	0.35	2.49	0.67	4.05	1.82	(0.99 to 2.66)
Senegal	1.37	2.89	2.62	9.77	0.28	(–2.15 to 2.70)
Eastern and Southern Africa						
Ethiopia	0.39	0.63	1.17	8.38	–0.54	(–2.20 to 1.12)
Kenya	3.21	9.41	2.69	11.16	6.72	(3.02 to 10.43)
Lesotho	3.35	7.71	8.23	11.50	–0.52	(–12.36 to 11.32)
Madagascar	0.32	2.08	1.62	5.89	0.46	(–1.87 to 2.80)
Malawi	3.23	4.96	2.94	8.44	2.02	(–1.31 to 5.34)
Mozambique	0.32	1.14	0.94	5.99	0.20	(–1.10 to 1.51)
Rwanda	5.01	6.70	7.51	17.53	–0.81	(–5.72 to 4.09)
Uganda	2.76	5.91	7.55	13.96	–1.63	(–8.02 to 4.76)
United Republic of Tanzania	2.30	4.55	0.95	9.96	3.60	(1.70 to 5.51)
Zambia	1.22	3.25	0.00	5.90	3.25	(1.79 to 4.70)
Zimbabwe	2.88	3.68	2.67	8.19	1.01	(–2.72 to 4.74)

[a] Caesarean delivery rates are expressed as percentages of deliveries that ended in a live birth, excluding all but the last-born of the neonates delivered in each multiple birth. They take into account sampling weights; confidence intervals additionally take into account clustering and stratification. The data presented come from the most recently published Demographic and Health Survey in each country. Women who lived in households that had wealth indices that fell above the national median value were considered to be "richer" whereas other women were categorized as "poorer".

[b] The caesarean delivery rate for the rural richer minus the corresponding rate for the urban poorer.

2.1.5. Discussion

Although caesarean delivery rates have been rising in almost all of the countries that we investigated in South Asia and sub-Saharan Africa, they remain astonishingly low. In our analysis, 18 countries still had national rates of less than 5% recorded in their most recent surveys, and none of the study countries had a national rate above 10%. Caesarean sections were extremely rare among the poor: they were below 1% for the poorest 20% of the population in each of 12 countries, the poorest 40% in 11 countries and the poorest 80% in eight countries. They fell below 2% for the poorest 20% in each of 21 countries. Over the study period, the study countries in South Asia experienced a much greater rise in caesarean delivery rates than the countries that we investigated in sub-Saharan Africa. Nevertheless, in the most recent surveys that we included in our analysis, the rates among the poorest 20% of the populations remained below 2% in all four of the South Asian study countries.

The low rates of caesarean delivery in sub-Saharan Africa are presumably a reflection of very low levels of access to caesarean sections, which are themselves associated with extremely poor access to emergency surgical care in general [114, 115]. A recent study in Ghana, Kenya, Rwanda, Uganda and the United Republic of Tanzania – five countries included in our study – revealed massive gaps in the infrastructure for emergency surgical care [116]. Fewer than 50% of the hospitals surveyed had dependable running water and electricity, and only 19–50% of the hospitals provided 24-hour emergency care [116]. Countries in sub-Saharan Africa generally have few skilled workers able to perform surgery – including caesarean sections – and most of their qualified doctors live in urban areas [115-117]. In the present study, caesarean delivery rates were extremely low among both the richer and poorer women who lived in rural areas, where structural and workforce constraints may be the most important barriers to access.

A household's ability to pay for the surgery is thought to be an important determinant of caesarean deliveries [118, 119]. The cost of emergency caesarean sections can be catastrophic for households [118, 119]. Although user fee exemptions have been one of the key strategies to increase access to delivery care in sub-Saharan Africa [120], their impact on caesarean delivery rates has yet to be rigorously evaluated. While such fee exemptions may have contributed to the rises seen in caesarean delivery rates in countries such as Ghana and Senegal [121, 122], such rises cannot be categorically attributed to the exemptions. Furthermore, a household's ability to pay for surgery may not be the main barrier to caesarean sections in settings where the necessary health facilities are sparsely distributed [123].

The rapid rises seen in caesarean delivery rates in South Asia over our study period are somewhat surprising, given that most births in this region still take place at home. In the latest DHSs for Bangladesh, India, Nepal and Pakistan, for example, only 15%, 39%, 37% and 35% of the recorded deliveries occurred in a health facility, respectively (data not shown). However, many of these deliveries probably took place in private hospitals [123], where obstetricians and general practitioners are available to lead delivery care and the incentives to perform caesarean sections may be relatively greater [124]. This may explain why such large proportions of the women who delivered in health facilities in Bangladesh, India, Nepal and Pakistan – 51%, 22%, 12% and 20%, respectively – had caesarean sections (data not shown). In the present analysis, caesarean delivery rates in the richest quintile were found to be more than 15% in Bangladesh, India and Pakistan, and the rates among the “rural richer” in all four study countries in South Asia were found to be substantially higher than those among the “urban poorer”.

In every country that we investigated, caesarean delivery rates among the women in the richest quintile were much higher than the rates seen in the poorest quintile. This difference was particularly noticeable in Bangladesh, India and Pakistan, where the poorest quintile probably receives fewer caesarean sections than are indicated, while the richest quintile receives too many – increasing maternal and neonatal morbidity [125]. In general – as postulated by the “inverse equity hypothesis” – the wealthy are more likely to adopt new medical interventions than the poor, often leading to increased health inequalities – at least in the short term [126]. In South Asia, however, the richest mothers appear to be receiving more caesarean sections than are warranted, with potentially adverse effects.

Our analysis has several limitations. First, we only had data for 26 of the 48 countries in sub-Saharan Africa and South Asia that were included in the “Countdown to 2015” initiative [110]. Second, the dates of the most recently published survey varied substantially between countries, and some countries may have made more progress since their most recent survey. The last available survey data for seven of the 11 study countries in western and central Africa were collected before 2007. Third, the caesarean delivery rates estimated in household surveys – generally from the statements of women of reproductive age – tend to be higher than the rates estimated from the records of the corresponding health facilities where caesarean deliveries may be performed [112]. However, the facility-derived estimates tend to fall within the 95% CIs of the corresponding household survey estimates [112], and there is no strong rationale to consider the facility-based estimates more valid than those obtained from population-based surveys. Validation studies have shown very high sensitivity and specificity (above 99.7%) of maternal self-report in both low- and high-income settings [127, 128], and the DHS provide representative data on caesareans for nearly 90% of births in low- and middle-income countries [129], indicating that they are a strong and valid data source for caesarean rates (particularly after the introduction of data quality checks in the phase 4 and phase 6 questionnaires).

Fourth, the wealth index used in the DHSs has several inherent biases that require careful scrutiny. The type of household assets investigated varies between the surveys, and the wealth index – which represents a household's wealth relative to other households in one particular country at the time of the survey – should not be used to compare absolute levels of wealth between surveys. Other shortcomings of wealth indices have been described in detail in the literature. In brief, monetary measures of wealth (income and consumption) tend to be difficult to estimate in low- and middle-income country settings, and hence asset-based approaches to measuring wealth were introduced [130]. However, wealth indices have been shown to be a poor proxy for consumption expenditure, and it is unclear what underlying concept is measured by a wealth index [131]. In addition, the association between household wealth and residence in an urban or rural area may be complex [132]. Although those who live in urban areas are typically richer than their rural counterparts (as evidenced by the large-scale migration to cities over the last century), the intrinsic meaning of the underlying wealth associated with many assets differs according to the area, and the wealth index may be biased towards urban residents – particularly before the DHS included rural assets such as livestock in the calculation of the wealth index [132]. These limitations imply that the true relationship between wealth and caesarean rates reported in this study may be biased; however, though this indicates that it is difficult to understand how women in various wealth quintiles differ from one another, they do not invalidate the magnitude of differences in caesarean rates or of the unmet need in the study countries.

We used national wealth indices – rather than urban- and rural-specific wealth indices – to enable direct comparisons between the richer and poorer halves of the populations in rural and urban areas. We were unable to analyse caesarean delivery rates according to wealth quintiles separately for urban and rural residents because the sample was too small, particularly in terms of the number of women from "urban poorer" households. Fifth, some women may have contributed more than one birth to the sample. However, restricting the analysis to only one birth per woman did not alter our findings (data not shown). Lastly, when computing annual rates of increase, we assumed that caesarean delivery rates increased in log–linear fashion. Our conclusions were, however, unaltered when RRs for the increases were calculated by comparing one survey to the next (data not shown).

Programmes to reduce maternal and neonatal mortality should have clear indicators to identify need, monitor implementation and change the course of action, as required [7]. There has been a reluctance to include caesarean delivery rates as a core indicator for the monitoring of safe motherhood programmes, partly because the thresholds for "acceptable" or target rates are so uncertain, and partly because such an indicator may be perceived as promoting the unnecessary medicalization of obstetric care. However, this reluctance is unjustified, particularly when very low thresholds are set for the minimum rate. While caesarean delivery rates cannot be a substitute for the measurement of levels of maternal mortality, caesarean rates among the poor should be a key indicator for measuring progress towards achieving MDG 5 [133]. In the post-2015 health agenda – where the focus is shifting towards measuring the coverage for essential interventions – rates of caesarean delivery among the poor will be critical indicators of access to emergency obstetric care. In addition, as general childhood mortality is reduced, neonatal deaths become relatively more important and access to caesarean sections – when indicated to save the fetus – increases in relative importance as well. Although estimates of the caesarean delivery rate required for indications related to the fetus are imprecise [29], this rate is unlikely to be less than 5% of all births.

Despite the encouraging progress made in increasing national rates of caesarean delivery, large sections of the population in sub-Saharan Africa still lack access to life-saving caesarean sections, and women and children – particularly poor women and their children – are dying as a consequence. Improvements in access to caesarean sections will require massive investments in health system strengthening, particularly in terms of addressing shortages in the health workforce and the infrastructure gaps in rural hospitals [134]. The human resource challenge could be partly addressed by allowing clinical officers to perform caesarean deliveries [135], although the sustainability of this strategy when implemented on a large scale remains uncertain.

However, as long as hospitals lack the core infrastructure to perform surgery safely – including access to water and electricity – one cannot begin to address the emergency obstetric needs of pregnant women in sub-Saharan Africa.

2.1.6. Acknowledgments

We thank the Pelotas Equity Center for help in preparing the datasets and the Department of Infectious Disease Epidemiology at the London School of Hygiene & Tropical Medicine for input on the statistical analyses.

2.1.7. Funding

This study was funded by the Bill & Melinda Gates Foundation, The World Bank and the Governments of Australia, Brazil, Canada, Norway, Sweden and the United Kingdom of Great Britain and Northern Ireland. FC was funded by a PhD studentship from the United Kingdom's Economic and Social Research Council, via grant ES/I903224/1.

2.2. Trends in caesarean rates by maternal education

There are concerns with potential misclassification of wealth at the national level based on asset indices [130], and the analysis of caesarean rates was repeated stratified according to maternal education, in order to assess whether the observed patterns are consistent to those observed across wealth quintiles. Caesarean rates for each educational level are presented for each country and survey in **Appendix B: Caesarean rates according** to maternal education. Caesarean rates in all countries were very low among women with no education (below 1% in 12 of the 26 study countries, and below 2% in 17 countries), and they were over 10% among women who had completed secondary school in all but five countries. Trends in caesarean rates according to education were therefore consistent with those observed across wealth quintiles, suggesting that the analysis by wealth is appropriate at the national level.

2.3. Conclusion

Caesarean rates have been increasing in most countries in sub-Saharan Africa and South Asia included in this analysis. Despite the observed increase, caesarean rates remain low in sub-Saharan Africa (below 5% in 17 sub-Saharan countries as well as Nepal). Caesarean rates were extremely low among the poorest 20% and women with no education in most countries and eight countries showed a pattern of large-scale deprivation in access to caesareans, with caesarean rates below 1% among all except the richest quintile. Rates below 1-2% are believed to indicate that women are dying because of lack of access to surgery [30, 48, 97, 98], however this assumption has not been validated and will be discussed in more detail in later chapters.

Chapter 3. Obstetricians' opinions of the optimal caesarean rate

Chapter 3 addresses the second objective of this thesis by presenting results from a global survey of doctors performing caesarean sections on their opinions of the optimal caesarean rate. The concept of optimal caesarean rates was introduced in chapter 1 and it is not repeated in this chapter, where I focus on the definition of optimal caesarean rates used in this study.

To the best of my knowledge, this is the first study to examine the variation in opinions of the optimal caesarean rate at the population level and within specific categories of deliveries, and the variation according to national caesarean rates in providers' country of practice.

This chapter begins by presenting the methods used to conduct this study. It subsequently describes the reported optimal caesarean rate for all deliveries, for the whole sample and stratified according to respondents' characteristics, as well as reported optimal rates among 26 clinical and reproductive categories of deliveries.

3.1. Introduction

The concept of optimal caesarean rates was introduced in chapter 1 (section 1.3.1), as well as its relevance for measuring the unmet need for caesareans. The review of evidence from ecological studies did not identify a clear minimum caesarean rate necessary to achieve low maternal and perinatal mortality. The evidence for the widely cited WHO 5-15% recommendation of the optimal caesarean rate is unclear, and no study has sought to determine the extent to which opinions of the optimal caesarean rate vary between obstetric care providers throughout the world. One survey of South African obstetricians conducted in 1992 found that the "ideal" rate was considered to be 20% among private providers and 16% among public providers [40], though the variation in responses was not explored. In particular, opinions of the optimal caesarean rate may vary from country to country: a large variation exists in national caesarean rates worldwide, from 1.4% of all deliveries in Niger in 2012 to 52.3% in Brazil in 2010 [2]. Differences of this magnitude are unlikely to be caused exclusively by different risk profiles or access to caesareans across countries, and they may be partly explained by cultural differences in the perceived appropriateness of caesareans in childbirth.

3.1.1. Objectives

The objective of this study was to gather the opinions on the optimal caesarean rate among obstetric care providers, for all deliveries and among specified groups of deliveries.

Specific objectives were:

1) To determine the extent of variation in opinions of the optimal caesarean rate among doctors who perform caesareans, in specified obstetric and reproductive groups of deliveries; and
2) To assess whether reported optimal rates vary according to the national caesarean rate in respondents' country of practice.

3.2. Methods

3.2.1. Study definition of optimal caesarean rates

As outlined in chapter 1, the concept of "optimal" caesarean rates is not always clearly defined. The percentage of caesarean deliveries considered optimal depends on whether both maternal and fetal outcomes are considered, and whether rates are to be optimised for averting morbidity as well as mortality. In the context of this study, I defined the optimal caesarean rate as that which minimised the risk of maternal and perinatal mortality and morbidity. An inclusive definition was thought to be the most relevant for the purposes of this survey because, as well as encompassing a larger disease burden, obstetricians generally perform caesareans to avert morbidity and with consideration for fetal as well as maternal outcomes.

3.2.2. Study design and population

I designed a cross-sectional online survey to collect doctors' opinions of the optimal caesarean rate. In high- and middle-income countries, caesareans are predominantly performed by obstetricians; in low-income countries however, a large proportion of caesareans are performed by non-specialist medical doctors, particularly in sub-Saharan Africa [136, 137]. Accordingly, the target study population consisted of all medical doctors worldwide who have performed caesareans in the last five years. These are collectively referred to as “obstetricians” throughout this chapter.

Non-physician clinicians perform a substantial proportion of caesareans in some countries of sub-Saharan Africa, including Malawi, Mozambique, and Tanzania [136, 138]. However, their training and scope of responsibilities varies substantially from country to country [139]. I decided to restrict the sample to medical doctors in order to ensure standardisation of respondents across countries.

3.2.3. Questionnaire development

I performed a literature search to identify any previous surveys of obstetricians' opinions of caesarean rates, by using the keywords “survey”, “obstetrician” and “caesarean” in a PubMed search. One survey of obstetricians in South Africa was identified, which asked respondents to report the “ideal” caesarean rate [40], though the wording of the question was not included in the article. One unpublished survey was also identified, asking experts for their opinion on “plausible” rates of emergency caesareans; this tool was used to help develop the wording of the questions [140]. Fifteen of 24 respondents in this survey answered that a “plausible range” could be established, and there was wide variation in their suggestions (from 1-3% to 5-20%).

I developed a questionnaire consisting of three sections. The first section collected background information from participants, including respondent's age (20-29, 30-39, 40-49, 50-59, 60 or older), gender (male, female), occupation (obstetrician, other clinical doctor, researcher), facility type (public only, private for-profit only, private not-for-profit only, mixed private, mixed public-private), facility level primary care, district, regional, national/university, other/private), and facility caesarean rate (0-14%, 15-29%, 30-49%, ≥50%). The second section asked respondents to report the optimal caesarean rate for specified categories of deliveries in 10% intervals (0%, 1-10%, 11-20% … 91-100%). In the final section respondents were asked to report the optimal caesarean rate for all deliveries in free text form, which allowed them to report an optimal rate or range of rates, as well as to qualify their response with text.

The draft questionnaire was piloted among 13 medical doctors who were MSc students at the London School of Hygiene and Tropical Medicine between 26th June and 5th July 2013, including two obstetricians. Respondents for the pilot were fluent in English and came from ten different countries (Australia, Cameroon, France, Germany, Malta, Nigeria, Portugal, United Kingdom, United States, and Taiwan). The objectives of the piloting were to refine the wording of the question in order to convey the study definition of “optimal caesarean rates”, and to select the categories of deliveries and order them within the questionnaire, taking into consideration the time taken to fill out the questionnaire online.

Wording of the question

Face validity – the extent to which a question subjectively conveys its intended meaning – was assessed during the piloting to ensure that the study definition of “optimal caesarean rates” was communicated clearly to respondents. Several formulations of the question were tested in an iterative process, by altering the wording based on a respondent’s feedback before the next pilot respondent. For each new proposed wording, the pilot respondent was presented with the new and previous wordings of the question and asked which corresponded more closely to the study definition of optimal caesarean rates.

The question was worded in the draft questionnaire as “For each of the following delivery characteristics, how likely would you be to recommend a caesarean for optimal maternal and fetal outcomes?” The formulation “for optimal maternal and fetal outcomes” communicated the fact that both morbidity and mortality was considered, for both mother and baby, in keeping with the study definition. It also relied on respondents’ own judgment about how to weigh maternal and fetal outcomes in the balance of optimal outcomes, in an attempt to replicate clinical practice. The wording was altered to convey the fact that the question referred to the population (rather than individual) level: it was changed to “Of all deliveries with [X characteristic], how likely…?” and then to “Of 1000 women with [X characteristic], how likely…?”

By the same process, the original wording of “how likely would you be to recommend a caesarean for optimal maternal and fetal outcomes?” was changed to “what proportion should receive a caesarean for optimal maternal and fetal outcomes?” after it appeared that certain respondents understood “recommend” to imply planned caesareans only (rather than any caesarean). The final wording for the question was therefore chosen as “Of 1000 women with the following characteristic, what proportion should receive a caesarean for optimal maternal and fetal outcomes?”

Selection of delivery categories

One objective of this study was to compare the variation in obstetricians’ opinions of the optimal caesarean rate across different categories of deliveries. These categories were selected with the aim of including a wide range of hypothesised need for caesareans, from categories thought to have a low need for caesareans to categories thought to have an elevated need (based on clinical experience). The evidence relating to risk factors for elevated need for caesareans was reviewed in chapter 1; in this section, I explain the rationale for including selected categories in this survey.

Four groups of delivery categories were selected for the draft questionnaire: these are presented in Table 3.1, according to hypothesised level of need. Absolute maternal indications (AMIs) are considered to require a caesarean in all cases [30], and are therefore considered as the categories with the highest need for caesarean. Other clinical categories include clinical conditions for which there is thought to be an elevated need for caesareans, but not all women with these complications require a caesarean (such as women with prolonged labour or a single previous caesarean section). Reproductive categories include more distal risk factors for obstetric complications which may be associated with higher need for caesarean: for example, low maternal height is thought to be a risk factor for small pelvic size, and therefore for major cephalopelvic disproportion [141]. The lowest risk category of deliveries is considered to be multipara with a singleton cephalic delivery, no previous caesarean, and no risk factors known at the onset of delivery.

Table 3.1 Categories of deliveries included in draft questionnaire, according to hypothesised level of need for caesarean

Absolute maternal indications *Highest need*	**Other clinical categories** *Higher need*	**Reproductive categories** *Somewhat higher need*	**Low-risk categories** *Lowest need*
• Complete placenta praevia • Antepartum haemorrhage from placental abruption • Uterine rupture • Uterine pre-rupture • Transverse/oblique lie • Face or brow presentation • Severe cephalopelvic disproportion	• Breech presentation • All non-cephalic presentations • Prolonged labour (active stage of labour >6hrs) • Previous caesarean section • Twin pregnancy • Eclampsia (convulsions) • Pre-eclampsia (blood pressure >140/90 and ++ proteinuria) • Maternal diabetes (gestational or pre-gestational) • Premature labour (<34 weeks) • Fetal distress during the latent phase of labour • Fetal distress during the active phase of labour • Cord prolapse • Cord around neck	• Birthweight >4,000g (weighed after delivery) • Birthweight <2,500g (weighed after delivery) • Grand multipara (parity ≥6) • Nullipara • Maternal height <150cm / <5"0' • Maternal BMI 25-29.9 kg/m^2 pre-pregnancy • Maternal BMI ≥30 kg/m^2 pre-pregnancy • Maternal history of stillbirth • Maternal history of very early neonatal death (<24hrs of birth) • Maternal age >35	• Multipara, singleton cephalic delivery, no other risk factors known at the onset of labour

The pilot questionnaire took on average 12 minutes to complete, longer than the target completion time of less than 10 minutes. Based on feedback from pilot respondents, five of the 31 categories were removed from the final questionnaire. "Uterine pre-rupture" was taken out because respondents indicated that uterine pre-rupture had the same need for caesarean as uterine rupture, and "all non-cephalic presentations" was removed because individual non-cephalic presentations were included as separate categories. "Fetal distress during the latent phase of labour" and "fetal distress during the active phase of labour" were removed due to the lack of standardised criteria to identify fetal distress. "Cord around neck" was taken out since clinical management depends on whether the condition is diagnosed by antepartum ultrasound, or by manual examination during delivery. Table 3.2 presents the categories of deliveries included in the final version of the survey.

Table 3.2 Categories of deliveries included in final questionnaire, according to hypothesised level of need for caesarean

Absolute maternal indications *Highest need*	**Other clinical categories** *Higher need*	**Reproductive categories** *Somewhat higher need*	**Low-risk categories** *Lowest need*
• Complete placenta praevia • Antepartum haemorrhage from placental abruption • Uterine rupture • Transverse/oblique lie • Face or brow presentation • Severe cephalopelvic disproportion	• Breech presentation • Prolonged labour (active stage of labour >6hrs) • Previous caesarean section • Twin pregnancy • Eclampsia (convulsions) • Pre-eclampsia (blood pressure >140/90 and ++ proteinuria) • Maternal diabetes (gestational or pre-gestational) • Premature labour (<34 weeks) • Cord prolapse	• Birthweight >4,000g (weighed after delivery) • Birthweight <2,500g (weighed after delivery) • Grand multipara (parity ≥6) • Nullipara • Maternal height <150cm / <5”0’ • Maternal BMI 25-30 pre-pregnancy • Maternal BMI >30 pre-pregnancy • Maternal history of stillbirth • Maternal history of early neonatal death (<24hrs of birth) • Maternal age >35	• Multipara, singleton cephalic delivery, no other risk factors known at the onset of labour

Ordering of categories

In the final questionnaire, the order of categories was chosen with the aim of helping respondents think about population-level caesarean rates (rather than the individual-level decision making they usually do in clinical practice). AMIs were placed at the start of the section, as these were thought to be easier to answer and expected to elicit reported optimal rates of 91-100%. The two AMI categories dealing with malpresentation (transverse/oblique lie, and face/brow presentation) were placed immediately before breech presentation, in order to group all non-cephalic presentations together. These were followed by the other clinical categories. The low-risk category of deliveries was placed before reproductive categories, with the aim of having respondents consider the optimal caesarean rate among the lowest need group, which would serve as a minimum benchmark for the other reproductive categories.

The optimal caesarean rate for all deliveries was asked after all groups of deliveries; this ordering was intended to help respondents take into consideration optimal rates for individual categories in their response for the optimal rate at the population level.

Translation

The final version of the questionnaire was translated into French, Portuguese and Spanish. The aim for the survey was to get as large and as diverse a sample as possible, and these languages were chosen due to their inter-regional reach in medical education. Other languages were considered with the aim of reaching respondents in large countries (including Arabic, Hindi and Mandarin); unfortunately, due to resource constraints, it was not possible to translate the questionnaire into these languages.

Online formatting and informed consent

The survey was designed on the online platform SurveyMonkey (https://www.surveymonkey.com). Informed consent was given by respondents by checking a box stating they had understood the information and terms of participation of the survey. Checking the box was required before being able to proceed to the questionnaire. Respondents were able to skip questions and quit the survey at any stage.

The online survey was accessible from 14th August 2013 to 31st January 2014. The final English version of the questionnaire, including the online consent form, can be found in **Appendix C: Optimal Caesarean Rates** Survey questionnaire.

3.2.4. Dissemination strategy

The study population for this survey consisted of obstetricians and medical doctors worldwide who have performed caesarean sections in the last five years. Although it would have been ideal to achieve a representative sample of this population, this was not possible for several reasons. First, there is no sampling frame for this population. While an approximate sampling frame may be constructed for practicing obstetricians by means of registration with a national obstetrics association, membership is not compulsory in all countries and this does not include non-obstetrician doctors (who perform a large proportion of caesareans in sub-Saharan Africa). Second, even if a representative target sample could be selected, there is a strong possibility of selection bias induced by non-response. Indeed, an unknown proportion of this population is not reachable online, particularly among rural practitioners in low-income countries, and even in high-income countries, surveys of medical doctors tend to have low response rates [142-145].

I therefore opted for a multi-pronged approach with the aim of recruiting the largest and most geographically diverse sample possible. The following strategies were used:

a) **Dissemination through national obstetrics societies.** I attempted to contact all 125 national member associations of the International Federation of Gynecology and Obstetrics (FIGO) via email. Three successive attempts were made to contact each association. In the event that electronic contact details were incorrect, attempts were made to find up to three alternate email addresses. I also attempted to contact national obstetrics societies which are not members of FIGO. 110 FIGO member and 4 non-FIGO member national obstetrics associations were contacted by email. Of these, 32 associations agreed to disseminate the survey to their members via email and/or by posting a link to the survey on their website. Table 3.3 lists these national associations and their membership.

Table 3.3 National obstetrics associations which disseminated the survey to their members

WHO region	Country	National obstetrics association name	Members (N)
Africa	Burkina Faso	Societé de Gynécologues et Obstétriciens du Burkina	58
	Ghana	Society of Gynaecologists and Obstetricians of Ghana	Unknown
	Kenya	Kenya Obstetrical and Gynaecological Society	Unknown
	Malawi	Association of Obstetricians and Gynecologists of Malawi	Unknown
	Mozambique	Associação Moçambicana de Obstetras e Ginecologistas	61
	Nigeria	Society of Gynaecology and Obstetrics of Nigeria	754
	Rwanda	Rwanda Society of Obstetricians and Gynecologists	32
	South Africa	South African Society of Obstetricians and Gynaecologists	542
	Sudan	Obstetrical & Gynaecological Society of the Sudan	c.800
	Uganda	Association of Obstetricians and Gynaecologists of Uganda	c.100
Americas	Bolivia	Sociedad Boliviana de Obstetricia y Ginecología	516
	Ecuador	Federación Ecuatoriana de Sociedades de Ginecología y Obstetricia	Unknown
	Haiti	Société Haitienne d'Obstétrique et de Gynécologie	116
	Honduras	Sociedad de Ginecología y Obstetricia de Honduras	Unknown
	Mexico	Federacion Mexicana de Colegios de Obstetricia y Ginecologia	Unknown
Eastern Mediterranean	Lebanon	Lebanese Society of Obstetrics & Gynecology	c.500
Europe	Denmark	Dansk Selskab for Obstetric og Gynaekologi	c.1,000
	Iceland	Icelandic Society of Obstetrics and Gynecology	Unknown
	Luxemburg	Société Luxembourgeoise de Gynécologie et d'Obstétrique	Unknown
	Norway	Norwegian Society for Gynecology and Obstetrics	c.900
	Slovenia	Slovene Association of Gynaecologists and Obstetricians	Unknown
	Spain	Sociedad Espanõla de Ginecología y Obstetricia	Unknown
	Switzerland	Société Suisse de Gynécologie & Obstétrique	Unknown
	Turkey	Turkish Society of Obstetrics and Gynecology	c.4,000
	United Kingdom	Royal College of Obstetrics and Gynaecology	c.12,500
South-East Asia	Nepal	Nepal Society of Obstetricians and Gynaecologists	300
	Thailand	Royal Thai College of Obstetricians and Gynaecologists	c.2,000
Western Pacific	Malaysia	Obstetrical & Gynaecological Society of Malaysia	c.850
	Papua New Guinea	Papua New Guinea Obstetrics and Gynaecology Society	40
	Singapore	Obstetrical & Gynaecological Society of Singapore	320
	Taiwan	Taiwan Association of Obstetrics and Gynecology	Unknown

b) **Dissemination through other maternal health organisations.** Leading organisations in the field of maternal health also helped disseminate the survey to their members, including the White Ribbon Alliance national associations in Bangladesh, Pakistan, Uganda and Zambia, the London School of Hygiene & Tropical Medicine alumni mailing list, as well as the online community forums Health care Information for All by 2015 and Global Health Delivery.

c) **Dissemination to collaborators on studies of maternal and perinatal health**. The survey invitation was disseminated among obstetricians involved in the following studies: the WHO Global Survey on Maternal and Perinatal Health in 24 countries in Latin America, Africa and Asia; the WHO INTERGROWTH-21st study with seven study sites in all global regions; the FEMHealth study of fee exemptions for maternal care in four francophone West African countries; and the WOMAN trial of tranexamic acid for the treatment of postpartum haemorrhage in 26 countries worldwide.

d) **Use of social networking sites**. Online Facebook groups of medical doctors were identified using a keyword strategy ("doctor" in association with each country name), and were contacted to invite participants. An online advert with link to the survey was posted on the Facebook page of 57 groups of obstetricians and medical doctors. Twitter was also used to disseminate the invitation by a series of short messages with a link to the online survey, which could be subsequently shared ("re-tweeted") by other users.

e) **Snowball sampling**. Respondents were encouraged to forward the invitation email to other potential respondents among their colleagues. Professional medical and research contacts with ties to obstetricians were also contacted for help with disseminating the survey among their networks.

3.2.5. Explanatory variables and data sources

The main explanatory variable of interest in this study was the national caesarean rate in the respondents' main country of practice, grouped into four categories (<5%, 5-14.9%, 15-29.9%, ≥30%). I updated the list of national caesarean rates compiled by Gibbons et al. in 2012 [1] with more recent estimates published in the WHO Global

Health Observatory [2], and in Demographic and Health Survey reports [146], where available. National figures were available for 161 countries. The national caesarean rates used in this survey, including the reference year and data source, are presented in **Appendix D: National caesarean rates** and source.

Secondary exposures of interest at the national level included geographical region of practice, which was categorised according to the WHO classification [147], as well as country income level, for which the World Bank classification (low income, lower-middle income, upper-middle income, and high income) was used [148].

3.2.6. Statistical analyses

The median reported optimal caesarean rate for all deliveries and corresponding interquartile range (IQR) was calculated. Where respondents gave an optimal range for all deliveries rather than a single rate (e.g. 15-20%), the interval midpoint was used to calculate the median optimal caesarean rate for the sample (in this example, 17.5%). The optimal caesarean rate for each clinical and reproductive category of deliveries was collected as an interval (e.g. 51-60%), and I therefore calculated the median interval for each delivery category.

I examined the magnitude of variation in optimal rates according to respondents' characteristics by calculating the median optimal caesarean rate stratified according to national caesarean rate and secondary explanatory variables (occupation, geographical region of main experience, country income level, facility type, highest facility level, facility caesarean rate, gender and age). Median optimal rates for each category of deliveries were also calculated for each group of national caesarean rate. I used Kruskal-Wallis one-way analysis of variance tests to investigate differences in opinions of the optimal rate between strata; a non-parametric test was necessary because of the skewness of responses. All analyses were conducted in Stata version 13.

3.3. Results

3.3.1. Sample description

A total of 1,377 respondents accessed the link to the survey, but 320 (23%) questionnaires had blank answers for all the questions on optimal rates and were excluded from the final sample. The final sample included 1,057 medical doctors from

96 countries (Table 3.4). The vast majority of respondents (88%) were obstetricians, with an additional 5% other clinical doctors, and 6% researchers not currently involved in clinical practice. One third of the respondents (34%) had practiced obstetrics primarily in the Americas; the region with the smallest number of respondents was South-East Asia (n=67, 6%). Most (83%) respondents had practiced in countries with a caesarean rate above 15%, while 7% practiced in countries with national rates below 5%. Half (50%) of respondents practiced in public facilities only, 29% in private facilities only, and 19% in both. The highest facility level of practice was national or university hospitals for the majority of respondents (44%), followed by regional hospitals (27%) and private/other facilities (15%). Forty-two percent estimated that the caesarean rate in their facility was between 15-29% of deliveries, and another 30% estimated it to be between 30-49%.

Table 3.4 Description of the sample of survey respondents

Characteristics	Final sample (%)
Total	**1,057**
Occupation	
Obstetrician	932 (88.2)
Other clinical doctor	57 (5.4)
Other (including non-clinical doctor and researcher)	60 (5.7)
Missing	8 (0.8)
Region of main experience in obstetrics	
Africa	147 (13.9)
Americas	364 (34.4)
Eastern Mediterranean	71 (6.7)
Europe	283 (26.8)
South-East Asia	67 (6.3)
Western Pacific	110 (10.4)
Missing	15 (1.4)
National caesarean rate	
<5%	75 (7.1)
5-15%	89 (8.4)
15-30%	489 (46.3)
>=30%	385 (36.4)
Missing	19 (1.8)
Country income level	
Low income	118 (11.2)
Lower middle income	148 (14.0)
Upper middle income	414 (39.2)
High income	362 (34.2)
Missing	15 (1.4)
Facility type	
Public only	525 (49.7)
Private for-profit only	221 (20.9)
Private not-for-profit only	73 (6.9)
Mixed private	13 (1.2)
Mixed public-private	204 (19.3)
Missing	21 (2.0)
Highest facility level of practice	
Primary care	32 (3.0)
District	115 (10.9)
Regional	286 (27.1)
National/University	461 (43.6)
Private/Other	158 (14.9)
Missing	5 (0.5)
Facility caesarean rate	
0-14%	89 (8.4)
15-29%	446 (42.2)
30-49%	315 (29.8)
50%+	174 (16.5)

Characteristics	Final sample (%)
Dont know	23 (2.2)
Missing	10 (0.9)
Gender	
Female	482 (45.6)
Male	560 (53.0)
Missing	15 (1.4)
Age	
20-29	52 (4.9)
30-39	262 (24.8)
40-49	306 (28.9)
50-59	289 (27.3)
60+	141 (13.3)
Missing	7 (0.7)
Language of survey	
English	657 (62.2)
French	71 (6.7)
Spanish	245 (23.2)
Portuguese	84 (7.9)

3.3.2. Missing data

There were very few missing values for respondents' background characteristics (at most 1.9%). The percentage of missing values on optimal caesarean rates increased with question order in the questionnaire. It ranged from 0.4% for complete placenta praevia to 3.0% for prolonged labour among clinical categories, and from 4.7% for low-risk deliveries to 6.7% for nulliparous women among reproductive categories. The optimal caesarean rate for all deliveries had the largest number of missing responses (11.0%).

3.3.3. Optimal caesarean rate for all deliveries

Table 3.5 presents the median reported optimal caesarean rate and IQR, stratified by respondent characteristics. Seven respondents were excluded from this analysis: four who replied that the optimal rate is "less than" a specific percentage (namely 5%, 20%, 20% and 25%) without giving a lower limit, and three who reported that it is "impossible" to know or depends on the population being cared for. The median reported optimal caesarean rate for all deliveries was 20% (IQR: 15-30%, range: 3-90%).

There was strong evidence of a difference in the optimal reported rates according to all explanatory variables (Kruskal-Wallis $p<0.01$ for all), except for age. Respondents practicing in Europe reported lower optimal rates (15%) than those in all other regions (between 20% in Africa and 25% in the Americas, South-East Asia and Western Pacific). Providers in countries with caesarean rates above 30% reported higher optimal rates (25%) than those in countries with caesarean rates below 30% (20% in all three groups). Obstetricians in low- and high-income countries reported similar optimal rates (20% and 17%, respectively), while those in lower- and upper-middle income countries reported higher optimal rates (25% and 28%, respectively). Providers exclusively from the private for-profit sector reported higher optimal rates than those practicing exclusively in the public sector (30% compared with 20%, respectively). Median reported optimal rates increased consistently with reported facility caesarean rates, from 15% among providers who report an institutional caesarean rate of 0-14%, to 30% for institutional rates over 50%.

For each of these stratifications, the 25^{th} percentile in each subgroup was at least 15%; the only exceptions were providers in Europe and in facilities with institutional caesarean rates below 15%, where the lower quartile was 14% and 10%, respectively.

Table 3.5 Optimal caesarean rate for all deliveries stratified by respondent characteristics (N=1,054)

Characteristic	Number of respondents	Median (%)	IQR (%)	Kruskal-Wallis p-value
Total	**941**	**20**	**15-30**	**-**
Occupation				
Obstetrician	835	20	15-30	0.0002
Other clinical doctor	47	20	15-40	
Other (including non-clinical doctor and researcher)	53	15	15-22	
Region of main experience in obstetrics				
Africa	127	20	15-30	<0.0001
Americas	337	25	20-30	
Eastern Mediterranean	61	23	18-30	
Europe	246	15	14-20	
South-East Asia	64	25	20-30	
Western Pacific	94	25	20-30	
National caesarean rate				
<5%	65	20	15-25	<0.0001
5-15%	76	20	15-30	
15-30%	434	20	15-30	
>=30%	350	25	20-30	
Country income level				
Low income	103	20	15-25	<0.0001
Lower middle income	131	25	16-30	
Upper middle income	381	28	20-30	
High income	314	17	15-25	
Facility type				
Public only	469	20	15-25	<0.0001
Private for-profit only	187	30	20-35	
Private not-for-profit only	65	20	15-30	
Mixed private	13	25	20-30	
Mixed public-private	189	23	16-30	
Highest facility level of practice				
Primary care	30	25	18-30	<0.0001
District	94	20	15-25	
Regional	261	20	15-30	
National/University	413	20	15-30	
Private/Other	139	30	23-35	
Facility caesarean rate				
0-14%	76	15	10-16	<0.0001
15-29%	396	20	15-25	
30-49%	285	25	20-30	
50%+	156	30	24-40	
Dont know	19	20	15-35	

Characteristic	Number of respondents	Median (%)	IQR (%)	Kruskal-Wallis p-value
Gender				
Female	429	20	15-30	0.0081
Male	502	25	15-30	
Age				
20-29	44	20	15-30	0.2405
30-39	237	20	15-30	
40-49	266	20	15-30	
50-59	264	25	15-30	
60+	126	20	15-30	

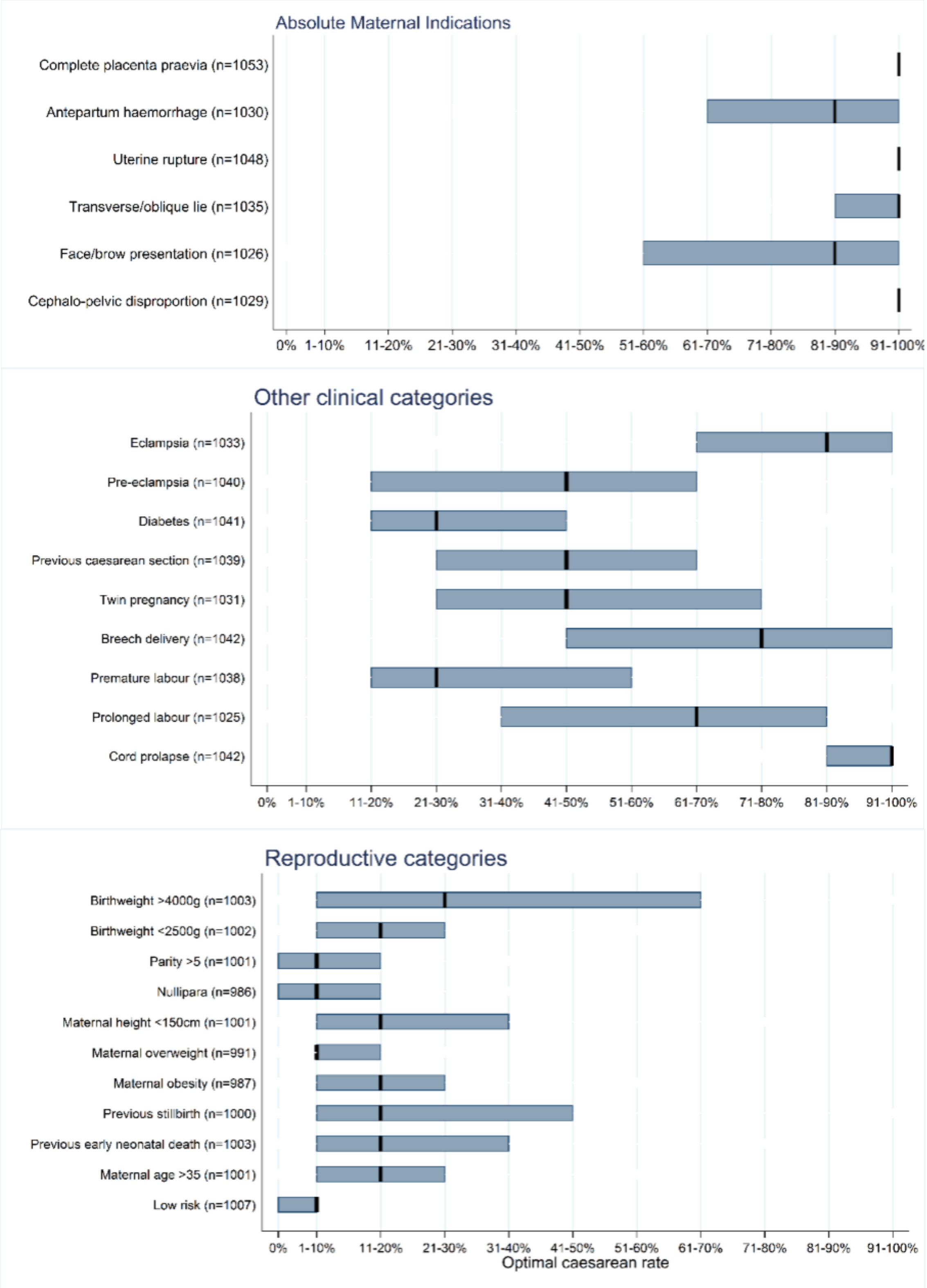
3.3.4. Optimal caesarean rate by clinical and reproductive category of deliveries

Figure 3.1 presents the median reported optimal caesarean rate and IQR for different categories of deliveries, gathered into three groups (AMIs, other clinical categories, and reproductive categories including low-risk). Four of the six AMIs had median rates of 91-100% (complete placenta praevia, uterine rupture, transverse/oblique lie and cephalopelvic disproportion). There was very little variation in the optimal caesarean rate within these categories, as indicated by the narrow IQRs. Antepartum haemorrhage from placental abruption and face/brow presentation both had a median optimal rate of 81-90%, and wider IQRs than the four other AMI categories.

There was substantial variation in reported optimal rates in most of the other clinical categories. The two exceptions were eclampsia and cord prolapse, with high optimal rates (81-90% and 91-100%, respectively) and relatively narrow IQRs. For the other categories included in this group, the median optimal rate varied between 21-30% for diabetes and premature labour, and 71-80% for breech delivery. The IQRs for these categories were very wide, reaching 50 percentage points for pre-eclampsia, twin delivery, breech delivery and prolonged labour.

The reported optimal rate was lower for reproductive categories than for clinical categories, with medians ranging between 1-10% and 21-30%. The median for most of these categories was at or below the median optimal rate for all deliveries (20%). They also tended to show less variation than clinical categories other than AMIs, with the exception of high birthweight which had an IQR of 60 percentage points. The reported optimal rate was lower for low-risk deliveries (singleton cephalic delivery, parity 2-5, with no known risk factors at the onset of labour) than for all other clinical and reproductive categories ($p<0.001$ for all).

Figure 3.1 Median optimal caesarean rate and IQR among different categories of deliveries



3.3.5. Optimal caesarean rates among specific categories, stratified according to national caesarean rate

Table 3.6 presents reported optimal rates for all clinical and reproductive categories of deliveries, stratified by national caesarean rate, and the p-value for the corresponding Kruskal-Wallis test. There was no difference in median reported optimal rates according to national caesarean rate for all AMI categories except for antepartum haemorrhage from placental abruption, where it increased with the national rate ($p<0.001$). There was also no difference in median optimal rates for the following categories: eclampsia, cord prolapse, grand multipara, maternal age>35 and low-risk pregnancy; these categories had a large overlap between IQRs for different levels of national caesarean rates. There was no clear trend according to national rate for the remaining categories (pre-eclampsia, maternal diabetes, previous caesarean, premature labour, prolonged labour, and high birthweight).

Reported optimal rates increased with the national caesarean rate for twin delivery and breech presentation (p-value <0.001). This trend was also observed but less pronounced among low birthweight and nullipara deliveries. In contrast, the median optimal rate decreased with national caesarean rate for low maternal height, maternal overweight and obesity, previous stillbirth, and previous early neonatal death.

Table 3.6 Optimal caesarean rate for different categories, stratified by national caesarean rate

National caesarean rate	25th percentile	Median	75th percentile	Rank-sum p value (Kruskal-Wallis)
Complete placenta praevia				
<5%	91-100%	91-100%	91-100%	0.797
5-15%	91-100%	91-100%	91-100%	
15-30%	91-100%	91-100%	91-100%	
>=30%	91-100%	91-100%	91-100%	
Antepartum haemorrhage from placental abruption				
<5%	41-50%	71-80%	91-100%	<0.001
5-15%	41-50%	71-80%	91-100%	
15-30%	61-70%	81-90%	91-100%	
>=30%	81-90%	91-100%	91-100%	
Uterine rupture or pre-rupture				
<5%	91-100%	91-100%	91-100%	0.627
5-15%	91-100%	91-100%	91-100%	
15-30%	91-100%	91-100%	91-100%	
>=30%	91-100%	91-100%	91-100%	
Transverse/oblique lie				
<5%	71-80%	91-100%	91-100%	0.023
5-15%	51-60%	91-100%	91-100%	
15-30%	81-90%	91-100%	91-100%	
>=30%	81-90%	91-100%	91-100%	
Face/brow presentation				
<5%	61-70%	81-90%	91-100%	0.882
5-15%	61-70%	81-90%	91-100%	
15-30%	51-60%	81-90%	91-100%	
>=30%	61-70%	81-90%	91-100%	
Cephalopelvic disproportion				
<5%	91-100%	91-100%	91-100%	0.150
5-15%	91-100%	91-100%	91-100%	
15-30%	91-100%	91-100%	91-100%	
>=30%	91-100%	91-100%	91-100%	
Eclampsia				
<5%	41-50%	81-90%	91-100%	0.005
5-15%	41-50%	81-90%	91-100%	
15-30%	61-70%	81-90%	91-100%	
>=30%	61-70%	81-90%	91-100%	
Pre-eclampsia				
<5%	11-20%	41-50%	71-80%	0.499
5-15%	21-30%	41-50%	61-70%	
15-30%	11-20%	31-40%	61-70%	
>=30%	11-20%	41-50%	61-70%	
Maternal diabetes				
<5%	11-20%	31-40%	51-60%	0.015

National caesarean rate	25th percentile	Median	75th percentile	Rank-sum p value (Kruskal-Wallis)
5-15%	11-20%	41-50%	61-70%	
15-30%	11-20%	21-30%	41-50%	
>=30%	11-20%	21-30%	41-50%	
Previous caesarean section				
<5%	21-30%	41-50%	61-70%	<0.001
5-15%	41-50%	51-60%	71-80%	
15-30%	21-30%	41-50%	61-70%	
>=30%	21-30%	41-50%	51-60%	
Twin delivery				
<5%	11-20%	31-40%	41-50%	<0.001
5-15%	21-30%	41-50%	51-60%	
15-30%	21-30%	41-50%	71-80%	
>=30%	31-40%	51-60%	81-90%	
Breech presentation				
<5%	21-30%	41-50%	71-80%	<0.001
5-15%	41-50%	61-70%	81-90%	
15-30%	41-50%	61-70%	81-90%	
>=30%	51-60%	81-90%	91-100%	
Premature labour				
<5%	1-10%	11-20%	41-50%	0.060
5-15%	11-20%	31-40%	41-50%	
15-30%	11-20%	21-30%	51-60%	
>=30%	11-20%	21-30%	61-70%	
Prolonged labour				
<5%	41-50%	51-60%	81-90%	0.857
5-15%	41-50%	71-80%	81-90%	
15-30%	31-40%	61-70%	81-90%	
>=30%	41-50%	61-70%	81-90%	
Cord prolapse				
<5%	71-80%	91-100%	91-100%	0.007
5-15%	71-80%	91-100%	91-100%	
15-30%	81-90%	91-100%	91-100%	
>=30%	81-90%	91-100%	91-100%	
High birthweight (>4,000g)				
<5%	1-10%	21-30%	71-80%	0.034
5-15%	1-10%	11-20%	41-50%	
15-30%	1-10%	21-30%	61%	
>=30%	11-20%	31-40%	61-70%	
Low birthweigth (<2,500g)				
<5%	0%	1-10%	11-20%	0.002
5-15%	1-10%	1-10%	21-30%	
15-30%	1-10%	11-20%	21-30%	
>=30%	1-10%	11-20%	21-30%	
Grand multipara (parity>5)				

National caesarean rate	25th percentile	Median	75th percentile	Rank-sum p value (Kruskal-Wallis)
<5%	1-10%	1-10%	11-20%	0.002
5-15%	0%	1-10%	11-20%	
15-30%	0%	1-10%	11-20%	
>=30%	0%	1-10%	1-10%	
Nullipara				
<5%	0%	1-10%	11-20%	0.157
5-15%	0%	1-10%	11-20%	
15-30%	1-10%	11-20%	11-20%	
>=30%	0%	11-20%	11-20%	
Low maternal height (<150cm)				
<5%	1-10%	31-40%	51-60%	0.002
5-15%	1-10%	11-20%	41-50%	
15-30%	1-10%	11-20%	41-50%	
>=30%	1-10%	11-20%	31-40%	
Maternal overweight				
<5%	1-10%	11-20%	31-40%	0.171
5-15%	1-10%	1-10%	11-20%	
15-30%	1-10%	1-10%	11-20%	
>=30%	0%	1-10%	11-20%	
Maternal obesity				
<5%	1-10%	21-30%	41-50%	0.070
5-15%	1-10%	11-20%	21-30%	
15-30%	1-10%	11-20%	21-30%	
>=30%	1-10%	11-20%	21-30%	
Previous stillbirth				
<5%	11-20%	31-40%	61-70%	0.003
5-15%	1-10%	21-30%	51-60%	
15-30%	1-10%	11-20%	41-50%	
>=30%	1-10%	11-20%	31-40%	
Previous early neonatal death				
<5%	1-10%	21-30%	41-50%	0.066
5-15%	1-10%	11-20%	41-50%	
15-30%	1-10%	11-20%	31-40%	
>=30%	1-10%	11-20%	31-40%	
Maternal age >35 years				
<5%	1-10%	11-20%	31-40%	0.333
5-15%	1-10%	11-20%	41%	
15-30%	1-10%	11-20%	21-30%	
>=30%	1-10%	11-20%	21-30%	
Low risk pregnancy (singleton, cephalic delivery with no other known risk factors at onset of labour)				
<5%	0%	1-10%	1-10%	0.244
5-15%	0%	1-10%	1-10%	
15-30%	0%	1-10%	1-10%	
>=30%	0%	1-10%	1-10%	

3.4. Discussion

3.4.1. Summary of main findings

Results from this survey show that obstetricians report a median optimal caesarean rate of 20% for all deliveries. The IQR of 15-30% indicates that 75% of respondents believe that the population-level caesarean rate should be 15% or higher. Respondents from countries with national rates above 30% reported higher optimal rates than those from countries with lower national rates, though there was no difference for national rates below 30%. At the regional level, obstetricians practicing in Europe reported the lowest optimal caesarean rate (15%), while the highest (25%) was reported in the Americas, South-East Asia and Western Pacific. Obstetricians working in private for-profit facilities and facilities with high caesarean rates reported substantially higher optimal rates than in public sector facilities and facilities with low caesarean rates, respectively.

Reported optimal caesarean rates for different categories of deliveries are consistent with clinical interpretation. The optimal rate was lowest for multipara singleton cephalic deliveries with no known risk factors than for all other categories. Most categories designated as absolute maternal indications in the literature had median optimal rates of 91-100%. Obstetricians reported higher median optimal rates for clinical than for reproductive categories, though there was a wide range of opinions across respondents for non-AMI clinical categories. These differences were not explained by the national caesarean rate, with the exception of twins, breeches and placental abruption, for which reported optimal rates tended to increase with national rates.

3.4.2. Interpretation

The results from this survey suggest that respondents believe the optimal caesarean rate at the population level is higher than the WHO “acceptable” range of 5-15%. Nonetheless, there remains substantial variation in opinions of the optimal rate, with 25% of respondents believing it is above 30%. This lack of agreement highlights the subjectivity of clinicians’ opinions of the optimal rate, and indicates that the median reported optimal rate of 20% is not a valid benchmark for measuring the unmet need for caesareans.

The optimal caesarean rate reported by respondents in this study is similar to that found in a survey of South African obstetricians from 1992, in which private providers reported an “ideal” rate of 20% and 16% for public hospital providers [40]. Variations in the optimal caesarean rate reported in different countries are likely to be partly due to cultural differences in the perceived risk associated with caesareans. Surveys in high-income countries have found that between 15% (in Spain) and 79% (in the UK) of providers report agreeing to caesareans on maternal request in the absence of medical indication [142, 143, 149-152], and between 1% of obstetricians in Denmark and 18% in the USA would prefer an elective pre-labour caesarean for themselves or their partner in the event of a term uncomplicated singleton cephalic delivery [143-145, 150, 152]. Changes in obstetricians' opinions over time have been documented, as in England and Wales, where 60% of respondents stated having recently changed their practice toward caesareans on maternal request [142]: this change in practice at the beginning of the 21st century probably reflects a real reduction in the risks associated with caesarean delivery, as a result of regional anaesthesia and routine use of thrombo-prophylaxis and antibiotics, as well as a cultural change in the acceptability of performing caesareans on maternal request.

Contrary to the study hypothesis, the national caesarean rate does not affect reported optimal rates when national rates are below 30%. There was greater variation in optimal rates according to self-reported facility caesarean rates: this association could be due to reporting bias, if respondents believing the optimal rate is higher were more likely to overestimate the institutional rate in their facility. If the association is real, these findings suggest that individual providers' opinions of the optimal rate are affected more by the immediate clinical environment in which they practice than by the wider national clinical context, perhaps in part because the safety of caesareans and clinical culture varies across facilities.

The high median optimal rate and narrow IQRs reported for AMIs suggest that obstetricians indeed consider these obstetric complications to be "absolute" indications for surgical delivery, supporting the 100% need for caesareans in these categories, with rates below 100% indicating an unmet need. The concept of AMIs was based on clinical experience, and hence it is not surprising that obstetricians' opinions support this concept, and the high agreement between respondents indicates that this belief is strongly held across countries. Among AMIs, the optimal rate and agreement were lower for face/brow presentation and antepartum haemorrhage. This may have been because these categories include less severe complications: brow presentation cannot be delivered vaginally, though it may be possible with face presentation; and placental abruption is not always associated with major haemorrhage. Though AMIs include life-threatening maternal complications only [30], cord prolapse and eclampsia have reported median optimal rates of 91-100% and 81-90%, respectively, suggesting that some obstetricians also consider these “absolute” indications for caesarean (for both maternal and fetal considerations).

The reported optimal range for breech delivery was 71-80%, indicating that obstetricians believe that most – but not all – breeches would benefit from a caesarean, consistent with the Cochrane systematic review which found that the benefits of planned caesarean at term outweighed the risks for the fetus, at the expense of increased maternal morbidity [51]. Reported optimal rates for both breech and twin deliveries varied widely (IQR = 50% for both), and increased with the national caesarean rate. These optimal rates are likely to reflect the level of risks associated with caesareans in different settings, as well as the level of interventionism of a medical culture, which would account for both higher reported optimal rates in these categories and higher national caesarean rates in these countries.

3.4.3. Strengths and limitations

To my knowledge, this study was the first global survey of obstetricians’ opinions of the optimal caesarean rate. Respondents were asked to report the optimal caesarean rate at the population level, rather than both a minimum and maximum threshold, and it was not possible to directly assess their opinion of the WHO 5-15% recommended range.

It achieved a large and geographically diverse sample, though there were relatively few respondents from Asia (in particular, there were only two Chinese obstetricians in the sample). Unfortunately, it was not possible to obtain a globally representative sample of doctors performing caesareans worldwide because there was no sampling frame for this population; moreover, they do not all have access to the internet, and it is likely that a substantial proportion of doctors who saw the survey advertised did not respond. Selection bias may have affected the study findings, if those who answered the survey tend to report different answers than those who are not reachable online or who chose not to answer the survey. Notably, the lack of responses from southern and eastern Europe (where national caesarean rates are higher than in western and northern Europe) may explain why the median reported optimal rate is lower in this region than in others. However, the variation in responses would be unlikely to be completely eliminated with a representative sample. The median response rate across 350 postal surveys of healthcare professionals was 59%, with an IQR of 42-71% [153]. It was not possible to calculate a response rate for this online survey since the number of people who received the invitation is unknown.

Missing values increased with question order, due to respondents dropping out after beginning to answer the survey. The 11% missing responses for the optimal rate for all deliveries could have been reduced by placing this question before individual delivery categories. Certain delivery categories could have been clarified: for example, face/brow presentation could have been split into separate categories, and “antepartum haemorrhage from placental abruption” would have been closer to the definition of AMIs if it had been changed to “from retroplacental haematoma”. Making these clarifications would have allowed for establishing whether these more specific categories are considered absolute indications for caesareans. If repeating this survey, I would choose to ask respondents for their opinion of the minimum optimal caesarean rate in addition to the maximum optimal rate, as well as ask them directly whether they believe the WHO recommended range is too low. I would also include an open response for each of these questions asking them to give their reasons or comments. In addition, it would be interesting to repeat this survey among non-physician obstetric care providers (such as midwives and clinical officers) in order to compare their responses.

Lastly, the p-values derived from the Kruskal-Wallis tests seem high relative to the magnitude of differences between subgroups, most likely because this test is sensitive to the extreme values reported in each category, but this non-parametric test was nonetheless the most appropriate for this analysis.

3.5. Conclusion

The median optimal caesarean rate reported by obstetricians lies above the “acceptable” range defined by the WHO, and the wide range of reported optimal rates indicates that these should not be used to identify the optimal caesarean rate for measuring the unmet need. In light of the wide range of thresholds for the minimum optimal caesarean rate identified in ecological studies, this lack of consensus confirms that the optimal caesarean rate remains unknown. There are no other available data sources based on which to assess the optimal caesarean rate, and therefore this concept appears not to be useful for measuring the unmet need for caesareans. Results from this survey nonetheless indicate that AMIs are indeed considered to be “absolute” indications for caesareans by obstetricians and that caesarean rates below 100% in these categories are a clear indicator of unmet need, but reported optimal rates for other clinical categories varied widely according to clinical context.

Chapter 4. Determinants of facility deliveries, caesarean sections and pregnancy-related deaths in the Brong-Ahafo region of Ghana

The purpose of chapter 4 is to describe the study population and data sources used in chapters 4, 5 and 6, and to present the socio-demographic determinants of facility deliveries, caesarean sections and pregnancy-related deaths in the Brong-Ahafo region of central Ghana (objective 3.1 of this thesis). These descriptive analyses are presented as a background to the analyses on unmet need for caesareans in chapters 5 and 6, in order to describe the context and help interpret findings in subsequent chapters.

This chapter begins by presenting the study setting and the ObaapaVitA trial, from which the study sample was drawn. It further describes how the sample was selected for the current analyses, and how variables used in the analysis were derived from the available data. The socio-demographic determinants of facility deliveries, caesareans and pregnancy-related deaths are then described. Causes of death based on verbal post-mortems are presented for all pregnancy-related deaths. Lastly, the prevalence of obstetric complications is presented for all hospital deliveries and stratified by maternal education, and causes of pregnancy-related deaths are described for hospital deliveries.

4.1. Introduction

Multiple barriers to delivery care exist in low- and middle-income countries; these have been summarised in several reviews [106, 108, 154, 155]. In their systematic review, Moyer and Mustafa identified five categories of factors affecting facility delivery in sub-Saharan Africa: maternal, social, antenatal, facility-related, and macro-level factors, of which maternal determinants were the most commonly studied [108]. Their review found that maternal education, household wealth, urban residence and number of antenatal visits had a consistent positive effect on the likelihood of facility delivery, while high parity and distance to the nearest facility were consistently negatively associated with facility delivery [108]. Additional factors (including age, ethnicity, religion, marital status and women's autonomy) were associated with facility delivery in some sub-Saharan African settings, but not all. Say and Raine also emphasise that predictors of the utilisation of delivery care are context-dependent [106].

Determinants of caesareans have rarely been studied in multivariable models in sub-Saharan Africa (though crude caesarean rates stratified by maternal characteristics are presented in Demographic and Health Surveys), but those identified in the literature are similar to determinants of facility delivery. Older women, primiparas, urban residents, more educated women and richer women are more likely to have a caesarean in several (but not all) low- and middle-income country settings [11, 156-158]. In Senegal and Mali, older and nulliparous women were more likely to deliver by caesarean than younger and multiparous women, respectively [158]. Certain hospital-level factors, including availability of intensive care units and 24-hour anaesthetist presence, were also found to increase the likelihood of caesarean delivery across institutions [158].

Factors associated with facility delivery and caesarean section tend to be associated in the opposite direction with maternal mortality, as high parity, rural residence and low education are predictive of maternal deaths [159-163], reflecting the fact that women with better access to delivery care are less likely to die during childbirth. One exception is older age at birth, which is positively associated with maternal mortality, as well as with facility and caesarean delivery [159, 160, 162]. These associations are less consistent than for determinants of delivery care utilisation, perhaps because most studies are not powered to detected differences in maternal mortality between subgroups: for instance, in the Tanzanian highlands, there was no difference in mortality according to maternal education [163].

Maternal education, relative wealth and residence have thus been shown to be associated with facility and caesarean delivery in most studies in sub-Saharan Africa, though other determinants vary between studies. This observed difference has been attributed to methodological differences between studies (particularly how socio-demographic variables are measured and which variables are adjusted for), as well as differences in social context [106, 155]. Use of facility delivery care is shaped by sociocultural behaviours as well as context-specific patterns of access to care: for example, some studies suggest a strong interaction between wealth and female autonomy, suggesting that autonomy may not increase the likelihood of facility delivery without access to financial resources [108].

Findings from chapter 2 showed a large within-country variation in the caesarean rate in many sub-Saharan African countries, including Ghana. Though determinants of facility deliveries and caesareans have been described in the Demographic and Health Survey report for Ghana nationally [164], examining the determinants of facility deliveries, caesareans and pregnancy-related mortality in the Brong-Ahafo region of Ghana is crucial to understanding access to care in the study area, as well as interpreting results in subsequent chapters of this thesis. Moreover, it is important to assess whether differences in the utilisation of delivery care across socio-economic groups result in differences in the case-mix among hospital deliveries.

4.1.1. Objectives

The overall objective of this chapter is to understand the context of delivery care and maternal health in central Ghana, in order to inform the interpretation of analyses on the unmet need for caesareans in subsequent chapters.

The primary objective is to examine the socio-demographic determinants of facility delivery, caesarean section and pregnancy-related death in the Brong-Ahafo region of Ghana. Secondary objectives are to:

- describe the causes of pregnancy-related deaths for all deaths in the study area and among deaths in hospital;
- describe the prevalence of obstetric complications for all hospital deliveries;
- determine whether the prevalence of obstetric complications varies with maternal education, and interpret any variation in light of differences in facility delivery and caesarean rates.

4.2. Methods

4.2.1. Study setting

The data used for this study are drawn from the ObaapaVitA trial, which took place between 2000 and 2008 in the Brong-Ahafo region of central Ghana.

Ghana is a small West African country with an estimated population size of 25 million in 2012 [165]. Most of the population is concentrated in the southern regions of the country. A lower-middle income country, Ghana has a history of political stability and a fast growing economy, though 29% of the population lived with less than $1.25 per day in 2006 [165]. Ghana is home to over 75 ethnic groups, among which the largest are the Akans (47.5% of the population), the Mole Dagbani (16.6%) and the Ewe (13.9%). The two predominant religions are Christianity and Islam, representing 71% and 18% of the population respectively. Around half (51%) of the population live in urban areas. The total fertility rate is moderately high at 4.0 children per woman, and 57% of births occurred in a health facility (health centre or hospital) in 2008 [164], though the range of delivery care available in these facilities probably varied substantially. The maternal mortality ratio has declined from 760 maternal deaths per 100,000 live births in 1990 to 380 in 2013, representing an annual decline of 2.9% [166]. This is short of the 5.5% needed to achieve Millennium Development Goal 5 of a 75% reduction in maternal mortality [166].

In an attempt to increase skilled attendance at delivery, the Government of Ghana rolled out a fee exemption policy for delivery care nationally in April 2005 for both uncomplicated and complicated deliveries, including caesareans [167]. In the same year, the National Health Insurance Scheme (NHIS) was also introduced at the national level, which aimed to remove point-of-care charges for patients and increase equity in access to a range of health services [168]. Membership is compulsory, though many Ghanaians remained uninsured several years after the introduction of the NHIS. Funding issues with the fee exemption policy meant that, in some regions, facilities re-introduced user fees and women who were not covered by the NHIS had to pay for delivery care. This prompted the Government to replace the fee exemption policy with free NHIS enrolment for all pregnant women in July 2008, which also covers charges for all deliveries including caesareans [168].

Data for this study were collected in the Brong-Ahafo region of central Ghana, which is situated approximately a ten-hour drive away from the capital city of Accra, and four hours away from the nearest teaching hospital in Kumasi. Brong-Ahafo has a population of 2.3 million and 45% of the population live in urban areas, according to the 2010 national census [169]. The only city is the regional capital, Sunyani, and there are several major towns in the region; many people classified as residing in “urban” areas in Brong-Ahafo live in semi-rural towns. The infrastructure in the region – including roads, schools and hospitals – is generally poor, and the primary economic occupation in the area is subsistence farming, as well as employment on commercial farms (including cocoa and timber farms) [170].

A higher proportion of deliveries occurred in health facilities than in Ghana as a whole (65% compared with 57% nationally) and the region has the highest NHIS coverage in the country; however, the caesarean rate was lower in Brong-Ahafo (5% compared with 7% nationally) [164]. Estimates from the 2010 census suggest that the pregnancy-related mortality ratio in Brong-Ahafo is lower than the national average (422 per 100,000 compared with 485 per 100,000) [91, 169], though the stillbirth rate appears to be higher (35 per 1,000 in the study area compared with 22 per 1,000) [171, 172]. HIV prevalence is around 2% in Brong-Ahafo [173]. Based on the 2003 Demographic and Health Survey dataset, 1% of women aged 15-49 years had experienced female genital mutilation in Brong-Ahafo, compared with 7% nationally.

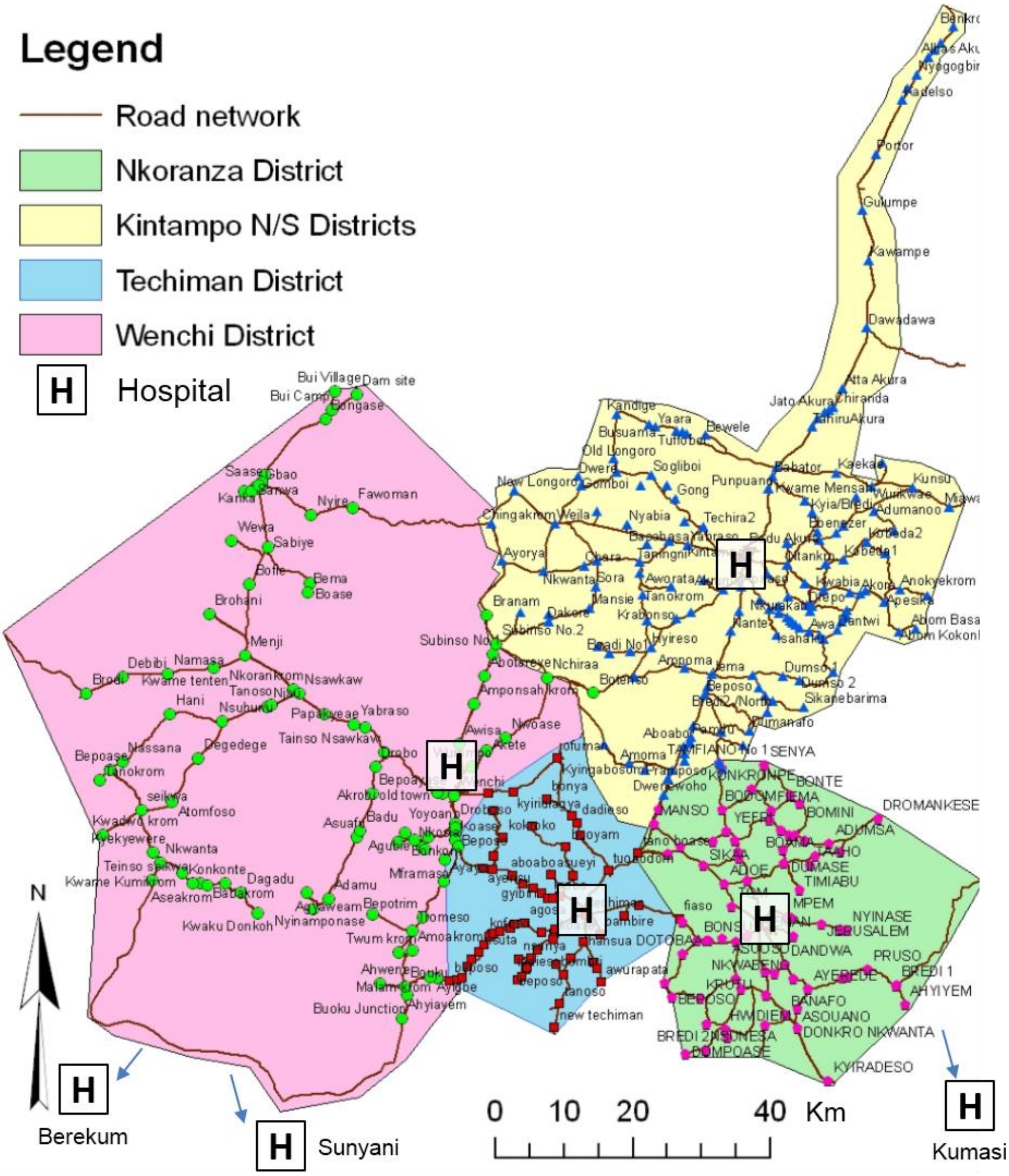
4.2.2. Access to delivery care in the study area

The ObaapaVitA trial, from which these data are drawn, took place in four districts in the Brong-Ahafo region (Kintampo, Nkoranza, Techiman and Wenchi). During the time period covered by these data, one district hospital in each district was equipped to perform caesareans (four hospitals in total). No other public or private facilities in the study area provided surgical care in the study period: there were three other hospitals in the study districts (two of which were private facilities), but they did not possess surgical capacity. However, other district hospitals performing surgery in neighbouring districts were accessible to women in the study area, located in Sunyani and Berekrum towns, as well as a teaching hospital in the city of Kumasi.

In total, 72 health facilities provided maternity care in the study area between 2005 and 2008, though the number of facilities operational at one time fluctuated, since some private facilities opened and closed during the study period. Based on women’s reports, in addition to the seven hospitals mentioned above, there were at least 38 health centres performing deliveries, as well as 11 private maternity homes (managed by the Ghana Registered Midwives Association), 12 clinics and health posts, and four private clinics. A map of the study area showing the main towns and hospitals performing surgery is shown in Figure 4.1.

An assessment of health facilities operational in the study area in 2010 found that quality of care was generally low, particularly for emergency obstetric care [174]. Of the 64 facilities providing delivery care, 58% were considered to have substandard quality of emergency obstetric care based on the availability of WHO signal functions (including parenteral antibiotics, manual removal of the placenta and instrumental vaginal delivery) [7]. The assessment found that most facilities designated as hospitals performed caesareans and blood transfusions, but almost none of the lower level facilities. Most health centres, clinics and maternity homes provided parenteral oxytocin and anti-convulsants, as well as manual removal of the placenta; however, very few lower level facilities performed manual removal of retained products or assisted vaginal delivery, and fewer than half of health centres and maternity homes provided antibiotics. Three quarters of facilities reported monitoring labour with a partograph, but, only 41% of facilities demonstrated a correctly filled partograph and had a clock in the delivery room to measure the duration of labour [174]. Although this assessment was carried out after the ObaapaVitA study period, it indicates that delivery care was substandard in a large number of facilities in the study area.

Figure 4.1 Map of study districts showing location of hospitals



4.2.3. ObaapaVitA study design

The ObaapaVitA trial was a cluster-randomised, double-blind, placebo-controlled trial conducted in the Brong-Ahafo region of Ghana. The primary aim of the trial was to "assess the effect of low-dose weekly vitamin A supplementation in women of reproductive age on pregnancy-related mortality and all-cause female mortality" [175].

Secondary outcomes of interest included maternal morbidity, and perinatal and infant mortality.

Full details on the design of the ObaapaVitA trial and the data collection methods are described in the article reporting the main study findings [175]. All women aged 15-45 capable of giving informed consent and planning to reside in the study area for at least 3 months after enrolment were eligible for inclusion. Once enrolled, women remained under surveillance until they moved out of the study area or died. Enrolled women also remained in the trial after age 45, as the reporting of age is known to be relatively inaccurate in the study area. The study area was divided into 1086 clusters of contiguous compounds in 272 fieldwork areas, with randomisation blocked such that two clusters in each fieldwork area were allocated to vitamin A and two allocated to placebo. Women were randomly assigned, according to their cluster of residence, to receive weekly vitamin A or placebo capsules. Information about the trial was provided during home visits by fieldworkers, and women gave their consent by signing the enrolment form or making a thumbprint. Ethical approval for the trial was obtained from the Ghana Health Service (the agency responsible for implementing national health policies in Ghana) and the London School of Hygiene and Tropical Medicine.

Capsule distribution started between December 2000 and January 2003 according to district, and distribution ended in September 2008 in all districts.

4.2.4. Data collection

Fieldworkers visited each compound every four weeks, to distribute study capsules and collect data on pregnancies, births and deaths. At the first home visit after delivery, data were collected from the mother on place of delivery, delivery characteristics and perinatal outcomes, for both home and facility deliveries (BIRTH form). The status of the mother and infant at the end of the postpartum period was ascertained through the regular surveillance, with an additional 6 weeks of surveillance to obtain follow-up to the end of the postpartum period for the births in the final month of the trial.

Socio-demographic information (including marital status, education, and fertility history) was collected in a random sample of 40 enrolled women per week (PROFILE form). From June 2003, detailed socio-demographic information was also collected from all women following a live or stillbirth, and this data collection was extended in May 2005 to all women as soon as they reported their pregnancy to their fieldworker. This PROFILE form also collected information on household assets, including ownership of livestock, electrical items, vehicles, and dwelling characteristics such as floor and wall materials.

Verbal post-mortems (VPM) were undertaken by field supervisors for all deaths in women of reproductive age (VPM form). Close relatives or friends who had cared for the deceased during their final illness were interviewed, usually around 6 weeks after the death. The questionnaires were based on WHO standard questionnaires, and included questions on the circumstances surrounding the death, signs and symptoms, as well as an open history. In order to obtain a cause of death, the forms were reviewed by two doctors who independently determined whether the woman was pregnant or had recently delivered, and then assigned a cause of death. In the event that they disagreed, the VPM was reviewed by a third doctor and pregnancy status and cause of death were assigned based on a consensus between two of the doctors. If there was no consensus, an obstetrician reviewed the VPM and assigned pregnancy status and cause of death. A single cause of death was assigned for all deaths.

In addition, the ObaapaVitA trial collected data from May 2005 on the labour and maternity wards of the four main district hospitals in the study area for admissions during pregnancy, delivery or postpartum for all trial participants (HOSPITAL form), which were linked to the community-based data. Extensively trained field supervisors based at the four study hospitals oversaw the prospective collection of clinical information, using a pre-coded data extraction form. Data were extracted from patient records and admission and discharge registers on hospital diagnoses, management, indications for obstetric surgery, and pregnancy outcomes. At a minimum, the discharge diagnosis was recorded for all deliveries with complications, and an effort was also made to capture any other diagnoses recorded in the medical notes, at any point during the hospital stay. As many diagnoses as applicable could be selected from an extensive pre-coded list of complications. Cause of death was ascertained by doctors at the hospital for women who died during admission, based on a pre-coded list. As with the VPM, a single cause of death was assigned in each case. Weekly supervisory visits by a doctor from the trial management team were made to all of the hospitals, at which time the data collected for as many admissions with complications as possible (i.e. excluding spontaneous vaginal delivery) were reviewed using the medical notes. Detailed information on the classifications used for obstetric complications, indications for obstetric surgery and cause of death are presented in section 4.2.6 below.

Table 4.1 summarises the information collected in each data collection form, including the data source. The PROFILE, BIRTH, HOSPITAL and VPM forms are included in **Appendix E: ObaapaVitA data collection** forms.

Table 4.1 Data collection forms and information collected in ObaapaVitA trial

Form	Source and time of data collection	Information collected
PROFILE	Woman's interview during pregnancy (sometimes after delivery)	• Maternal socio-demographic information (age; educational attainment; marital status; ethnicity; religion) • Household assets (including source of water; electricity; ownership of livestock, TV and mattress; dwelling characteristics) • Maternal reproductive history (number of live births, stillbirths and abortions; previous caesarean and instrumental delivery)
BIRTH	Woman's interview during first home visit after delivery	• Delivery information (place of delivery; mode of delivery; birth attendant) • Perinatal outcomes (live or stillbirth)
HOSPITAL	Data extraction from hospital records after discharge	• Delivery information (mode of delivery; obstetric surgery; fetal presentation) • Diagnoses of obstetric complications (including dystocia, hypertensive diseases, haemorrhage, postpartum infection, and other obstetric and non-obstetric complications) • Maternal outcomes (maternal death; cause of maternal death)
VPM	Interview with close friends or relatives, approximately 6 weeks after death	• Pregnancy status at death • Signs and symptoms • Open history

4.2.5. Selection of sample for study

The main sample used in this analysis consisted of all deliveries (live births and stillbirths after 22 weeks gestation) in the study population between 1st June 2005 and 9th October 2008, including pregnancy-related deaths where the mother died undelivered in late pregnancy. The study period was chosen because more extensive hospital data collection was introduced in June 2005, and the last deliveries with follow-up for 42 days postpartum occurred on 9th October 2008.

Early pregnancy losses and deaths were excluded from the sample since caesareans are not useful for treating pregnancy complications at this stage. The 22-week threshold used to distinguish stillbirths from miscarriages was ascertained based on the reported date of the last menstrual period (ultrasound scans in early pregnancy were not routinely used in the study area). The main sample included pregnancy-related deaths where the mother died undelivered in the second or third trimester of pregnancy, since it was not possible to ascertain timing of death more precisely. The second trimester includes 13 to 28 weeks gestation, therefore some pregnancy-related deaths in the main sample will have occurred before 22 weeks. I excluded eight women who died undelivered with unknown gestational length from the sample. The main sample of deliveries was used to address two primary objectives of this chapter (examining risk factors for facility delivery and caesareans in the population).

A separate sample was used to analyse pregnancy-related deaths, consisting of all deliveries after 22 weeks and all pregnancy-related deaths, regardless of gestational age, in the study period and population (i.e. the main sample plus pregnancy-related deaths in the first trimester). This sample was used to address the remaining primary objective for this chapter (examining risk factors for pregnancy-related deaths in the population), and to describe causes of death in the study population.

I also selected a sub-sample of hospital deliveries to describe obstetric complications and pregnancy-related deaths in hospitals. This sample included all deliveries after 22 weeks or postpartum admissions with a district hospital record in the study area, during the study period.

Section 4.3.1 describes the main sample and hospital sub-sample of deliveries used in chapters 4, 5 and 6 of this thesis.

4.2.6. Definition of outcomes

Facility delivery

Women who reported delivering in a district/regional hospital, a government clinic or a private/maternity home were coded as having a facility delivery. Women who reported delivering at home but who had a hospital record were included under facility deliveries. In the event of multiple pregnancy, the delivery of any baby at one of these health facilities was considered a facility delivery.

Caesarean section

Two sources existed for information on mode of delivery:

- Maternal self-report for all deliveries ["Was this baby born via a normal delivery through the vagina?" Response options: "Normally, through the vagina", "Baby was pulled with an instrument", "By caesarean section", "Other, specify"]
- Hospital record for hospital deliveries only ["How was the [first/second/third] baby delivered?" Response options: "Normally through the vagina", "Forceps", "Vacuum", "Emergency caesarean section", "Elective caesarean section", "Not applicable"]

Hospital deliveries were coded as caesareans if the mode of delivery was recorded as emergency or elective caesarean in the hospital records. Deliveries occurring outside of the four district hospitals in the study area were coded as caesareans if the woman reported delivering by caesarean, with the following exceptions. Caesareans reported to have occurred at home were recoded as vaginal deliveries [112]. Deliveries reported as caesareans occurring in health centres (without surgical capacity) were recoded as missing information for mode of delivery, because it was not possible to determine whether women had misreported the mode or place of delivery. For multiple pregnancies, a caesarean for any of the fetuses was recorded as a caesarean delivery.

Classification of obstetric complications

The hospital form recorded information on diagnoses during admission, and as many diagnoses as applicable could be listed for one delivery.

Table 4.2 presents the classification of delivery complications used in this study. I grouped 84 available diagnoses into 35 broader categories of complications (for instance, grouping frank breech and footling breech together under "breech presentation"). These were further organised under seven headings: dystocia, haemorrhage, hypertension, infection, other obstetric complications, other non-obstetric complications, and fetal complications.

Table 4.2 Classification of delivery complications

Categories	Available diagnoses
DYSTOCIA	
Obstructed labour	Obstructed labour
Cephalopelvic disproportion	Cephalopelvic disproportion (CPD)
	Macrosomia
Cervical/vaginal dystocia	Cervical stenosis, cervical dystocia
	Vaginal stenosis, vaginal rings
Prolonged labour (cause unspecified)	Prolonged labour
Breech presentation	Breech presentation, frank breech
	Foot or footling breech
Malpresentation	Transverse lie
	Oblique lie
	Face presentation
	Brow presentation
Other dystocia	Shoulder dystocia
	Compound presentation
	Other dystocia
HAEMORRHAGE	
Uterine rupture or pre-rupture	Uterine rupture
	Pre-uterine rupture, Bandl's ring
Antepartum haemorrhage from major placenta praevia	Partial placenta praevia, placenta praevia type III
	Complete placenta praevia, placenta praevia type IV
Other antepartum haemorrhage	ANY Antepartum haemorrhage [excluding placenta praevia type III or IV]
	Low lying placenta, placenta praevia types I or II
	Unspecified placenta praevia
	Placental abruption
	Unspecified antepartum haemorrhage
Postpartum haemorrhage	ANY Postpartum haemorrhage
	Uterine atony
	Retained placenta
	Retained products
	Placenta accreta
	Inverted uterus
	Perineal tear
	Vaginal tear
	Cervical tear
	Disseminated intravascular coagulation (DIC)
	Unspecified postpartum haemorrhage
HYPERTENSION	
Pregnancy-induced hypertension	Pregnancy-induced hypertension
Pre-eclampsia	Pre-eclampsia
Eclampsia	Eclampsia
INFECTION	
Septicaemia/sepsis	Septicaemia, sepsis
	Septic shock
Wound infection	Wound infection (post-caesarean)
	Wound infection (post-tear, post episiotomy)
Other postpartum infection	Endometritis
	Salpingitis

Categories	Available diagnoses
	Peritonitis
	Other postpartum infection
Malaria	Malaria
HIV	HIV
Other infection	Tuberculosis
	Meningitis
	Pneumonia
	Urinary tract infection
	Gastroenteritis
OTHER OBSTETRIC COMPLICATIONS	
Embolism	Pulmonary embolism
	Amniotic fluid embolism
Premature labour	Premature labour
Premature rupture of membranes	Premature rupture of membranes
False labour	False labour
Hyperemesis gravidarum	Hyperemesis gravidarum
OTHER NON-OBSTETRIC COMPLICATIONS	
Diabetes	Diabetes
Sickle cell disease	Sickle cell disease
Anaemia	ANY Anaemia
	Anaemia associated with malaria
	Anaemia associated with haemorrhage
	Anaemia associated with sickle cell disease
	Unspecified anaemia
Injury	ANY Injuries
	Assault
	Self-induced
	Snake bite
	Road traffic accident
	Other injury
Other non-obstetric complication	Asthma
	Cerebrovascular accident
	Epilepsy
	Hepatitis
	Other non-obstetric complication
FETAL COMPLICATIONS	
Fetal distress	Fetal distress
Meconium staining	Meconium staining
Amniotic fluid conditions	Hydramnios, Polyhydramnios
	Oligoamnios
Cord prolapse	Cord prolapse
Cord around the neck	Cord around the neck

Pregnancy-related death

Pregnancy-related death was defined in the ObaapaVitA trial as “the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of death," in accordance with the International Classification of Diseases version 10 (ICD-10) definition [166]. Pregnancy-related mortality was favoured over maternal mortality due to the known difficulties in ascertaining the cause of death and the lack of evidence regarding which non-obstetric causes are aggravated by pregnancy [166, 176, 177]. I calculated the pregnancy-related mortality ratio as the total number of deaths during pregnancy or within 42 days postpartum, divided by the total number of deliveries (live births and stillbirths after 22 weeks gestation). Deaths in early pregnancy were included in the calculation of pregnancy-related mortality as they are an important proportion of pregnancy-related deaths, even though they were not included in the main sample for this analysis.

Timing of pregnancy-related deaths

The timing of pregnancy-related deaths was ascertained based on several data sources. Postpartum deaths were classified into week 1, weeks 2-3 and weeks 4-6 after delivery based on the reported dates of delivery and death, which were obtained during monthly home visits, as well as hospital records for hospital deliveries. Women recorded as dying as a result of ectopic pregnancy or abortion were classified as deaths before 22 weeks gestation. Timing of deaths in pregnancy was ascertained by doctors based on VPM information; deaths thought to have occurred in the first trimester were categorised as deaths before 22 weeks, while those occurring in the second and third trimester were classified as deaths after 22 weeks (including the day of delivery). In cases where the timing of death relative to gestational age was unclear for the doctors after reviewing the VPM information, timing of death was ascertained based on the VPM report by friends or relatives of the deceased. It was not possible to distinguish women who died in labour among deaths after 22 weeks, since the doctors' assessment did not specify the labour status, and relatives' reports were considered unreliable. Estimated timings of death were not specific enough to allow for calculating pregnancy-related mortality ratios for distinct time periods during pregnancy and postpartum.

Classification of VPM and hospital causes of pregnancy-related death

Based on information collected in the VPM form, doctors assigned a single cause among 52 pre-coded causes to each pregnancy-related death, including an "Uncertain" category. In the hospital form, cause of death was coded as one of 19 options, including an "Unknown" category.

Table 4.3 presents the classification of cause of pregnancy-related deaths used in this study, based on the causes available in the hospital form and the VPM form. Individual causes were grouped into 27 broader categories. An attempt was made to group causes of death under headings consistent with the ICD-10 classification of causes of pregnancy-related death [178], though it was not possible to assign some available codes to the ICD-10 causes (for example, “infection-related excluding malaria” could correspond either to an indirect maternal or coincidental death). Some broad hospital causes of death were classified into more specific causes based on available complications data. Deaths from “haemorrhage” were classified as antepartum, postpartum, or timing unknown based on diagnoses; deaths “post-caesarean” were classified as deaths from anaemia if they had a diagnosis of anaemia (but no diagnosis of sepsis or haemorrhage); deaths coded as “infection-related excluding malaria” were recoded as deaths from HIV/AIDS or postpartum sepsis if they had a diagnosis of HIV or sepsis and died postpartum, respectively. The VPM cause of death was recoded to match the hospital cause of death in the event of discrepancies for women who died in hospital, because the hospital cause of death was considered more valid than that assigned based on VPM.

Table 4.3 Classification of cause of pregnancy-related deaths

Causes of death used in this study	Available causes – Hospital cause of death	Available causes – VPM cause of death
EARLY PREGNANCY LOSS		
Abortion	Induced abortion	Induced abortion
	Ectopic	Spontaneous abortion
	Molar pregnancy	Abortion, cause unknown
	Abortion, cause unknown	Other early pregnancy loss
DYSTOCIA		
Obstructed labour	Obstructed labour	Other obstructed labour (non-rupture)
HAEMORRHAGE		
Uterine rupture	Uterine rupture	Uterine rupture
Antepartum haemorrhage	Haemorrhage, with diagnosis of antepartum haemorrhage	Antepartum haemorrhage
Postpartum haemorrhage	Haemorrhage, with diagnosis of postpartum haemorrhage	Postpartum haemorrhage
Haemorrhage, timing unknown	Haemorrhage, with missing diagnosis of haemorrhage	Haemorrhage, timing unknown
HYPERTENSION		
Hypertension	Eclampsia	Hypertensive diseases of pregnancy
OTHER OBSTETRIC COMPLICATIONS		
Embolism	Pulmonary embolism	Pulmonary embolism
	Amniotic fluid embolism	Amniotic fluid embolism
COMPLICATIONS OF MANAGEMENT		
Post-caesarean	Post-caesarean, with no diagnosis of anaemia	-
Bowel obstruction	Bowel obstruction	-
INFECTION		
Postpartum sepsis	Infection-related excluding malaria, with diagnosis of postpartum sepsis	Sepsis after caesarean
		Other postpartum sepsis
Tetanus	-	Tetanus
Malaria	Malaria	Malaria
HIV/AIDS	Infection-related excluding malaria, with diagnosis of HIV infection	HIV/AIDS
Other infection (excluding sepsis, malaria and HIV/AIDS)	Infection-related excluding malaria, with no diagnosis of postpartum sepsis or HIV	Tuberculosis
		Meningitis
		Hepatitis
		Respiratory infection (not tuberculosis)
		Cellulitis
		Intestinal infection (including typhoid)
		Rabies
		Chicken pox
		Respiratory
Infection, cause unknown	-	Fever of unknown origin

Causes of death used in this study	Available causes – Hospital cause of death	Available causes – VPM cause of death
	-	Septicaemia, cause unknown
	-	Abscess
	-	Unknown infection
	-	Other infection
OTHER CAUSES		
Diabetes	-	Diabetes
Hepatorenal failure	-	Renal failure
		Liver failure
Sickle cell disease	Sickle cell crisis	Sickle cell disease
Anaemia	Severe anaemia Post-caesarean, with diagnosis of postpartum sepsis	Anaemia
Mental illness	-	Mental illness
Non-communicable disease	Chronic illness	Digestive disease
		Breast cancer
		Other cancer
		Epilepsy
		Cardiovascular disease
Injury	Injury related	External
UNKNOWN/UNDETERMINED		
Not known/no information	Not known, no information	Unattended death
		No respondent
Undetermined	Uncertain	Uncertain
		Acute abdomen
		Instantaneous death
		Death within 24hrs of symptoms
		No significant pathology
		Other non-infectious illness
		Other

Note: this table indicates which hospital and VPM causes of death (separately) are included under the joint classification of cause of death. Two hospital and VPM causes on the same line are not necessarily considered equivalent.

Stillbirth

Stillbirths were defined in the ObaapaVitA trial as any baby born dead after 22 weeks gestation, who did not move, cry or breathe after birth. Among hospital deliveries, stillbirths were ascertained from medical records based on the birth attendant's evaluation. Among other deliveries, stillbirths were ascertained by maternal report ["Was the baby born alive i.e. did it cry or move or breathe after birth?"]. The stillbirth rate was calculated as the ratio of stillbirths to all births (stillbirths and live births after 22 weeks).

4.2.7. Definition of exposures

Maternal age

Maternal age was calculated based on self-report on enrolment into the trial. Age at pregnancy was then calculated. In this analysis, age is classified in 5-year age groups, from 15-19 to 35-39, except for the last interval of 40 and above.

Ethnic group

Women were asked what ethnic group they belong to, with 12 response options including “Other”. Ethnic group was classified as “Akan” or “Other” because the Akan represented the largest and most privileged group in the study area.

Marital status

Women were asked “Are you currently single, married, or living with a man, or are you widowed, divorced or separated?” This variable was coded in the dataset into five categories (Married, Co-habitating, Widowed/divorced/separated, Single, Unknown).

Maternal education

Women were asked to report their highest educational level reached. The eight response options in the questionnaire were recoded into five categories in the dataset (None, Primary school, Secondary school, Post-secondary school, Unknown).

Wealth quintile

Wealth quintile was calculated according to the method used in the Demographic and Health Surveys for Ghana, as described by Gwatkin et al. [179] and in chapter 2 (section 2.1.3). In the ObaapaVitA study, asset scores were calculated using individual women as the unit of analysis (rather than households as in the DHS). Asset scores were calculated for the random sample of women of reproductive age on whom asset information was collected, and population level cut-offs for the wealth quintiles were calculated. Asset scores were then calculated for all pregnant women in the study area, and the population-level quintile cut-offs were used to assign each pregnant woman into wealth quintiles

District and area of residence

In the study area, women commonly move in the last few months of pregnancy, either to go back to their birth family's home for the delivery or to relatives who live in a major town, closer to health facilities. Location of residence (village or town) was ascertained in order to best estimate the location at the time of birth, as follows:

- For hospital deliveries, I used the location where the woman lived at the time of delivery (recorded in the hospital form).
- For deliveries outside of the district hospitals, I used the location where the woman lived at the first home visit after delivery (recorded in the routine visit form); if this information was missing, I used the location where the woman lived at the time of the last home visit before delivery.

Based on this location, district of residence was coded into the four districts covered by data collection at the start of the trial (Kintampo, Nkoranza, Techiman and Wenchi). Three of the districts were split into two over the course of the trial period; however, district continued to be recorded under four response categories (based on the four original district boundaries), in order to standardise the data collection and study identifiers.

Area of residence ("major town" or "small town or village") was ascertained for the same location based on the study team's classification.

4.2.8. Statistical analyses

In order to address the primary objectives of this chapter, the percentage of facility deliveries and caesareans, as well as the pregnancy-related mortality ratio, were calculated for all deliveries as well as stratified according to demographic characteristics (age, parity, ethnic group and marital status), socio-economic characteristics (maternal education and wealth quintile), and residence (district and area of residence). Maternal education and wealth quintile were cross-tabulated in order to assess overlap between these variables as a data quality check, and the distribution of deliveries according to wealth, education and urban-rural residence was described for each district in order to understand how these varied across the four districts.

Bivariate logistic regression models were used to calculate crude odds ratios for the association between the exposure variables and facility delivery, caesarean and pregnancy-related death separately. A multivariable model was then constructed for each outcome to examine the change in effect estimates and confidence intervals after adjusting for other variables. All socio-demographic and residence variables were included as explanatory variables in the multivariable models, and deliveries with missing explanatory or outcome data were excluded from the models. Some women had more than one delivery during the three-year study period (7.6% of deliveries in the sample were repeat deliveries); robust standard errors were used to calculate 95% confidence intervals in order to account for clustering at the woman level.

The secondary objectives of this chapter were addressed by describing the distribution of causes of pregnancy-related deaths, separately for all deaths and for deaths occurring in hospitals. In light of known limitations of cause of death ascertainment based on VPM (see section 4.4.2 below), the quality of VPM cause of death was assessed by cross-tabulating it with the timing of death (gestational age) in order to determine whether the two were coherent, and with hospital cause of death in order to examine the agreement between the two assigned causes of death for women who died in hospital. The prevalence of delivery complications was described among all hospital deliveries, and stratified according to education, in order to understand how differences in access to facility deliveries affect the case mix of women delivering in hospitals.

4.3. Results

4.3.1. Description of deliveries

There were 50,289 singleton and multiple deliveries after 22 weeks gestation in the study population between 1st June 2005 and 9th October 2008 to 46,484 women. Of these, 50,242 were live births and stillbirths occurring after 22 weeks and 47 were women who died undelivered in the second or third trimester of pregnancy. The stillbirth rate was 31.6 per 1,000 births.

Figure 4.2 describes the place of delivery for all deliveries in the sample. There were 20,517 (41%) reported home deliveries. 29,659 (59%) deliveries were reported to have occurred in a health facility, of which 14,929 (50.3%) were reported as deliveries in one of the four district hospitals in the study area. Of these 14,929 reported hospital deliveries, there were hospital records for 13,544 (90.7%) deliveries and no records for

1,385 (9.3%). These 1,385 deliveries were considered facility deliveries but were excluded from the sample of hospital deliveries. In addition, there were hospital records for 342 deliveries which were reported by women as having occurred elsewhere. For the purposes of this analysis, these were considered to have occurred in one of the four district hospitals in the study area, and were included in the hospital sub-sample. The hospital sample thus includes 13,886 deliveries.

The remaining facility deliveries (n=15,773) primarily occurred in government health centres (n=8,354). A substantial number of deliveries took place in private clinics (n=3,390, or 11% of the 29,659 reported facility deliveries). These facility deliveries include 328 deliveries in hospitals performing surgery outside the study area, and 88 deliveries in other hospitals without surgical capacity (including two private hospitals).

Figure 4.2 Description of selection for whole sample and sample of hospital deliveries

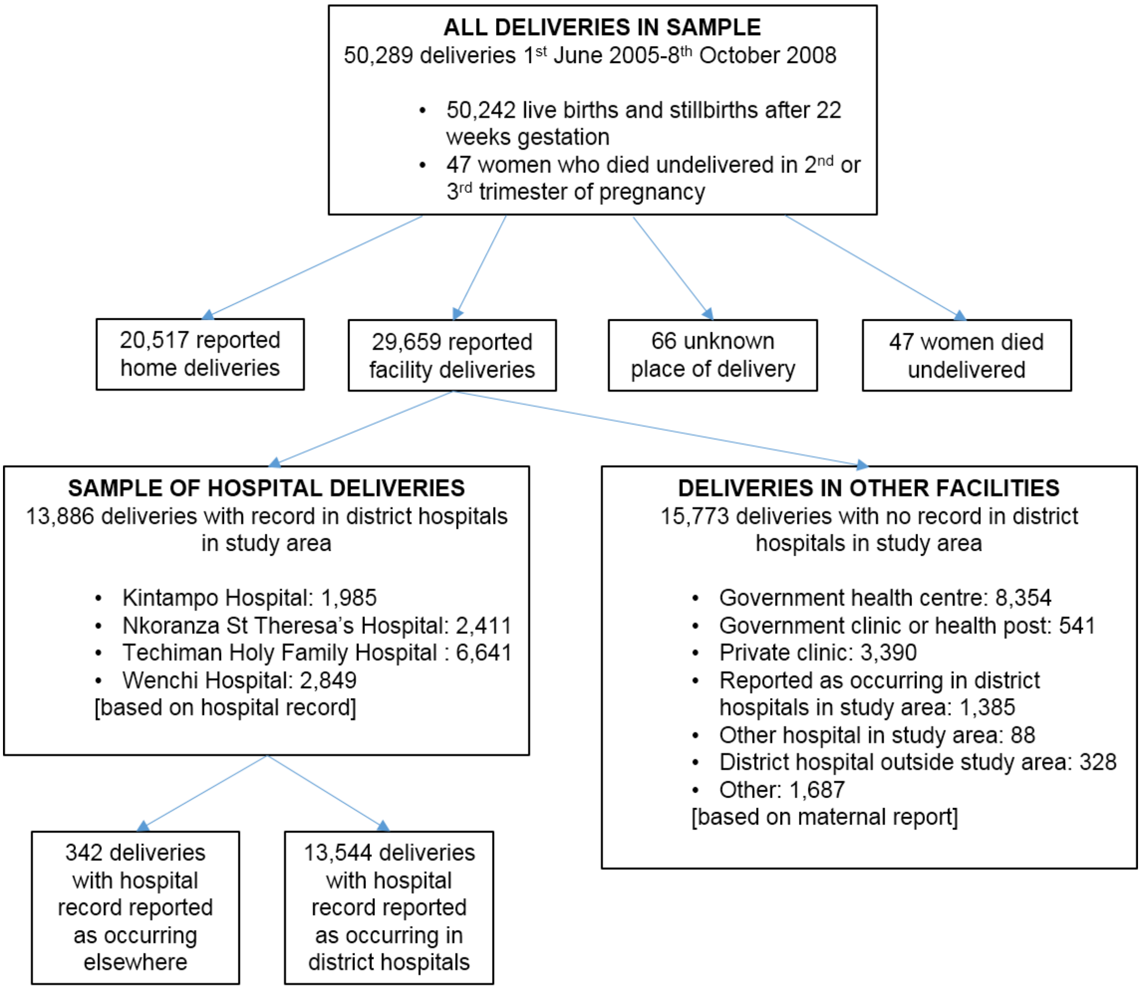


Table 4.4 presents the distribution of the sample according to maternal socio-economic characteristics in all 50,289 deliveries. More than half of deliveries in the sample (54%) were to women aged 20-29 at the time of delivery. One quarter of deliveries were to primiparas and more than 16% of deliveries were to women of parity five or above. The Akan were the largest ethnic group, representing 44% of deliveries. More than half of deliveries were to women who were married at the time of the pregnancy, and one third were co-habitating with their partner. Women who had reached secondary school represented the largest group (42%), though over a third of women had no education (37%). Less than 1% of women had received post-secondary education (n=469). There were 12,228 deliveries to women in the poorest quintile (24%), compared with 8,231 (16%) in the richest quintile. The level of missing data was very low for all socio-economic variables (at most 0.47% deliveries with missing information for wealth quintile).

All 13,886 hospital deliveries were classified according to their district of residence as recorded on the hospital form. Of the 36,403 deliveries outside the four district hospitals, 36,356 (99.9%) were classified according to district of residence at the first postnatal visit. The 47 women who died undelivered had missing postnatal district, and were classified according to district at the last home visit before delivery. Techiman district accounted for 30% of deliveries in the sample, Kintampo and Wenchi districts each for a quarter of deliveries, and Nkoranza for 20% of deliveries. The area of residence was predominantly small towns or villages (71% in the sample as a whole, n=14,504), except in Techiman district where half of women lived in Techiman town.

Table 4.4 also describes the socio-demographic distribution of deliveries according to place of delivery (hospital deliveries, other facility deliveries, and home deliveries). There was little difference in maternal age between the three groups of deliveries. Women who delivered in the district hospitals and other facilities were more likely to be primipara, and less likely to be of higher parity and from the Akan ethnic group, compared to women who delivered at home. Women delivering in facilities other than the district hospitals were less likely to be married than women delivering in hospital or at home.

Women delivering in hospitals tended to be better educated and have higher household wealth: 57% of women had received secondary or post-secondary education among hospital deliveries, compared to 52% among other facility deliveries and 27% among home deliveries. Among hospital deliveries, 9% of women belonged to the poorest quintile and 33% to the richest; these figures were 14% and 19% for deliveries in other facilities and 42% and 3% for home deliveries, respectively. Women delivering in the district hospitals were more likely to live in Techiman district, and substantially more likely to live in major towns than women delivering in other facilities or at home.

Table 4.4 Socio-demographic description of deliveries after 22 weeks gestation between 1st June 2005 and 8th October 2008 (N=50,289)

Characteristic		Total		Hospital deliveries	Other facility deliveries	Home deliveries
		N	%	%	%	%
Number of deliveries		50,289	-	13,886	15,773	20,517
Demographic characteristics						
Age at pregnancy	15-19	4,754	9.5	9.4	10.0	9.1
	20-24	13,303	26.5	24.9	27.8	26.5
	25-29	13,965	27.8	27.7	27.7	27.9
	30-34	10,184	20.3	21.3	19.4	20.2
	35-39	5,670	11.3	12.2	10.8	11.0
	40 and above	2,413	4.8	4.5	4.4	5.3
Parity	0	11,879	23.6	32.1	26.5	15.7
	1	10,193	20.3	20.8	21.7	18.9
	2	8,524	17.0	16.4	17.2	17.1
	3	6,484	12.9	11.6	12.0	14.5
	4	4,805	9.6	7.7	8.6	11.6
	5+	8,284	16.5	11.3	13.8	22.0
	Unknown	120	0.2	0.2	0.2	0.3
Ethnic group	Akan	22,199	44.1	57.1	49.3	31.4
	Other	27,969	55.6	42.7	50.5	68.3
	Unknown	121	0.2	0.2	0.3	0.3
Marital status	Married	29,531	58.7	59.5	53.3	62.4
	Co-habitating	16,166	32.1	31.3	36.1	29.6
	Widowed/Divorced	1,136	2.3	2.1	2.3	2.3
	Single	3,319	6.6	6.9	8.0	5.4
	Unknown	137	0.3	0.2	0.3	0.3
Socio-economic characteristics						
Highest educational level	None	18,465	36.7	24.3	27.7	52.0
	Primary	10,101	20.1	18.9	20.2	20.7
	Secondary	21,113	42.0	54.6	50.8	26.7
	Post-secondary	469	0.9	2.0	1.0	0.2
	Unknown	141	0.3	0.2	0.3	0.3
Household wealth quintile	Poorest	12,228	24.3	9.3	14.1	42.3
	Poorer	10,582	21.0	12.5	19.1	28.3
	Middle	9,820	19.5	18.7	24.0	16.7
	Richer	9,190	18.3	26.0	23.3	9.1
	Richest	8,231	16.4	33.3	18.6	3.2
	Unknown	238	0.5	0.3	0.8	0.4
Residence						
District of residence	Kintampo	12,477	24.8	17.7	17.4	35.3
	Nkoranza	9,928	19.7	18.4	18.6	21.5
	Techiman	15,095	30.0	43.3	32.9	18.8
	Wenchi	12,789	25.4	20.6	31.2	24.3
Area of residence	Major town	14,504	28.8	58.5	27.8	9.5
	Small town or village	35,785	71.2	41.5	72.2	90.5

Maternal education and wealth quintile were positively associated in the study population (Chi-square p-value<0.001), as expected, though non-negligible variation remained in educational attainment within each wealth quintile (Table 4.5). Sixty-five percent of deliveries in the poorest quintile were to women who had received no education, compared with 15% in the richest quintile. Among deliveries in the poorest quintile, only 15% occurred to women with secondary education, compared with 66% in the richest.

Table 4.5 Distribution of deliveries across educational category, according to wealth quintile

Maternal education	Wealth quintile				
	Poorest (n=12,228)	Poorer (n=10,582)	Middle (n=9,820)	Richer (n=9,190)	Richest (n=8,231)
No education	65.1	43.6	25.7	22.0	15.3
Primary	19.7	23.2	22.5	19.2	14.9
Secondary	15.0	32.8	51.3	57.7	65.6
Post-secondary	0.0	0.2	0.4	0.8	3.9

The wealth, educational and urban-rural distribution of deliveries also varied according to district of residence (p<0.001 for all, Table 4.6). Kintampo district had the largest percentage of deliveries in the poorest quintile (39.5%) and the smallest percentage in the richest quintile (8.3%), compared with 11.1% and 26.2%, respectively, in Techiman. Half (51.7%) of deliveries in Kintampo were to women with no education, while half were to women with secondary education in Nkoranza and Techiman (48.4% and 49.2%, respectively). Techiman also had the most urban population, with 48.4% of deliveries among women living in major towns, compared with 18.2-22.7% in the three other districts.

Table 4.6 Distribution of deliveries across wealth quintile, educational level and residence, according to district of residence

	Kintampo	Nkoranza	Techiman	Wenchi
Total deliveries	12,477	9,928	15,095	12,789
Wealth quintile				
Poorest	39.5	24.8	11.1	24.8
Poorer	27.4	20.5	15.1	22.2
Middle	14.2	25.1	20.2	19.6
Richer	10.4	16.5	27.1	17.0
Richest	8.3	13.0	26.2	15.3
Maternal education				
No education	51.7	27.5	30.1	37.0
Primary	19.3	23.0	19.2	19.7
Secondary	27.9	48.4	49.2	42.2
Post-secondary	0.7	0.9	1.2	0.9
Area of residence				
Major town	22.7	20.5	48.4	18.2
Small town or village	77.3	79.5	51.6	81.8

4.3.2. Determinants of facility deliveries

There were 29,659 facility deliveries, and the percentage of deliveries occurring in a health facility was 59%. Table 4.7 presents facility delivery rates stratified according to maternal socio-demographic characteristics, as well as the unadjusted and adjusted odds ratios of facility delivery. This analysis is based on the main sample of deliveries, and excludes 66 deliveries with missing information on place of delivery and 47 women who died undelivered, as well as deliveries with missing socio-demographic data.

Facility delivery rates varied by parity, ethnicity and marital status, but not by age. The percentage of facility deliveries increased sharply with educational level, from 42% among women with no education to 93% among those with post-secondary education. Similarly, facility delivery rates rose from 29% in the poorest quintile to 92% in the richest. There was wide variation according to district of residence, ranging from 42% facility deliveries in Kintampo to 74% in Techiman. Women living in major towns had almost double the percentage of facility deliveries compared with those living in small towns or villages (86% compared with 48%). This variation was also found within each district (see Figure 4.3 on page 135).

After controlling for socio-demographic and residence variables, the odds of facility delivery increased with age and decreased with parity, while the associations with ethnic group were maintained. The association between facility delivery and maternal socio-economic status showed a similar pattern in the unadjusted and multivariable models, though the odds ratios were reduced: after controlling for other risk factors, women with post-secondary education had 3.10 (95% CI: 2.15-4.46) times the odds of facility delivery of women with no education, and the adjusted odds ratio for facility delivery was 7.17 (95% CI: 6.45-7.97) in the richest quintile compared to the poorest. The relationship between facility delivery and residence was also maintained, with reduced magnitude.

Table 4.7 Crude and adjusted odds ratios of risk factors for facility delivery (n=49,834 in adjusted model)

Risk factor		N	% facility delivery	Crude odds ratio (95% CI)	Adjusted[a] odds ratio (95% CI)
Demographic characteristics					
Age group	15-19	4,740	61	1.07 (1.00-1.15)	0.91 (0.84-0.99)
	20-24	13,278	59	1 (ref)	1 (ref)
	25-29	13,936	59	0.99 (0.95-1.04)	1.26 (1.18-1.34)
	30-34	10,161	59	1.01 (0.95-1.06)	1.56 (1.44-1.68)
	35-39	5,654	60	1.04 (0.97-1.11)	1.89 (1.72-2.07)
	40 and above	2,408	55	0.85 (0.78-0.93)	1.91 (1.69-2.14)
Parity	0	11,858	73	1 (ref)	1 (ref)
	1	10,165	62	0.61 (0.57-0.64)	0.49 (0.46-0.53)
	2	8,502	59	0.53 (0.50-0.56)	0.42 (0.39-0.45)
	3	6,465	54	0.44 (0.41-0.47)	0.38 (0.34-0.41)
	4	4,797	50	0.38 (0.35-0.41)	0.36 (0.32-0.39)
	5+	8,269	45	0.31 (0.29-0.33)	0.36 (0.33-0.39)
	Unknown	120	53	-[b]	-[b]
Ethnic group	Akan	22,152	71	1 (ref)	1 (ref)
	Other	27,903	50	0.41 (0.39-0.42)	0.74 (0.70-0.79)
	Unknown	121	54	-[b]	-[b]
Marital status	Married	29,472	57	1 (ref)	1 (ref)
	Co-habitating	16,122	62	1.27 (1.22-1.32)	0.98 (0.92-1.03)
	Widowed / Divorced	1,131	57	1.03 (0.92-1.16)	0.84 (0.73-0.98)
	Single	3,317	67	1.55 (1.44-1.67)	1.11 (1.01-1.22)
	Unknown	137	53	-[b]	-[b]
Socio-economic characteristics					
Education	None	18,412	42	1 (ref)	1 (ref)
	Primary	10,075	58	1.89 (1.79-1.98)	1.33 (1.25-1.41)
	Secondary	21,079	74	3.92 (3.75-4.09)	1.73 (1.63-1.83)
	Post-secondary	469	93	18.20 (12.78-26.02)	3.10 (2.15-4.46)
	Unknown	141	52	-[b]	-[b]
Wealth quintile	Poorest	12,198	29	1 (ref)	1 (ref)
	Poorer	10,561	45	2.02 (1.91-2.14)	1.47 (1.38-1.56)
	Middle	9,802	65	4.61 (4.35-4.88)	2.38 (2.23-2.55)
	Richer	9,166	79	9.61 (9.00-10.3)	3.60 (3.34-3.89)
	Richest	8,215	92	28.50 (26.08-31.21)	7.17 (6.44-7.98)
	Unknown	238	68	-[b]	-[b]
Residence					
District	Kintampo	12,445	42	1 (ref)	1 (ref)
	Nkoranza	9,910	55	1.73 (1.64-1.83)	1.20 (1.12-1.28)
	Techiman	15,056	74	4.05 (3.84-4.26)	1.84 (1.73-1.96)
	Wenchi	12,765	61	2.17 (2.06-2.29)	1.87 (1.76-1.99)
Area of residence	Major town	14,468	86	6.92 (6.56-7.31)	3.12 (2.92-3.33)
	Small town or village	35,708	48	1 (ref)	1 (ref)

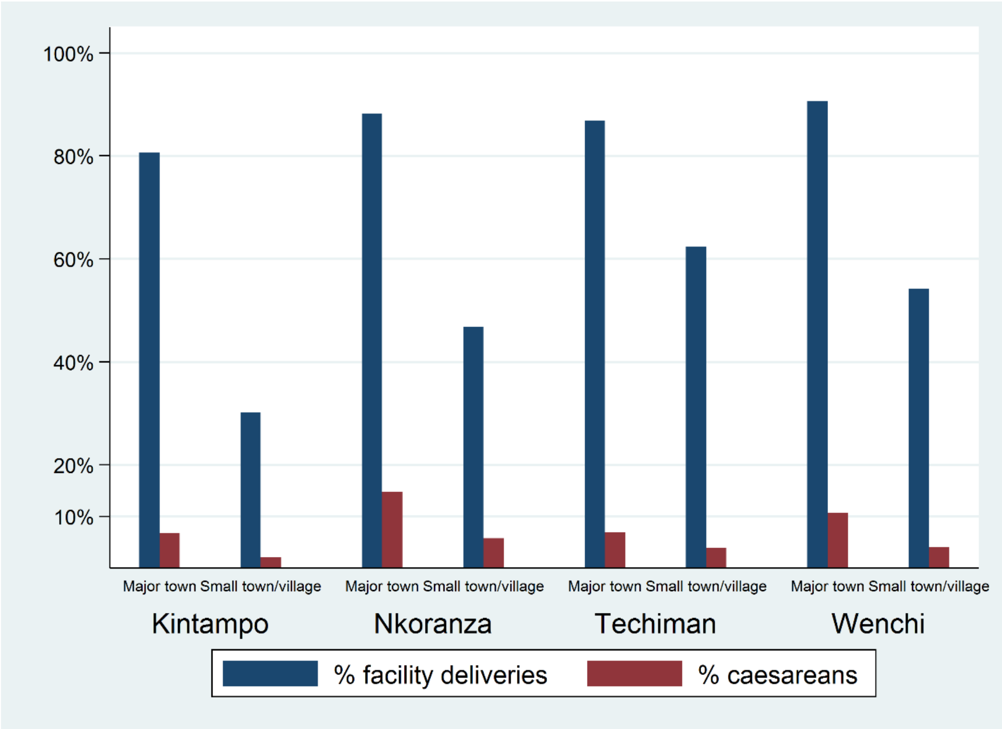
[a]The adjusted odds ratios control for all risk factors presented in this table
[b]Deliveries with missing socio-demographic information were excluded from the crude and adjusted models

4.3.3. Determinants of caesarean sections

There were 2,316 caesareans among hospital deliveries. An additional 366 women delivering in hospitals outside the study area reported having a caesarean, though 8 of these were recoded as vaginal deliveries because they were reported to have occurred at home, and 78 were recoded as missing because they were reported to have taken place in facilities not equipped to perform caesareans. The total number of caesareans was 2,596, yielding a caesarean rate of 5.2% among all deliveries. The caesarean rate in the district hospitals varied between 12% at Kintampo hospital, 14% at Techiman, 18% at Wenchi and 28% at Nkoranza hospital.

Table 4.8 presents caesarean rates according to maternal socio-demographic characteristics, as well as the crude and adjusted odds ratios for caesarean delivery. These analyses are based on the main sample of deliveries, but exclude 404 deliveries with missing information on mode of delivery. Deliveries with missing information for each socio-demographic variables were excluded from the corresponding bivariate model, and from the adjusted model. Caesarean rates varied according to parity and ethnic group. Caesarean rates increased steeply with maternal education, from 2.9% among women with no education to 14.3% among those with post-secondary education, and with household wealth quintile, from 2.3% in the poorest quintile to 9.9% in the richest. Caesarean rates varied substantially according to residence, between 3.1% in Kintampo district and 7.5% in Nkoranza, while women living in major towns had more than double the caesarean rate (8.6%) of small towns or villages (3.8%). As with facility deliveries, this variation was observed within districts (see Figure 4.3): the caesarean rate ranged from 2% in small towns in Kintampo district to 14% in major towns in Nkoranza district.

Figure 4.3 Percentage of facility deliveries and caesareans according to district and residence



After adjustment, women were increasingly likely to have a caesarean with older age but less likely to deliver by caesarean with rising parity, while the association with marital status was no longer significant. Similar to facility delivery, the odds ratio for caesarean section by maternal education, wealth quintile and rural-urban residence decreased, but remained significant at the 5% level. Women were more likely to deliver by caesarean if they lived in Nkoranza or Wenchi districts compared with Kintampo district.

Table 4.8 Crude and adjusted odds ratios of risk factors for caesarean section (n=49,587 in adjusted model)

Risk factor		N	% caesarean delivery	Crude odds ratio (95% CI)	Adjusted[a] odds ratio
Demographic characteristics					
Age group	15-19	4,726	4.6	0.98 (0.84-1.14)	0.81 (0.69-0.96)
	20-24	13,196	4.7	1 (ref)	1 (ref)
	25-29	13,859	5.1	1.08 (0.97-1.21)	1.43 (1.26-1.62)
	30-34	10,092	5.8	1.23 (1.10-1.39)	2.14 (1.84-2.49)
	35-39	5,621	5.7	1.21 (1.05-1.39)	2.56 (2.13-3.08)
	40 and above	2,391	5.2	1.10 (0.90-1.34)	2.76 (2.17-3.51)
Parity	0	11,769	7.5	1 (ref)	1 (ref)
	1	10,128	5.5	0.72 (0.65-0.80)	0.59 (0.52-0.67)
	2	8,460	4.8	0.62 (0.55-0.70)	0.44 (0.38-0.51)
	3	6,432	4.0	0.51 (0.44-0.59)	0.34 (0.29-0.40)
	4	4,774	3.7	0.48 (0.40-0.56)	0.32 (0.26-0.39)
	5+	8,234	3.5	0.45 (0.39-0.51)	0.32 (0.26-0.38)
	Unknown	120	5.0	-[b]	-[b]
Ethnic group	Akan	22,008	7.3	1 (ref)	1 (ref)
	Other	27,788	3.5	0.46 (0.42-0.50)	0.71 (0.63-0.79)
	Unknown	121	5.0	-[b]	-[b]
Marital status	Married	29,311	4.8	1 (ref)	1 (ref)
	Co-habitating	16,048	5.7	1.19 (1.09-1.29)	1.00 (0.90-1.10)
	Widowed / Divorced	1,122	5.0	1.04 (0.80-1.37)	0.99 (0.75-1.31)
	Single	3,310	5.5	1.13 (0.96-1.32)	0.99 (0.82-1.18)
	Unknown	137	6.6	-[b]	-[b]
Socio-economic characteristics					
Education	None	18,361	2.9	1 (ref)	1 (ref)
	Primary	10,017	4.6	1.62 (1.42-1.84)	1.19 (1.04-1.37)
	Secondary	20,937	7.2	2.57 (2.32-2.84)	1.34 (1.17-1.52)
	Post-secondary	461	14.3	5.60 (4.23-7.41)	1.68 (1.24-2.27)
	Unknown	141	4.3	-[b]	-[b]
Wealth quintile	Poorest	12,172	2.3	1 (ref)	1 (ref)
	Poorer	10,522	3.6	1.60 (1.36-1.87)	1.25 (1.07-1.48)
	Middle	9,758	5.4	2.50 (2.15-2.90)	1.50 (1.27-1.76)
	Richer	9,101	6.4	2.96 (2.56-3.43)	1.52 (1.28-1.80)
	Richest	8,133	9.9	4.82 (4.18-5.55)	1.87 (1.56-2.25)
	Unknown	238	2.9	-[b]	-[b]
Residence					
District	Kintampo	12,383	3.1	1 (ref)	1 (ref)
	Nkoranza	9,855	7.5	2.55 (2.24-2.90)	1.96 (1.71-2.25)
	Techiman	14,931	5.3	1.75 (1.54-1.98)	1.03 (0.90-1.18)
	Wenchi	12,716	5.2	1.71 (1.50-1.95)	1.49 (1.30-1.71)
Area of residence	Major town	14,328	8.6	2.35 (2.16-2.55)	1.78 (1.60-1.98)
	Small town or village	35,557	3.8	1 (ref)	1 (ref)

[a]The adjusted odds ratios control for all risk factors presented in this table
[b]Deliveries with missing socio-demographic information were excluded from the crude and adjusted models

4.3.4. Determinants of pregnancy-related deaths

There were 203 deaths during pregnancy (including first trimester), delivery or within 42 days postpartum, yielding a pregnancy-related mortality ratio of 404 per 100,000 deliveries (n=50,289). Table 4.9 presents pregnancy-related mortality stratified by maternal socio-demographic characteristics, as well as crude and adjusted odds ratios for pregnancy-related death. These analyses are based on the main sample plus all pregnancy-related deaths, including first trimester deaths. There were no missing data for pregnancy-related death, but deliveries with missing socio-demographic information were excluded from the adjusted model and corresponding bivariate analyses. In particular, 32 (16%) of the 203 deaths were excluded due to missing information on wealth quintile.

There was no clear trend in pregnancy-related mortality according to parity (see Table 4.9). Widowed, divorced and separated women had a substantially higher mortality ratio (968 per 100,000) compared to women of other marital status (318-512 per 100,000), as did women aged 40 or above (705 per 100,000 compared with 353 among 20-24 year-olds). Pregnancy-related mortality decreased with rising education, from 417 per 100,000 among women with no education to 213 among women with post-secondary education, though these differences were not significant. In contrast, mortality increased with household wealth, from 278 per 100,000 in the poorest quintile to 425 in the richest; these differences were also not statistically significant. There was some variation in pregnancy-related mortality across districts: compared with women living in Kintampo district, there was no difference in pregnancy-related death for Techiman district, though women were less likely to die in pregnancy or postpartum in Nkoranza and Wenchi districts. Women in major towns had a relatively higher mortality ratio than women in small towns and villages (489 per 100,000 compared with 368); there was weak evidence that this difference is statistically significant (p=0.053).

Pregnancy-related mortality was highest among subgroups where information on socio-economic variables was missing (including parity, ethnic group, marital status, maternal education, and household wealth quintile); in particular, it was 13,445 per 100,000 deliveries among the 238 deliveries with missing wealth quintile. Deliveries with missing socio-demographic information were excluded from the unadjusted and adjusted models.

After adjusting for socio-demographic variables, there was no association between pregnancy-related deaths and parity or ethnic group, while the elevated mortality risk among co-habitating and divorced women, and women aged 40 or more, became more pronounced. There continued to be no statistically significant association of pregnancy-related mortality with maternal education or wealth quintile. The association with district of residence was maintained, with lower odds of death for women living in Nkoranza and Wenchi districts than in Kintampo and Techiman districts. The increased likelihood of pregnancy-related death in major towns disappeared after controlling for other socio-demographic variables.

Table 4.9 Crude and adjusted odds ratios of risk factors for pregnancy-related death (n=49,972 in adjusted model)

Risk factor		N	PRMR[a] (per 100,000 deliveries)	Crude odds ratio (95% CI)	Adjusted[b] odds ratio
Demographic characteristics					
Age group	15-19	4,754	421	1.19 (0.70-2.01)	0.95 (0.47-1.91)
	20-24	13,303	353	1 (ref)	1 (ref)
	25-29	13,965	329	0.93 (0.62-1.40)	1.12 (0.65-1.92)
	30-34	10,184	501	1.42 (0.95-2.11)	1.79 (0.99-3.21)
	35-39	5,670	388	1.10 (0.66-1.82)	1.52 (0.70-3.28)
	40 and above	2,413	705	2.00 (1.15-3.48)	2.91 (1.30-6.52)
Parity	0	11,879	345	1 (ref)	1 (ref)
	1	10,193	441	1.28 (0.84-1.96)	1.30 (0.77-2.21)
	2	8,524	458	1.33 (0.86-2.06)	1.36 (0.76-2.44)
	3	6,484	386	1.12 (0.68-1.84)	1.12 (0.55-2.28)
	4	4,805	312	0.91 (0.50-1.64)	1.00 (0.45-2.23)
	5+	8,284	410	1.19 (0.75-1.88)	0.97 (0.45-2.08)
	Unknown	120	3,333	-[c]	-[c]
Ethnic group	Akan	22,199	459	1 (ref)	1 (ref)
	Other	27,969	347	0.75 (0.57-1.00)	0.89 (0.61-1.30)
	Unknown	121	3,306	-[c]	-[c]
Marital status	Married	29,531	318	1 (ref)	1 (ref)
	Co-habitating	16,166	427	1.34 (0.98-1.83)	1.82 (1.22-2.72)
	Widowed / Divorced	1,136	968	3.06 (1.63-5.72)	4.21 (2.11-8.41)
	Single	3,319	512	1.61 (0.96-2.70)	1.66 (0.76-3.61)
	Unknown	137	8,759	-[c]	-[c]
Socio-economic characteristics					
Education	None	18,465	417	1 (ref)	1 (ref)
	Primary	10,101	376	0.90 (0.61-1.33)	0.80 (0.50-1.30)
	Secondary	21,113	388	0.93 (0.68-1.27)	0.62 (0.39-1.00)
	Post-secondary	469	213	0.51 (0.07-3.66)	0.41 (0.06-2.96)
	Unknown	141	3,546	-[c]	-[c]
Wealth quintile	Poorest	12,228	278	1 (ref)	1 (ref)
	Poorer	10,582	331	1.19 (0.74-1.91)	1.17 (0.70-1.97)
	Middle	9,820	367	1.32 (0.82-2.11)	1.45 (0.83-2.53)
	Richer	9,190	337	1.21 (0.75-1.98)	1.28 (0.67-2.45)
	Richest	8,231	425	1.53 (0.96-2.46)	1.99 (0.99-3.98)
	Unknown	238	13,445	-[c]	-[c]
Residence					
District	Kintampo	12,477	489	1 (ref)	1 (ref)
	Nkoranza	9,928	332	0.68 (0.44-1.04)	0.57 (0.35-0.94)
	Techiman	15,095	464	0.95 (0.67-1.34)	0.72 (0.48-1.08)
	Wenchi	12,789	305	0.62 (0.42-0.93)	0.59 (0.37-0.94)
Area of residence	Major town	14,522	489	1.33 (1.00-1.77)	0.90 (0.57-1.44)
	Small town or village	35,827	368	1 (ref)	1 (ref)

[a]Pregnancy-related mortality ratio
[b]The adjusted odds ratios control for all risk factors presented in this table
[c]Deliveries with missing socio-demographic information were excluded from the crude and adjusted models

4.3.5. Timing and causes of pregnancy-related deaths in the population

Figure 4.4 presents the proportional distribution of all pregnancy-related deaths in the population according to time since delivery. Based on VPM ascertainment, 29% of pregnancy-related deaths occurred from 7 months gestation to the end of the pregnancy (including the day of delivery). One quarter of deaths were thought to have occurred before 7 months. Based on recorded dates of delivery and of death for those occurring after delivery, over one fifth of deaths took place in the first week postpartum; this percentage decreased with time since delivery. The timing of death was unknown for 6 of the 203 pregnancy-related deaths.

Figure 4.4 Timing of pregnancy-related deaths (N=203)

I cross-tabulated the hospital and VPM causes of death for women who died in hospital in order to examine the agreement between these causes (Table 4.10). The VPM and hospital cause of death were identical for 13 of the 37 deaths occurring in hospital, corresponding to 35% agreement between the two methods of ascertainment. Seven of the eight postpartum haemorrhage deaths in hospitals were identified as such in the VPM; however, none of the anaemia or HIV/AIDS deaths were coded as anaemia or HIV/AIDS, respectively, in the VPM. The VPM cause was recoded to match the hospital cause for these 24 women.

Table 4.10 Hospital and VPM cause of death for women who died in hospital (N=37)

Hospital cause of death		VPM cause of death																
		Ab	Obs lab	Ut rup	APH	PPH	H unk	Hyp	Bow obs	Emb	Sep	HIV	Oth inf	Anae	NCD	No inf	Und	**Total**
Ab	Abortion	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Obs lab	Obstructed labour	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Ut rup	Uterine rupture	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
APH	Antepartum haemorrhage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
PPH	Postpartum haemorrhage	0	0	0	0	7	0	0	0	1	0	0	0	0	0	0	0	**8**
H unk	Haemorrhage, timing unknown	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Hyp	Hypertension	0	0	1	0	0	0	1	0	0	2	0	0	0	0	0	1	**5**
Bow obs	Bowel obstruction	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	**2**
Emb	Embolism	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**0**
Sep	Postpartum sepsis	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	**2**
HIV	HIV/AIDS	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	**3**
Oth inf	Other infection (excluding sepsis, malaria and HIV)	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	**3**
Anae	Anaemia	0	0	1	0	0	0	1	0	0	2	0	0	0	0	0	0	**4**
NCD	Non-communicable disease	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
No inf	Not known/no information	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Und	Undetermined	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	**4**
	Total	**1**	**1**	**3**	**2**	**11**	**0**	**5**	**0**	**1**	**7**	**0**	**1**	**2**	**0**	**0**	**3**	**37**

Note: this table only shows causes for which there were recorded deaths; shaded boxes identify the same cause of death for hospital and VPM

Table 4.11 Cause of pregnancy-related deaths based on verbal post-mortem data

Cause of death	N	%
Early pregnancy loss		
Abortion	28	13.8
Dystocia		
Obstructed labour	2	1.0
Haemorrhage		
Uterine rupture	3	1.5
Antepartum haemorrhage	8	3.9
Postpartum haemorrhage	26	12.8
Haemorrhage, timing unknown	1	0.5
Hypertension		
Hypertension	19	9.4
Complications of management		
Post-caesarean	0	0.0
Bowel obstruction	2	1.0
Other obstetric complications		
Embolism	1	0.5
Infection		
Postpartum sepsis	18	8.9
Tetanus	0	0.0
Malaria	6	3.0
HIV/AIDS	11	5.4
Other infection (excluding sepsis, malaria and HIV/AIDS)[a]	14	6.9
Infection, cause unknown	4	2.0
Other causes		
Diabetes	0	0.0
Hepatorenal failure	2	1.0
Sickle cell disease	7	3.5
Anaemia	12	5.9
Mental illness	0	0.0
Non-communicable disease	8	3.9
Injury	3	1.5
Unknown/undetermined		
Not known/no information	1	0.5
Undetermined	27	13.3
Total	**203**	**100**

[a]Other infections include tuberculosis (1), meningitis (2), hepatitis (3), non-tuberculosis respiratory infection (1), intestinal infections (4) [VPM]; and infection-related excluding malaria (3) [hospital]
Note: cause of death was recoded to match the hospital cause for deaths occurring in hospitals

Table 4.11 presents the cause of death for pregnancy-related deaths as ascertained during the VPM, recoded based on hospital cause of death for the 24 women who died in hospital and had different recorded causes of death. The most common cause of death was haemorrhage, which was assigned as the cause in 17% of pregnancy-related deaths. Abortion (including all early pregnancy complications) was the second most prevalent cause, accounting for 14% of deaths, while hypertension and postpartum sepsis each accounted for 9% of deaths. The cause of death was undetermined in 27 (13%) of deaths.

I cross-tabulated the VPM cause of death with the estimated timing of pregnancy-related deaths in order to examine the coherence of these variables (Table 4.12). The causes of death appear to be largely coherent with the timings of individual complications: deaths from postpartum complications (such as postpartum haemorrhage and sepsis) occurred in late pregnancy – including the day of delivery – and postpartum, while deaths due to antepartum or intrapartum complications (such as obstructed labour, uterine rupture and antepartum haemorrhage) mostly took place in late pregnancy. One death from abortion was estimated to have occurred after 6 months gestation, which is inconsistent with the study definition of abortion as pregnancy losses before 22 weeks, though otherwise the timing and causes of death appear compatible. However, the fact that it was not possible to identify women who died in labour among those who died in late pregnancy limited the ability to assess the coherence of these data.

Table 4.12 VPM cause of death and timing of pregnancy-related deaths (N=203)

Cause of death	Timing unknown	1-6 months gestation	≥7 months gestation (inc. day of delivery)	Week 1 post-partum	Weeks 2-3 post-partum	Weeks 4-6 post-partum
Early pregnancy loss						
Abortion	0	19	1	6	0	2
Dystocia						
Obstructed labour	0	0	2	0	0	0
Haemorrhage						
Uterine rupture	0	0	1	2	0	0
Antepartum haemorrhage	0	2	6	0	0	0
Postpartum haemorrhage	0	0	14	9	3	0
Haemorrhage, timing unknown	0	0	1	0	0	0
Hypertension						
Hypertension	0	0	10	4	4	1
Complications of management						
Bowel obstruction	0	0	0	1	1	0
Other obstetric complications						
Embolism	0	0	0	1	0	0
Infection						
Postpartum sepsis	0	0	0	4	6	8
Malaria	0	2	3	1	0	0
HIV/AIDS	3	3	1	2	1	1
Other infection (excluding sepsis, malaria and HIV/AIDS)	1	9	1	3	0	0
Infection, cause unknown	1	2	1	0	0	0
Other causes						
Hepatorenal failure	1	0	0	1	0	0
Sickle cell disease	0	2	2	1	2	0
Anaemia	0	3	4	4	1	0
Non-communicable disease	0	2	3	0	0	3
Injury	0	2	1	0	0	0
Unknown/undetermined						
Not known/no information	0	0	0	0	1	0
Undetermined	0	5	8	8	5	1
Total	**6**	**51**	**59**	**47**	**24**	**16**

4.3.6. Complications among hospital deliveries

Among hospital deliveries, 70% of women (n=9,685) had no recorded complications, among whom the great majority (96%) were spontaneous vaginal deliveries; 193

instrumental vaginal deliveries and 159 caesareans (including 97 elective caesareans) did not have any recorded complications. Among the remaining 4,201 deliveries with any complication, 15% had one recorded complication, 9% had two recorded complications, and 6% had three or more recorded complications.

Table 4.13 presents the prevalence of obstetric complications among hospital deliveries, as recorded by diagnoses in the hospital records. Dystocia was the most common group of complications, affecting 13% of all hospital deliveries. Among these, cephalopelvic disproportion (including macrosomia) was the most common dystocic complication (5% of deliveries), and 1.6% of deliveries were diagnosed with obstructed labour. Haemorrhage occurred in 7% of hospital deliveries, with postpartum haemorrhage the most common type (5% of hospital deliveries). Hypertension affected 3.5% of hospital deliveries, including 0.6% with eclampsia. Malaria was the most common infection-related complication, with 3% prevalence at delivery among mothers. Pregnancy-related infection affected 0.7% of hospital deliveries altogether (including septicaemia/sepsis, wound infection and other postpartum infection). Less than 1% of women delivering in hospital had a clinical diagnosis of HIV-related illness. Anaemia was a common complication, occurring in 7% of hospital deliveries. Fetal complications were also common: 6% of births experienced meconium staining and an additional 3% experienced fetal distress.

The stillbirth rate was 48 per 1,000 births among hospital deliveries, which was evenly distributed between fresh and macerated stillbirths.

Table 4.13 Prevalence of obstetric complications among hospital deliveries (N=13,886)

Obstetric complication	N	%
Dystocia	1,851	13.3
Obstructed labour	216	1.6
Cephalopelvic disproportion	661	4.8
Cervical/vaginal dystocia	513	3.7
Prolonged labour (cause unspecified)	499	3.6
Breech presentation	155	1.1
Malpresentation	108	0.8
Other dystocia[a]	364	2.6
Haemorrhage	982	7.1
Uterine rupture or pre-rupture	59	0.4
Antepartum haemorrhage from major placenta praevia	16	0.1
Other antepartum haemorrhage	214	1.5
Postpartum haemorrhage	727	5.2
Hypertension	486	3.5
Pregnancy-induced hypertension	277	2.0
Pre-eclampsia	142	1.0
Eclampsia	84	0.6
Infection	630	4.5
Septicaemia/sepsis	34	0.2
Wound infection	50	0.4
Other postpartum infection[b]	19	0.1
Malaria	434	3.1
HIV-positive	98	0.7
Other infection[c]	102	0.7
Other obstetric complications	344	2.5
Embolism	1	0.0
Premature labour	150	1.1
Premature rupture of membranes	206	1.5
False labour	6	0.0
Hyperemesis gravidarum	2	0.0
Other non-obstetric complications	1,121	8.1
Diabetes	15	0.1
Sickle cell disease	29	0.2
Anaemia	993	7.2
Injury	7	0.1
Other non-obstetric complication[d]	127	0.9
Fetal complications	1,175	8.5
Fetal distress	395	2.8
Meconium staining	783	5.6
Amniotic fluid conditions	36	0.3
Cord prolapse	52	0.4
Cord around the neck	154	1.1
Any complication	**4,201**	**30.3**

[a]Other dystocia includes “shoulder dystocia” (10), “compound presentation” (28) and “other dystocia” (328), based on data extraction sheet

[b]Other postpartum infection includes “endometritis” (7), “peritonitis” (1) and “other postpartum infection” (11)

[c]Other infection includes “tuberculosis” (0), “meningitis” (1), “pneumonia” (21), “urinary tract infection” (76) and “gastroenteritis” (6)

[d]Other non-obstetric complication includes “asthma” (4), “cerebrovascular accident” (0), “epilepsy” (5), “hepatitis” (3) and “other non-obstetric complication” (115)

Table 4.14 presents the prevalence of delivery complications according to maternal education. This analysis excludes 141 deliveries with missing information on educational level. The percentage of complicated deliveries was similar among women with no, primary or post-secondary education (28-29%), but higher among women with secondary education (32%). More educated women were more likely to experience dystocia (p=0.004), however the prevalence of uterine rupture was highest among women with no education and lowest among women with post-secondary education (0.7% compared with no cases, respectively). Hypertension was also more common among more educated women, rising from 2.8% of hospital deliveries among women with no education to 4.4% among women with post-secondary education (p=0.042). This trend was predominantly driven by a rise in the prevalence of pregnancy-induced hypertension and pre-eclampsia with educational level, though the prevalence of eclampsia was lowest among women with post-secondary education (no cases of eclampsia, compared with 0.5-0.7% among deliveries to women with no, primary or secondary education). There was no educational difference in the prevalence of infection, other obstetric or non-obstetric complications, or fetal complications among hospital deliveries.

Table 4.14 Prevalence of obstetric complications by maternal education among hospital deliveries

Complication	Maternal education				Chi-square p-value
	No education (n=3,368)	*Primary (n=2,628)*	*Secondary (n=7,587)*	*Post-secondary (n=273)*	
Dystocia	11.6	13.1	14.1	13.9	0.004
Obstructed labour	1.5	1.6	1.5	2.6	0.567
Feto-pelvic disproportion	4.5	5.2	4.8	4.4	0.620
Cervical/vaginal dystocia	2.0	3.6	4.5	3.3	<0.001
Prolonged labour (cause unspecified)	3.2	3.9	3.6	4.0	0.560
Breech presentation	0.9	1.0	1.2	2.2	0.115
Malpresentation	0.9	0.8	0.7	0.7	0.759
Other dystocia	2.8	2.1	2.7	3.3	0.288
Haemorrhage	7.0	6.4	7.4	5.9	0.297
Uterine rupture or pre-rupture	0.7	0.2	0.4	0.0	0.052
Antepartum haemorrhage from major placenta praevia	0.2	0.0	0.1	0.4	0.254
Other antepartum haemorrhage	2.1	1.4	1.4	1.1	0.032
Postpartum haemorrhage	4.6	4.8	5.7	4.4	0.061
Hypertension	2.8	3.3	3.8	4.4	0.042
Pregnancy-induced hypertension	1.8	1.9	2.1	3.3	0.310
Pre-eclampsia	0.6	1.0	1.2	1.1	0.026
Eclampsia	0.5	0.5	0.7	0.0	0.395
Infection	3.9	4.4	4.9	4.8	0.204
Septicaemia/sepsis	0.4	0.3	0.2	0.0	0.374
Wound infection	0.4	0.5	0.3	0.0	0.474
Other postpartum infection	0.2	0.2	0.1	0.0	0.796
Malaria	2.8	3.2	3.3	3.3	0.548
HIV-positive	0.5	0.5	0.9	0.0	0.028
Other infection	0.7	0.7	0.7	1.5	0.566
Other obstetric complications	2.3	2.3	2.6	1.8	0.622
Embolism	0.0	0.0	0.0	0.0	0.233
Premature labour	1.0	1.1	1.1	0.7	0.926
Premature rupture of membranes	1.4	1.2	1.6	1.1	0.300
False labour	0.0	0.1	0.0	0.0	0.816
Hyperemesis gravidarum	0.0	0.0	0.0	0.0	0.808
Other non-obstetric complications	8.1	7.3	8.3	6.6	0.336
Diabetes	0.0	0.0	0.2	0.0	0.026
Sickle cell disease	0.1	0.3	0.2	0.4	0.545
Anaemia	7.3	6.6	7.4	4.4	0.183
Injury	0.0	0.1	0.0	0.0	0.438
Other non-obstetric complication	1.2	0.6	0.9	1.8	0.040
Fetal complications	8.6	7.6	8.7	8.8	0.388
Fetal distress	2.6	2.3	3.1	2.6	0.150
Meconium staining	5.7	5.0	5.8	7.0	0.351
Amniotic fluid conditions	0.4	0.3	0.2	0.0	0.126
Cord prolapse	0.5	0.4	0.3	0.0	0.397
Cord around the neck	1.0	1.0	1.1	1.5	0.868
Any complication	**28.4**	**29.0**	**31.6**	**28.2**	**0.002**

4.3.7. Distribution of pregnancy-related deaths among hospital deliveries

There were 46 deaths among the 13,886 hospital deliveries, giving a pregnancy-related mortality ratio of 330 per 100,000 births in hospital. Of these 46 deaths, 37 occurred before discharge from the hospital and have a cause of death assigned by doctors. The remaining 9 women were alive at discharge and died several weeks after leaving the hospital.

Table 4.15 presents the causes of the 37 pregnancy-related deaths recorded in hospital notes. As with cause of death assigned after verbal post-mortem, haemorrhage was the most common cause, accounting for 9 of the 37 pregnancy-related deaths in hospital. The second most common cause was hypertension (n=5), followed by anaemia (n=4). No deaths occurring in the district hospitals were due to antepartum haemorrhage or obstructed labour. The cause of death was unknown for one hospital death, and undetermined in 4 of the 37 deaths.

Table 4.15 Cause of pregnancy-related deaths based on hospital records (N=37)

Cause of death	**N**	**%**
Early pregnancy loss		
Abortion	1	2.7
Dystocia		
Obstructed labour	0	0.0
Haemorrhage		
Uterine rupture	1	2.7
Antepartum haemorrhage	0	0.0
Postpartum haemorrhage	8	21.6
Haemorrhage, timing unknown	1	2.7
Hypertension		
Hypertension	5	13.5
Other obstetric complications		
Embolism	1	2.7
Complications of management		
Post-caesarean	0	0.0
Bowel obstruction	2	5.4
Infection		
Postpartum sepsis	2	5.4
Tetanus	0	0.0
Malaria	0	0.0
HIV/AIDS	3	8.1
Other infection (excluding sepsis, malaria and HIV/AIDS)	3	8.1
Infection, cause unknown	0	0.0
Other causes		
Diabetes	0	0.0
Hepatorenal failure	0	0.0
Sickle cell disease	0	0.0
Anaemia	4	10.8
Mental illness	0	0.0
Non-communicable disease	1	2.7
Injury	0	0.0
Unknown/undetermined		
Not known/no information	1	2.7
Undetermined	4	10.8
Total	**37**	**100**

4.4. Discussion

4.4.1. Summary of main findings

In the four study districts in central Ghana between 2005 and 2008, 59% of deliveries occurred in a health facility and the caesarean rate was 5.2%; these estimates are similar to the 2008 DHS estimates for Brong-Ahafo [164]. The pregnancy-related mortality ratio of 404 per 100,000 births is comparable to maternal mortality estimates for Ghana and Brong-Ahafo [169, 180]; it was slightly higher than the pregnancy-related mortality found for the whole duration of the ObaapaVitA trial, though the trial reported mortality as a ratio of all pregnancies [175], rather than all deliveries. The main causes of pregnancy-related deaths in the population (haemorrhage, abortion, and hypertension) were consistent with findings from the national Ghana Maternal Health Survey in 2007 [181], and a WHO systematic review which attributed one quarter of maternal deaths to haemorrhage in sub-Saharan Africa [42].

Higher education, greater household wealth and living in a major town were important determinants of both health facility delivery and caesarean section, but were not associated with the pregnancy-related mortality ratio. Women residing in Kintampo district, which had the lowest rates of facility deliveries and caesareans (42% and 3% respectively), had higher pregnancy-related mortality than in other districts. Co-habitating and divorced/widowed women also had higher pregnancy-related mortality than married women, even after adjusting for other socio-demographic characteristics.

Delivery complications occurred in one third (30%) of hospital deliveries, and dystocia was the most common complication type. The prevalence of any delivery complication among hospital deliveries showed no clear trend with education; however antepartum haemorrhage, uterine rupture and eclampsia were more common among deliveries to women with less education, while pre-eclampsia was more prevalent in more educated groups.

4.4.2. Interpretation

The lack of association of pregnancy-related mortality with maternal education and wealth was surprising, considering both variables were strong predictors of facility deliveries and caesareans in Brong-Ahafo, as previously found in Ghana [164] and throughout sub-Saharan Africa [108]. The larger mortality differences by marital status and district were significant at the 5% level: the higher mortality observed in Kintampo district is consistent with the fact that this district had the lowest facility delivery and caesarean rates, however widowed and cohabitating women had similar delivery care utilisation rates to married women, which cannot explain the higher mortality in these groups. The lack of association with wealth and education is unlikely to be due to confounding, since it was maintained after adjusting for other maternal characteristics. This study may not have been powered to detect mortality differences between the highest and lowest wealth and educational groups, since these differences are smaller than those for district and marital status (particularly considering the small number of deliveries among women with post-secondary education). The lack of association may also be due to bias in the ascertainment of pregnancy-related deaths or socio-economic status: women with missing socio-demographic data had high rates of pregnancy-related mortality, probably because data collection sometimes occurred after delivery and women who died were therefore less likely to have that information collected. In particular, missing data for household wealth in 16% of pregnancy-related deaths is likely to have contributed to the borderline significant positive association between wealth quintile and mortality. If all deaths with missing quintile were assumed to have occurred in the poorest quintile, the association between wealth and pregnancy-related mortality would disappear. Though the surveillance of deaths in the study area is thought to have been strong, it is possible that deaths may have been less likely to be captured among poor and less educated women, leading to underestimating mortality in these groups.

On the other hand, the observed lack of association of pregnancy-related mortality with maternal education and wealth may be real. There is growing evidence that delivering in a facility may not be associated with lower pregnancy-related mortality, particularly in contexts where the quality of delivery care is poor. Population-based studies have consistently found a strong negative association between facility delivery and distance to health facility in Burkina Faso [182], Zambia [183], Tanzania [184, 185] and Bangladesh [186]. However, while two studies in urban India and rural Guinea-Bissau found evidence of higher maternal mortality with longer distance to facility [187, 188], others found no association with distance in Pakistan [189] and Burkina Faso [190]. In southern Tanzania, the trend of increasing maternal mortality with distance to hospital was more pronounced when including direct obstetric deaths only, but no such trend was observed with distance to first-line facilities [184]. These findings suggest that, while socio-economic and residence characteristics may be associated with the utilisation of delivery care, these might not translate into mortality differences in settings where the quality of emergency obstetric care is low, such as in Brong-Ahafo [174].

Several studies have reported the prevalence of obstetric complications among deliveries in selected facilities. In a large urban maternity hospital in Sudan, fewer than 1% of deliveries were found to develop antepartum or postpartum haemorrhage, or eclampsia in 2007, while pre-eclampsia occurred in approximately 2% of deliveries [191]. The estimates for hypertensive diseases are similar to those found in this study, though antepartum and postpartum haemorrhage were more frequent in hospitals in Brong-Ahafo. A population-based cohort study in Senegal found a much higher prevalence of obstetric complication among facility deliveries in two areas: between 21-32% for obstructed labour, 18-46% for antepartum haemorrhage and 14-30% for pre-eclampsia [192]. This higher prevalence was not explained by a lower facility delivery rate, which was similar or higher in both study areas than in Brong-Ahafo (57% and 70%), though it is likely to be partly explained by differences in definitions of obstetric complications between studies.

To the best of my knowledge, this is the first study to compare the prevalence of obstetric complications among hospital deliveries according to maternal education, which is not routinely recorded in many low-income settings. The lack of a clear trend in the prevalence of complications at birth with maternal education was not expected, considering the educational gradient in facility delivery rates. Nonetheless, differences in the prevalence of some complications reflect differences in access to delivery care. The higher prevalence of uterine rupture among less educated women suggests that these women may have been delayed in reaching the hospital after an obstructed labour. Pre-eclampsia was more common among more educated women, but no women with post-secondary education had eclampsia. More educated women are more likely to be overweight and suffer from hypertension (38% of women with secondary education and 47% in the richest quintile were found to be overweight or obese in the Ghana 2008 DHS [164]), but pre-eclampsia is less likely to progress to eclampsia than among less educated women, perhaps because the symptoms of hypertension are subtle and require good access to antenatal and delivery care in order to be detected and kept under control [193].

4.4.3. Strengths and limitations

Data source

The major strength of the ObaapaVitA dataset lies in having linked clinical information from hospitals to socio-economic and residence characteristics for a defined population; to my knowledge, this is the first study to have combined both data sources: this allowed me to describe obstetric complications according to maternal socio-economic status among hospital deliveries, and interpret these findings in relation to population-based indicators of delivery care utilisation. In addition, the large number of deliveries in this sample (n=50,289) is a major asset of this dataset.

It was not possible to match all reported births reported to occur in district hospitals to a hospital record. Approximately 9% of women who reported delivering in a study hospital do not have a record there, either because women misreported the place of delivery, or because they were not linked to their population-based records (women may not have been identified as study participants, study staff may not have found the correct identification number based on the information provided, and other women may have used study participants' identity cards in the belief that it would guarantee access to care; L Hurt, personal communication). Data were not available on hospital deliveries in neighbouring districts, but these represent less than 1% of facility deliveries in the four study districts, and would have been unlikely to change the interpretation of results. Information was also not collected from health centres and maternity homes, and the prevalence of obstetric complications may have been lower if all facilities had been included (assuming that the prevalence of complications is lower in first-line facilities).

The agreement between hospital and VPM cause of death was low (35%) for women who died in hospital, similar to other studies in Kenya [194], and a high proportion of deaths were reported to have occurred in early pregnancy, contrary to the expectation that most deaths occur in late pregnancy or the first week postpartum [195]. There are known issues with the quality of cause of death data derived from verbal autopsy at the individual level, compared with hospital cause of death as gold standard [194, 196, 197], suggesting that these findings should be interpreted with caution.

As mentioned in chapter 2, there are concerns with assessing relative wealth based on a household asset index. Constructing a single index from different types of assets makes it unclear exactly what dimension of socio-economic status is measured, and wealth indices demonstrate only modest agreement with consumption expenditure [130, 131]. More importantly, the wealth index used in this study was constructed based on a random sample of the female population of reproductive age in the four study districts, rather than in Ghana as a whole. It is unclear how well an index based on variation in household assets can capture differences in wealth within a fairly homogeneous and predominantly rural population, and the absolute magnitude of wealth differences between quintiles is unknown.

Logistic regression

The odds ratio is a good approximation of the risk ratio when the outcome is rare [198]. As the percentage of caesarean deliveries was around 5%, the odds ratios are likely to be reasonably similar to the risk ratios; however, they substantially overestimate the risk ratios for facility delivery since it is a much more common outcome. Logistic regression was chosen over binomial log-linear regression models of risk ratios because the latter are computationally intensive and do not always converge when a large number of covariates are included. However, caution should be taken in the interpretation of the odds ratios.

Around 8% of deliveries in the population were repeat deliveries, and 3,776 of 46,542 women contributed more than one birth to the sample over the three-year study period; robust standard errors were to used calculate 95% confidence intervals in the logistic regression models to correct for this clustering.

4.5. Conclusion

In Brong-Ahafo, there was a large gradient in facility delivery and caesarean rates according to maternal education, relative wealth, and district and area of residence. However, there was no evidence that pregnancy-related mortality varied according to these characteristics in the study area, though mortality was higher in Kintampo district and among widowed/divorced women. This suggests that delivering in facilities in Brong-Ahafo may not lower the risk of pregnancy-related mortality. The prevalence of dystocia and hypertension among hospital deliveries increased with education, though severe complications (uterine rupture and eclampsia) were absent among women with post-secondary education, reflecting better access to care in this group.

Chapter 5. Validation of the Unmet Obstetric Need approach

The literature review in chapter 1 presented the Unmet Obstetric Need approach for measuring the unmet need for obstetric surgery, using the concept of absolute maternal indications. Chapter 5 addresses objective 3.2 of this thesis, by validating the Unmet Obstetric Need indicator.

In this chapter, I begin by presenting the definitions of absolute maternal indications used in this analysis. The validation of the Unmet Obstetric Need indicator is carried out in two samples: among hospital deliveries, I assess whether absolute maternal indications are “absolute” by analysing the percentage of these deliveries receiving surgery, and resulting in the death of the woman among those not receiving surgery. At the population level, the indicator is validated by determining whether the sum of deliveries receiving surgery for absolute maternal indications and of pregnancy-related deaths from these causes accounts for 1.4% of deliveries across educational subgroups.

5.1. Introduction

5.1.1. Rationale for validating the Unmet Obstetric Need approach

The Unmet Obstetric Need (UON) approach to measuring the unmet need for life-saving obstetric surgery was described in chapter 1 (section 1.3.2), including the concept of absolute maternal indications (AMIs) thought to require surgery to avert the death of the mother. The UON indicator is calculated as the expected proportion of all deliveries which develop an AMI but do not receive surgery, and this shortfall is interpreted as the mortality from these complications attributable to the lack of access to surgery.

The two main assumptions underlying the UON approach are (1) that women with an AMI will die without receiving surgery (i.e. they are absolute), and (2) that 1.4% of deliveries across populations will develop an AMI; neither of these assumptions has been demonstrated to be valid. First, it is unclear whether AMIs are indeed “absolute” complications, that is, that women with AMIs will necessarily die without surgery. The AMI complications were selected based on clinical evidence: for example, women with complete placenta praevia (where the placenta blocks the cervix) have low chances of delivering safely and experience high mortality with vaginal delivery, however there is no epidemiological evidence that all women with AMIs who do not receive surgery necessarily die.

Second, while the concept of AMIs may be valid, there are concerns related to misclassifying surgeries for non-life threatening complications as surgeries for AMIs. In particular, major cephalopelvic disproportion (where vaginal delivery is impossible) is difficult to distinguish from prolonged labour (where vaginal delivery is possible, but the fetus may suffer adverse outcomes) among caesarean deliveries [199].

Third, in addition to conceptual and misclassification issues, the prevalence of AMIs at birth has not been validated, nor has the assumption that this prevalence varies little across groups or over time. The 1.4% threshold was suggested by the UON on the basis of observed rates of surgery for AMIs in areas thought to have good access to care. In four countries that carried out UON assessments (Benin, Burkina Faso, Mali and Niger), the median percentage of deliveries receiving surgery for AMIs was 1.4% (95% CI: 1.27-1.52%) in urban areas with functioning surgical hospitals [41]. The UON Network interprets this figure as “a sensible low-end estimate of the proportion of deliveries that require a major obstetric intervention to avoid a maternal death” [200].

This estimate was considered consistent with maternal mortality ratios of 900 to 2,200 per 100,000 births (0.9-2.2%) in populations without access to surgery, and with a caesarean rate of less than 2% in the Netherlands in 1968 when maternal mortality was around 20 per 100,000 births [30]. Nonetheless, the percentage of facility deliveries in these urban areas is not reported [41], and surgeries for AMIs in these studies may also be subject to misclassification. As a result, the true proportion of deliveries with AMIs may be either underestimated or overestimated.

5.1.2. Validation approach

The UON indicator and its interpretation have not yet been proven to be valid. A previous validation study in Bangladesh concluded that low rates of surgery for AMIs could not be interpreted as indicating excess mortality from these causes, and found evidence of misclassification of surgeries for less severe complications as surgeries for AMIs [50]. It is important to repeat this validation study in order to determine whether misclassification is also an issue in sub-Saharan Africa and whether the UON indicator is valid in a different setting.

The first assumption can be validated in two different samples: among hospital deliveries, the “absoluteness” of AMIs can be assessed by determining what proportion of AMIs receive surgery (an indication of whether obstetric care providers consider them absolute), as well as whether AMIs that do not receive surgery always result in the death of the woman. At the population level, we can test whether deaths from AMIs compensate for the expected shortfall in surgeries for AMIs, that is, whether the sum of surgeries for AMIs and of pregnancy-related deaths from AMI-related causes accounts for a constant percentage of deliveries across different subgroups of women. This population-based analysis would also allow us to test the second assumption – that 1.4% of deliveries develop AMIs – by determining whether this sum is equal to 1.4% across subgroups.

5.1.3. Objectives

The aim of this study was to validate the Unmet Obstetric Need indicator for measuring the unmet need for obstetric surgery in Ghana. Specific objectives of this analysis were to:

1) Construct a definition of AMIs based on diagnoses and indications recorded in hospital notes in the ObaapaVitA population;

2) Determine the variation in the percentage of hospital deliveries with AMIs across educational subgroups;
3) Examine the absoluteness of AMIs among hospital deliveries, by assessing the percentage of AMIs receiving surgery and the number of deaths among those that did not receive surgery;
4) Assess the absoluteness of AMIs at the population level, by determining whether the sum of pregnancy-related deaths from AMIs and surgeries for AMIs represent a constant percentage of deliveries across educational subgroups; and
5) Determine whether this percentage is equal to 1.4% of deliveries across educational subgroups.

5.2. Methods

A full description of the study population and definitions (including pregnancy-related mortality ratio) is provided in section 4.2. Additional methods specific to the following analysis are described below.

5.2.1. Definition of absolute maternal indications

The Unmet Obstetric Need Network's definition of AMI consists of the following complications:

- severe ante-partum haemorrhages caused by a placenta praevia or a retro-placental haematoma;
- incoercible post-partum haemorrhages;
- major foeto-pelvic disproportions (due to a narrow pelvis or a hydrocephaly);
- transverse positions (shoulders neglected);
- face presentations.

[201]

I categorised deliveries in the ObaapaVitA hospital sample based on this classification, with minor alterations. Uterine rupture and pre-rupture are complications resulting from major feto-pelvic disproportion, and were included as a distinct AMI category [49]. I additionally grouped transverse lie and face presentation under "malpresentation" to avoid very small groups. Therefore, I constructed definitions for five types of AMIs:

1) Severe antepartum haemorrhage;
2) Incoercible postpartum haemorrhage;
3) Uterine rupture or pre-rupture;

4) Major cephalopelvic disproportion; and
5) Malpresentation.

Among hospital deliveries, two sources of clinical data could be used to identify AMIs: diagnoses of delivery complications and indications for obstetric surgery (the complications or conditions for which the woman was considered to need surgery). Both diagnosis and indication data were used to construct a combined definition of AMIs, though I also compared the cases of AMIs included under diagnosis- and indications-based definitions in order to examine their agreement. For example, obstetric providers may have forgotten to write down all diagnoses before an emergency caesarean, but have recorded the indication appropriately after the intervention; conversely, indications may be poorly recorded [202] (this issue will be discussed in more detail in chapter 6).

Because of the potential misclassification of diagnoses and indications, and because the variables available in the ObaapaVitA dataset did not exactly match the AMIs defined above, I constructed two definitions: a strict definition, with high specificity but low sensitivity, and a broad definition, with high sensitivity but lower specificity. The strict definition is predicted to include more severe complications (and therefore be more “absolute”), but to underestimate the prevalence of AMIs and of surgeries for AMIs, while the broad definition is predicted to include some non-absolute complications, and this to overestimate the prevalence of AMIs.

Table 5.1 presents the strict and broad definitions of AMIs used, which was devised following consultations with three obstetricians.

Severe antepartum haemorrhage

Only deliveries with a recorded diagnosis of major placenta praevia (partial or complete placenta praevia) were included in the strict definition of AMIs. All diagnoses of antepartum haemorrhage, including with unspecified cause, were included in the broad definition. Indications for surgery did not distinguish the severity of the placenta praevia, and “antepartum haemorrhage due to placenta praevia” was included in the strict definition, while indications of placental abruption and unspecified antepartum haemorrhage were included in the broad definition.

Incoercible postpartum haemorrhage

The strict and broad definition of incoercible postpartum haemorrhage included all hysterectomies, regardless of recorded diagnosis or indication, since emergency peripartum hysterectomy is usually performed in response to life-threatening intractable postpartum haemorrhage [203]. Cases of postpartum haemorrhage without hysterectomy were not included in either of the definitions of AMIs, since subjective evaluation of the volume of blood loss is known to be unreliable [204] and 33% of women with postpartum haemorrhage had no information on blood loss volume.

Uterine rupture

There were two available codes for uterine rupture and pre-uterine rupture. Pre-uterine rupture is defined in the ObaapaVitA trial as a threatened uterine rupture, with a visible Bandl's ring, indicating that the woman should be attended to as an emergency. I included both pre-uterine and uterine rupture (as diagnoses and indications) in the strict and broad definitions of AMI.

Malpresentation

Transverse lie and brow presentation were the only malpresentations included in the strict diagnosis- and indication-based definitions, since it is not possible to deliver these fetuses vaginally. Oblique lie, face presentation and compound presentation (where the baby's arm presents alongside the head) were additionally included in the broad definition of AMIs, because they occasionally result in obstructed labour and require surgery to save the mother's life.

Major cephalopelvic disproportion

Obstructed labour was available as a diagnosis but not an indication, and I included it under the strict and broad diagnosis-based definitions. Cephalopelvic disproportion was available as both a diagnosis and an indication, however I only included it under the broad definitions of AMIs since the severity of the disproportion was not specified. Similarly, deliveries with macrosomia were classified as major cephalopelvic disproportion in the broad AMI definition. All craniotomies, embryotomies and symphysiotomies were included under the strict and broad definitions of major cephalopelvic disproportion, since these interventions are only used in the case of obstructed labour (see section 5.2.2. below).

Dealing with multiple AMIs

A single AMI was assigned to deliveries receiving surgery for AMIs, in order to examine whether the type of AMIs varied according to education. Deliveries with multiple AMIs (ascertained according to the definitions above) were classified hierarchically in the following order: uterine rupture, incoercible postpartum haemorrhage, severe antepartum haemorrhage, malpresentation, and major cephalopelvic disproportion. This hierarchy was chosen with the aim of distinguishing surgeries for major cephalopelvic disproportion but no other AMI.

Table 5.1 Strict and broad definitions of absolute maternal indications, using hospital diagnoses and recorded indications for surgery

Hospital diagnosis	Strict	Broad	Indication for Major Obstetric Interventions	Strict	Broad
Severe antepartum haemorrhage					
Low lying placenta, placenta praevia types I or II		✓	Antepartum haemorrhage due to placenta praevia	✓	✓
Partial placenta praevia, placenta praevia type III	✓	✓	Antepartum haemorrhage due to placental abruption		✓
Complete placenta praevia, placenta praevia type IV	✓	✓	Antepartum haemorrhage, cause unspecified		✓
Unspecified placenta praevia		✓			
Placental abruption		✓			
Unspecified antepartum haemorrhage		✓			
Incoercible postpartum haemorrhage (Any hysterectomy, for strict and broad definitions)					
Uterine atony	✓	✓	Postpartum haemorrhage	✓	✓
Retained placenta	✓	✓	Inverted uterus	✓	✓
Retained products	✓	✓	Any hysterectomy	✓	✓
Placenta accreta	✓	✓			
Inverted uterus	✓	✓			
Perineal tear	✓	✓			
Vaginal tear	✓	✓			
Cervical tear	✓	✓			
Unspecified postpartum haemorrhage	✓	✓			
Any hysterectomy	✓	✓			
Uterine rupture					
Uterine rupture	✓	✓	Uterine rupture	✓	✓
Pre-uterine rupture, Bandl's ring	✓	✓	Pre-uterine rupture, Bandl's ring	✓	✓
			Previous caesarean section/scarred uterus		

Hospital diagnosis	Strict	Broad	Indication for Major Obstetric Interventions	Strict	Broad
Malpresentation					
Transverse lie	✓	✓	Transverse lie	✓	✓
Oblique lie		✓	Shoulder presentation		
Breech presentation, frank breech			Brow presentation	✓	✓
Foot or footling breech			Face presentation		✓
Face presentation		✓	Breech presentation		
Brow presentation	✓	✓	Footling breech		
Compound presentation		✓	Oblique lie		✓
Shoulder dystocia					
Major cephalopelvic disproportion					
Cephalopelvic disproportion, CPD		✓	CPD		✓
Prolonged labour			Macrosomia		✓
Obstructed labour	✓	✓	Cervical stenosis/dystocia		
Cervical stenosis, cervical dystocia			Vaginal stenosis/dystocia		
Vaginal stenosis, vaginal rings			Prolonged labour		
Macrosomia			ANY craniotomy, embryotomy or symphysiotomy	✓	✓
Other dystocia					
ANY craniotomy, embryotomy or symphysiotomy	✓	✓			
Other non-absolute direct obstetric complications (excluding first trimester complications)					
Pregnancy-induced hypertension			Congenital malformation (woman)		
Pre-eclampsia			Pregnancy-induced hypertension		
Eclampsia			Pre-eclampsia		
Endometritis			Eclampsia		
Salpingitis			Postpartum infection		
Peritonitis			Septicaemia		
Septicaemia, sepsis			Peritonitis		
Septic shock			Endometritis		
Wound infection (post-caesarean)			Salpingitis		
Wound infection (post-tear, post episiotomy)			Premature rupture of membranes		

Hospital diagnosis	Strict	Broad	Indication for Major Obstetric Interventions	Strict	Broad
Other postpartum infection			Multiple pregnancy		
Pulmonary embolism			Hydramnios		
Amniotic fluid embolism			Oligoamnios		
Disseminated intravascular coagulation (DIC)			Medical conditions in the mother		
Anaemia associated with malaria					
Anaemia associated with haemorrhage					
Anaemia associated with sickle cell disease					
Unspecified anaemia					
Episiotomy or minor perineal tear					
False labour					
Premature labour					
Premature rupture of membranes					
Hydramnios, Polyhydramnios					
Oligoamnios					
Hyperemesis gravidarum					
Female genital mutilation					
Foetal complications					
Foetal distress			Hydrocephalus		
Meconium staining			Foetal distress		
Cord around the neck			Congenital malformation (baby)		
Cord prolapse			Cord prolapse		
Fresh stillbirth			Cord around the neck		
Macerated stillbirth					

5.2.2. Definition of obstetric surgery

Caesareans are the most common obstetric surgery used to treat AMIs, though other types of surgery can be required to save the mother's life, particularly in the case of postpartum complications or known fetal death. The Unmet Obstetric Need approach includes the following surgeries ("major obstetric interventions") in the calculation of met need:

- caesareans (for severe ante-partum haemorrhages, major cephalopelvic disproportions where the child is alive, transverse and frontal presentations);
- laparotomies (for suture of a uterine breach in a reparable rupture);
- hysterectomies (in a major uterine rupture or an incoercible post-partum haemorrhage);
- internal versions (in a case of transverse position);
- craniotomies or embryotomies (in cases of dystocia when the child is dead);
- a symphysiotomy which is carried out to avoid a caesarean in a case of cephalopelvic disproportion [30]

In the ObaapaVitA dataset, caesareans were identified in the hospital subsample based on recorded mode of delivery, and among deliveries outside the district hospitals based on maternal self-report (as detailed in section 4.2.6). The remaining types of surgery were identified in the hospital sample based on recorded major operations ("Were any of the following procedures performed?"; response options included "Hysterectomy", "Laparotomy", "Internal version", "Craniotomy or Embryotomy", and "Symphysiotomy"). It was not possible to identify surgeries for AMIs among deliveries outside of the study hospitals.

5.2.3. Definition of mortality outcomes

Section 4.2.6 detailed the data used to identify the cause of pregnancy-related deaths and the cause of death classification used in this study. In brief, the cause of death was assigned by doctors in the hospital notes for women who died in hospital, while it was assigned by physician review based on verbal post-mortem (VPM) for women who died in the community or within lower-level facilities. As noted in section 4.3.5, 37 of the 203 (18%) pregnancy-related deaths occurred before discharge from one of the four district hospitals in the study area and have a cause of death assigned by doctors who attended the woman; the remaining 82% took place at home or in lower-level facilities, and thus have a cause of death assigned by VPM.

The first assumption of the UON indicator implies that AMIs that are not treated with surgery necessarily result in a maternal death. Different definitions of mortality are used in the two different samples. Among hospital deliveries, the absoluteness of AMIs was tested by assessing whether deliveries with AMIs that do not receive surgery always result in the death of the woman. All deaths occurring before discharge from the hospital, irrespective of cause, were included in the definition of mortality used to address objective 3 of this chapter.

At the population level, the UON indicator implies that the sum of surgeries for AMIs and deaths from AMI-related causes should represent a constant percentage of deliveries across subgroups. The definition of AMI-related deaths used in objectives 4 and 5 included the following causes: obstructed labour, uterine rupture, antepartum haemorrhage, postpartum haemorrhage, and haemorrhage with timing unknown.

However, as described in section 4.2.6, there are concerns with misclassification of cause of death based on the verbal post-mortem: for example, of the five deaths from hypertension in hospitals, only one was also recorded as a hypertension-related death in the VPM (chapter 4). I therefore also present results using pregnancy-related deaths after 22 weeks gestation and all pregnancy-related deaths irrespective of gestational age, in order to assess whether the results are likely to have been affected by misclassification of cause of death.

5.2.4. Statistical analyses

In order to address objective 1, I first described the number of AMIs identified in the strict and broad definitions among hospital deliveries (n=13,886), for the diagnosis-based, indications-based and combined definitions. I also examined the variation in the percentage of hospital deliveries with AMIs across all obstetric complications, including complications that did not contribute to the definition of AMIs, in order to understand the distribution of AMIs according to other complications.

The prevalence of AMIs among hospital deliveries was calculated for each educational level (objective 2), and was predicted to be higher among groups with lower rates of facility delivery and caesarean sections. Maternal education was chosen as a stratifying variable since it showed the greatest variation in facility delivery and caesarean rates (see sections 4.3.2 and 4.3.3).

In order to assess the absoluteness of AMIs among hospital deliveries (objective 3), I calculated the percentage of deliveries with AMIs receiving surgery, to determine whether these complications were considered “absolute” by obstetric care providers in the district hospitals. I further examined whether all deliveries with AMIs that did not receive surgery resulted in the death of the woman.

The absoluteness of AMIs was assessed at the population level by analysing whether the sum of surgeries for AMIs and deaths from AMI-related causes accounted for a constant percentage of deliveries across educational groups (objective 4). Some women died after receiving surgery for an AMI, hence these two groups are not mutually exclusive, and I tested whether the percentage of all deliveries with either surgery for AMIs or death from an AMI-related cause varied according to education. The validity of the 1.4% threshold was tested by assessing whether this percentage was equal to 1.4% across subgroups (objective 5). I repeated this analysis with pregnancy-related deaths after 22 weeks and all pregnancy-related deaths in order to determine whether any observed variation in the sum of AMI-related deaths and surgeries could be due to misclassification of AMI-related deaths. The analyses were also repeated excluding surgeries for major cephalopelvic disproportion, since this AMI category was the most subjective and accounted for more than half of all AMIs. Lastly, I described the unique, hierarchical type of AMI for all deliveries receiving surgery for an AMI across educational levels, to assess whether the percentage of surgeries for major cephalopelvic disproportion varied across groups.

Chi-square tests were used to test for educational differences in the percentage of deliveries receiving surgeries for AMIs (including for major cephalopelvic disproportion only), pregnancy-related mortality from AMI-related causes, and the sum of these two outcomes.

5.3. Results

5.3.1. Description of absolute maternal indications in hospital deliveries

Table 5.2 and Figure 5.1 present the number of AMIs among hospital deliveries identified using diagnoses, indications, and combined data. In total, 2.8% (n=388) and 8.4% (n=1,168) of the 13,886 hospital deliveries had an AMI according to the strict and broad definition, respectively. Major cephalopelvic disproportion was the most common AMI, representing more than half of AMIs in both the strict and broad definitions, while postpartum haemorrhage was the least common. There was no difference between strict and broad definitions of uterine rupture, since the same complications and indications were included in both definitions.

For most types of AMIs, few cases were captured by indications data which were not identified using diagnoses. For example, only two additional uterine ruptures were identified by the indications data that were not captured in the diagnosis data (61 in the combined definition compared with 59 in the diagnosis-based definition), and three additional strict and broad malpresentations. Severe antepartum haemorrhage was the only exception, where the indications-based definition added 38 AMIs to the combined strict definition (54 in the combined definition, compared with 16 in the diagnosis-based definition), likely because the indication for placenta praevia included all cases regardless of severity. Using indications data only identified substantially fewer AMIs than using diagnosis data or both types of data combined in this setting. In total, information on indications captured an extra 38 strict AMIs (388 in the combined definition compared with 350 using diagnoses only) and four additional broad AMIs (1,168 compared with 1,164).

Table 5.2 Strict and broad definitions of AMIs, using diagnosis, indications, and combined data

Diagnosis-based definition			Indications-based definition			Combined definition	
Hospital diagnosis	*N (strict)*	*N (broad)*	*Indication for surgery*	*N (strict)*	*N (broad)*	*N (strict)*	*N (broad)*
Severe antepartum haemorrhage (APH)	**16**	**228**		**50**	**113**	**54**	**228**
Placenta praevia (types I or II)	-	41	APH due to placenta praevia	50	50		
Partial placenta praevia (type III)	13	13	APH due to placental abruption	-	35		
Complete placenta praevia (type IV)	3	3	APH, cause unspecified	-	30		
Unspecified placenta praevia	-	19					
Placental abruption	-	47					
Unspecified antepartum haemorrhage	-	106					
Incoercible postpartum haemorrhage	**33**	**33**		**33**	**33**	**23**	**33**
Uterine atony	6	6	Postpartum haemorrhage	4	4		
Retained placenta	12	12	Inverted uterus	0	0		
Retained products	3	3	Any hysterectomy	33	33		
Placenta accreta	0	0					
Inverted uterus	0	0					
Perineal tear	0	0					
Vaginal tear	1	1					
Cervical tear	1	1					
Unspecified postpartum haemorrhage	4	4					
Any hysterectomy	33	33					
Uterine rupture	**59**	**59**		**43**	**43**	**61**	**61**
Uterine rupture	51	51	Uterine rupture	41	41		
Pre-uterine rupture (Bandl's ring)	9	9	Pre-uterine rupture or Bandl's ring	2	2		
Malpresentation	**49**	**135**		**46**	**94**	**52**	**138**
Transverse lie	47	47	Transverse lie	45	45		
Oblique lie	-	18	Brow presentation	1	1		
Face presentation	-	42	Face presentation	-	34		
Brow presentation	2	2	Oblique lie	-	14		
Compound presentation	-	28					

Diagnosis-based definition			Indications-based definition			Combined definition	
Hospital diagnosis	*N (strict)*	*N (broad)*	*Indication for surgery*	*N (strict)*	*N (broad)*	*N (strict)*	*N (broad)*
Major cephalopelvic disproportion	**219**	**798**		**5**	**590**	**219**	**804**
Obstructed labour	216	216	CPD	-	573		
Cephalopelvic disproportion	-	588	Macrosomia	-	13		
Macrosomia	-	83					
Any craniotomy, embryotomy or symphysiotomy	5	5	Any craniotomy, embryotomy or symphysiotomy	5	5		
Total	**350**	**1,164**	**Total**	**161**	**835**	**388**	**1,168**

Figure 5.1 Distribution of absolute maternal indications among hospital deliveries (N=13,886)

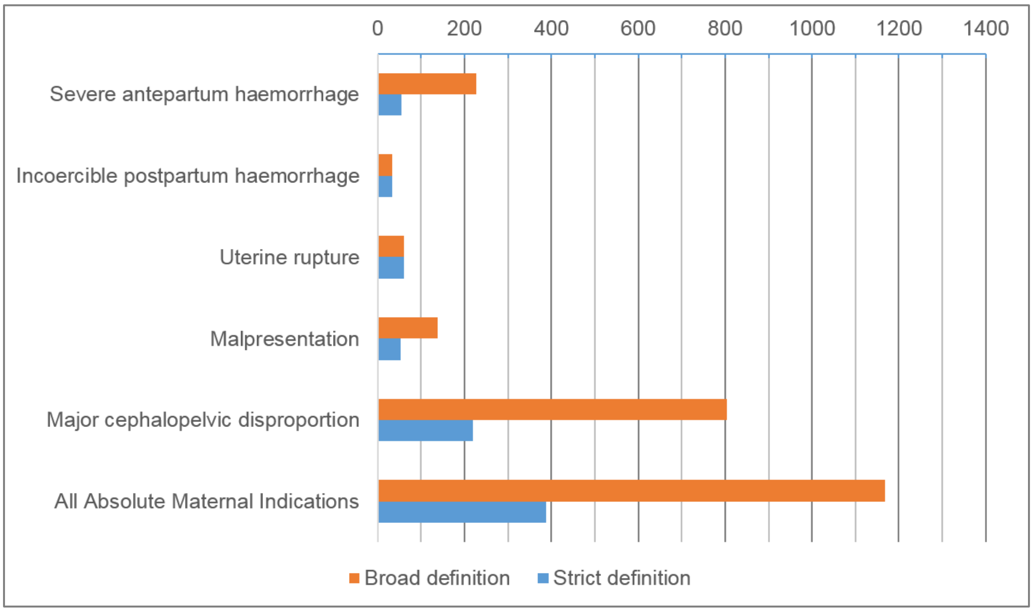


Table 5.3 presents the percentage of deliveries with obstetric complications that were classified as AMIs among hospital deliveries with at least one recorded complication. Overall, 9% of hospital deliveries with complications had a strict AMI and 28% had a broad AMI. Among the six types of complications contributing to the definition of AMIs (bolded in Table 5.3), the percentage of AMIs according to the broad definition was 100% except for postpartum haemorrhage (7%). Using the strict definition, all cases of obstructed labour, uterine rupture and antepartum haemorrhage from major placenta praevia were categorised as AMIs. The percentage of deliveries with cephalopelvic disproportion, malpresentation and other antepartum haemorrhage considered as strict AMIs ranged from 14% to 56%, while 3% of postpartum haemorrhages were categorised as strict AMIs.

Deliveries could have multiple recorded diagnoses of obstetric complications, and therefore the prevalence of AMIs was above zero for most complications which did not contribute to the definition of AMIs. Among these, the percentage of deliveries with an AMI ranged between 0-26% for the strict definition (highest for prolonged labour, other dystocia, and cord around the neck) and 0-50% for the broad AMI definition (including 41% for prolonged labour and 36% for other dystocia). Overall, 16% of dystocia cases and 14% of haemorrhage cases were considered strict AMIs.

Table 5.3 Percentage of absolute maternal indications among categories of obstetric complications

Obstetric complication	Number	Percentage of AMIs (strict)	Percentage of AMIs (broad)
Dystocia	1,851	15.9	50.6
Obstructed labour[a]	**216**	**100.0**	**100.0**
Cephalopelvic disproportion[a]	**661**	**14.2**	**100.0**
Cervical/vaginal dystocia	513	6.8	16.0
Prolonged labour (cause unspecified)	499	25.5	41.7
Breech presentation	155	17.4	27.1
Malpresentation[a]	**108**	**55.6**	**100.0**
Other dystocia	364	19.5	40.9
Haemorrhage	982	14.0	30.9
Uterine rupture or pre-rupture[a]	**59**	**100.0**	**100.0**
Antepartum haemorrhage from major placenta praevia[a]	**16**	**100.0**	**100.0**
Other antepartum haemorrhage[a]	**214**	**28.5**	**100.0**
Postpartum haemorrhage[a]	**727**	**3.0**	**6.6**
Hypertension	486	3.7	11.1
Pregnancy-induced hypertension	277	3.6	13.7
Pre-eclampsia	142	4.9	10.6
Eclampsia	84	2.4	6.0
Pregnancy-related infection	630	5.9	17.9
Septicaemia/sepsis	34	2.9	11.8
Wound infection	50	10.0	14.0
Other postpartum infection	19	0.0	5.3
Malaria	434	7.1	19.8
HIV-positive	98	3.1	14.3
Other infection	102	3.9	17.6
Other obstetric complications	344	1.5	8.7
Embolism	1	0.0	0.0
Premature labour	150	2.0	8.0
Premature rupture of membranes	206	1.0	7.8
False labour	6	0.0	16.7
Hyperemesis gravidarum	2	0.0	50.0
Other obstetric complications	1,121	8.3	25.9
Diabetes	15	0.0	13.3
Sickle cell disease	29	10.3	10.3
Anaemia	993	8.5	27.6
Injury	7	0.0	28.6
Other non-obstetric complication	127	7.1	14.2
Fetal complications	1,175	8.9	24.3
Fetal distress	395	8.9	26.3
Meconium staining	783	8.4	24.3
Amniotic fluid conditions	36	2.8	25.0
Cord prolapse	52	9.6	17.3
Cord around the neck	154	18.8	31.2
Any complication	**4,201**	**9.0**	**27.7**

[a]The bolded complications represent categories with diagnoses that contributed to the definition of AMIs

There was no evidence of a difference in the percentage of hospital deliveries with either strict or broad AMIs according to maternal education (Chi-square p=0.432 and p=0.660, respectively; see Table 5.4).

Table 5.4 Prevalence of AMIs among hospital deliveries, stratified by maternal education

Maternal education	Hospital deliveries (N)	*Strict definition*			*Broad definition*		
		N	% (95% CI)	p-value	N	% (95% CI)	p-value
None	3,368	106	3.1 (2.6-3.8)	0.432	300	8.9 (8.0-9.9)	0.660
Primary	2,628	71	2.7 (2.1-3.4)		219	8.3 (7.3-9.5)	
Secondary	7,587	199	2.6 (2.3-3.0)		621	8.2 (7.6-8.8)	
Post-secondary	273	9	3.3 (1.7-6.2)		23	8.4 (5.7-12.4)	
Total	**13,886**	**388**	**2.8 (2.5-3.1)**	**-**	**1,168**	**8.4 (8.0-8.9)**	**-**

5.3.2. Absoluteness of AMIs among hospital deliveries

Table 5.5 and Figure 5.2 present the percentage of AMIs which received surgery. Over 98% of deliveries with a strict AMI underwent surgery; this percentage was highest for postpartum haemorrhage (100%) and lowest for malpresentation (94%). Eighty-seven percent of broad AMIs had a major obstetric intervention. This figure was over 89% for all types of AMIs excluding antepartum haemorrhage, among which 60% of cases received surgery according to the broad AMI definition.

Table 5.5 also presents the number of deaths before discharge among deliveries with AMIs that did not receive surgery. Based on the first assumption of the UON indicator, women with AMIs who do not receive surgery are predicted to die. However, there were no deaths among the seven hospital deliveries with strict AMIs who did not receive surgery (388 strict AMIs minus 381 surgeries). There were only two deaths among deliveries with broad AMIs, compared with the 155 expected deaths based on the number of broad AMIs who did not undergo surgery (1,168 broad AMIs minus 1,013 surgeries).

Figure 5.2 Percentage of hospital deliveries with absolute maternal indications receiving surgery (N=384 strict AMIs and 1,168 broad AMIs)

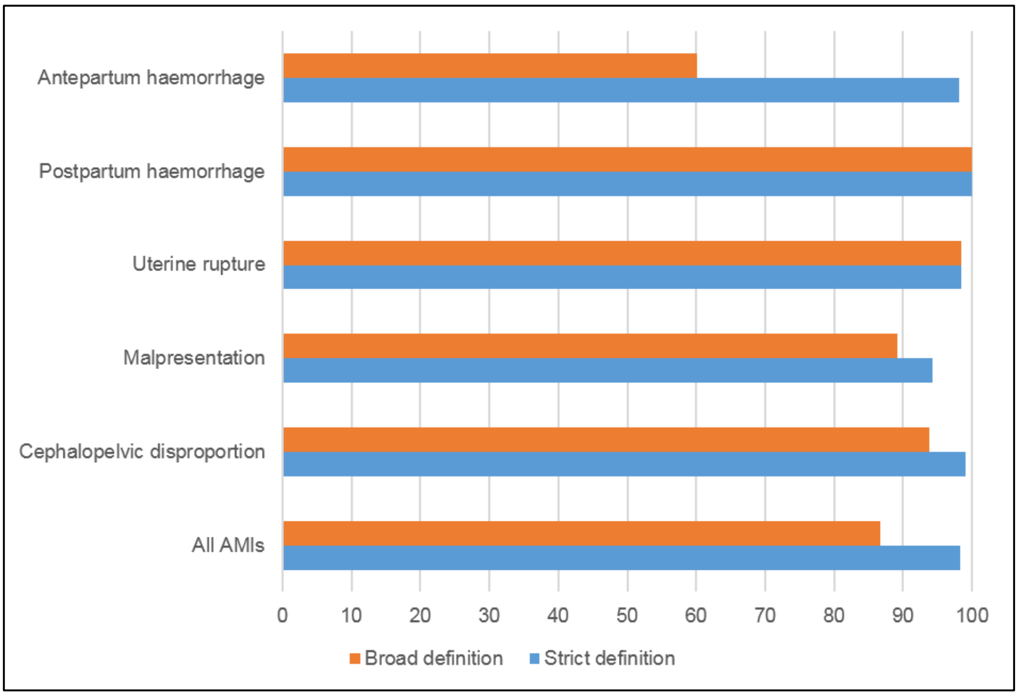


Table 5.5 Percentage of surgeries among absolute maternal indications

AMI	Number		Deliveries with AMIs receiving surgery (%)		Deliveries with AMIs not receiving surgery and resulting in death before discharge	
	Strict	*Broad*	*Strict*	*Broad*	*Strict*	*Broad*
Antepartum haemorrhage	54	228	53 (98.1)	137 (60.1)	0	2
Postpartum haemorrhage	33	33	33 (100.0)	33 (100.0)	0	0
Uterine rupture	61	61	60 (98.4)	60 (98.4)	0	0
Malpresentation	52	138	49 (94.2)	123 (89.1)	0	0
Cephalopelvic disproportion	219	804	217 (99.1)	754 (93.8)	0	0
Total	388	1,168	381 (98.2)	1,013 (86.7)	0	2

5.3.3. Absoluteness of AMIs at the population level and validity of the 1.4% threshold

Table 5.6 presents the distribution of caesareans, deliveries with surgery for AMIs, and pregnancy-related deaths from AMI-related causes according to maternal education. This analysis excludes 141 deliveries with missing educational level (including five pregnancy-related deaths), leaving 50,148 deliveries in the sample. There were 39 deaths from AMI-related causes in the sample, corresponding to a pregnancy-related mortality from AMIs of 78 per 100,000 deliveries. Among all deliveries in the population, 0.75% received surgery for a strict AMI and 2.01% for a broad AMI.

AMI-related mortality ranged between 62 and 92 per 100,000 deliveries in the three lower educational groups, and was 213 per 100,000 among women with post-secondary education; this difference was not statistically significant (p=0.511), as illustrated by the overlap between confidence intervals for these estimates. The percentage of deliveries receiving surgery for strict AMIs increased with education, from 0.56% among women with no education to 1.92% among women with post-secondary education (p<0.001). This percentage also increased when looking at surgeries for broad AMIs, between 1.33% among women with no education and 4.05% among women with post-secondary education (p<0.001). The educational trend in the percentage of surgeries for AMIs parallels the trend in caesarean rate, with a gradual increase across the three lowest educational levels, followed by a substantial increase between the secondary and post-secondary education groups.

I calculated the sum of deaths from AMI-related causes and surgeries for AMIs in order to assess whether it accounted for a constant percentage of deliveries (i.e. whether mortality from these causes made up the predicted deficit in surgeries) and whether this percentage was equal to 1.4%. Table 5.6 also presents the percentage of deliveries in each educational group with surgery for AMIs or death from AMI-related causes. Figure 5.3 and Figure 5.4 present the sum of pregnancy-related deaths from AMIs and surgeries for AMIs separately. Five women who received surgery for an AMI subsequently died; these five deliveries are included among pregnancy-related deaths from AMIs in these graphs since the need for obstetric care was not met for these women.

Among all deliveries in the population, 0.82% received surgery for a strict AMI or ended in death from AMI, compared with 2.08% for broad AMIs; neither 95% confidence interval includes the 1.4% threshold suggested by the UON Network. Across educational levels, mortality from AMIs did not compensate for the shortfall in the percentage of surgery for AMIs. The percentage of deliveries with AMI-related deaths or surgeries increased consistently with maternal education, from 0.64% among women with no education to 2.13% among women with post-secondary education for strict AMIs ($p<0.001$). The confidence interval only included 1.4% for post-secondary education. When using the broad definition, deliveries with surgery for AMIs or pregnancy-related deaths ranged between 1.41% with no education and 4.26% for post-secondary education ($p<0.001$), and the 95% confidence interval for this percentage included 1.4% only among women with no education. In the highest educational group, 4.3% of deliveries ended in AMI-related death or surgery (three times higher than the UON threshold).

Table 5.6 Sum of surgeries for AMIs and pregnancy-related deaths from AMI-related causes, stratified by maternal education

Maternal education	Total deliveries	Caesarean rate (%)	Pregnancy-related deaths from AMIs		Percentage of deliveries with surgery for AMIs (95% CI)		Percentage of deliveries with pregnancy-related deaths from AMIs or surgeries for AMIs (95% CI)[a]	
			N	*Ratio per 100,000 deliveries (95% CI)*	*Strict*	*Broad*	*Strict*	*Broad*
None	18,465	2.9	17	92 (57-148)	0.56 (0.46-0.68)	1.33 (1.17-1.50)	0.64 (0.54-0.77)	1.41 (1.25-1.59)
Primary	10,101	4.6	8	79 (40-158)	0.68 (0.54-0.86)	1.91 (1.66-2.20)	0.75 (0.60-0.94)	1.98 (1.73-2.27)
Secondary	21,113	7.2	13	62 (36-106)	0.93 (0.81-1.07)	2.61 (2.40-2.83)	0.98 (0.86-1.12)	2.66 (2.45-2.88)
Post-secondary	469	14.3	1	213 (30-1,500)	1.92 (1.00-3.65)	4.05 (2.60-6.27)	2.13 (1.15-3.92)	4.26 (2.77-6.52)
Total	**50,148**	**5.2**	**39**	**78 (57-106)**	**0.75 (0.68-0.83)**	**2.01 (1.89-2.13)**	**0.82 (0.75-0.90)**	**2.08 (1.96-2.21)**

[a]Five women died after having received surgery for an AMI (both in the strict and broad definitions); therefore the percentage of deliveries with deaths from AMIs or surgeries for AMIs is slightly lower than the sum of these two groups

Figure 5.3 Among all deliveries, percentage with surgery for AMIs and pregnancy-related deaths from AMIs, stratified by maternal education – Strict definition (N=50,148)

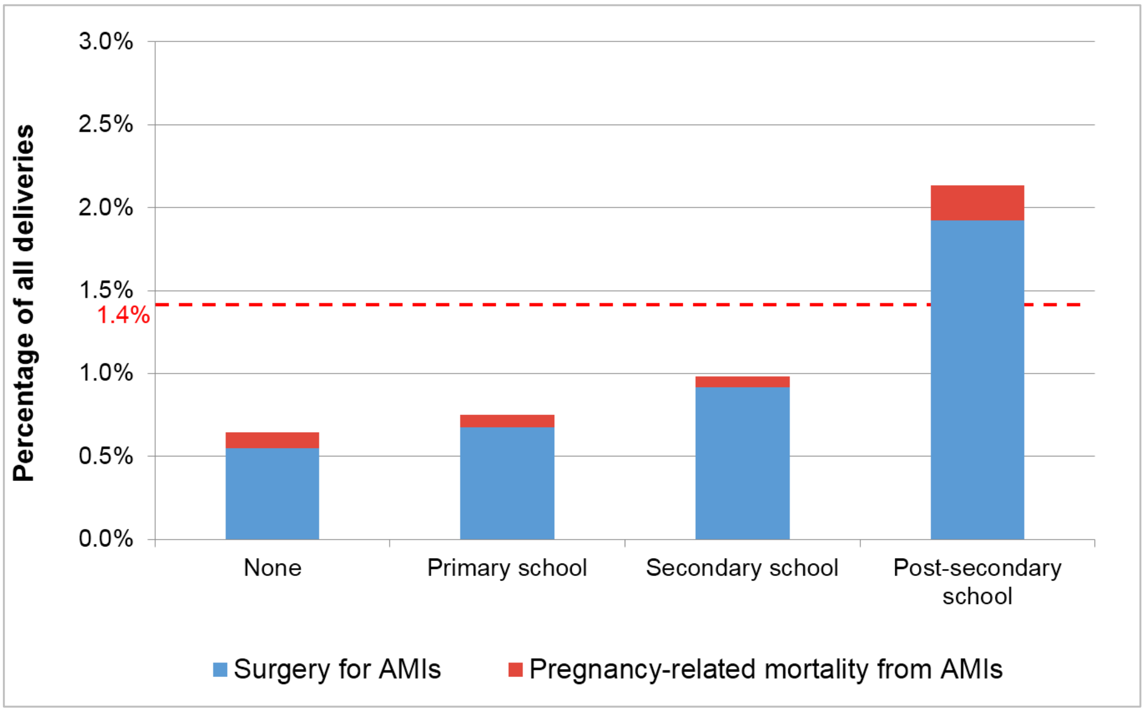
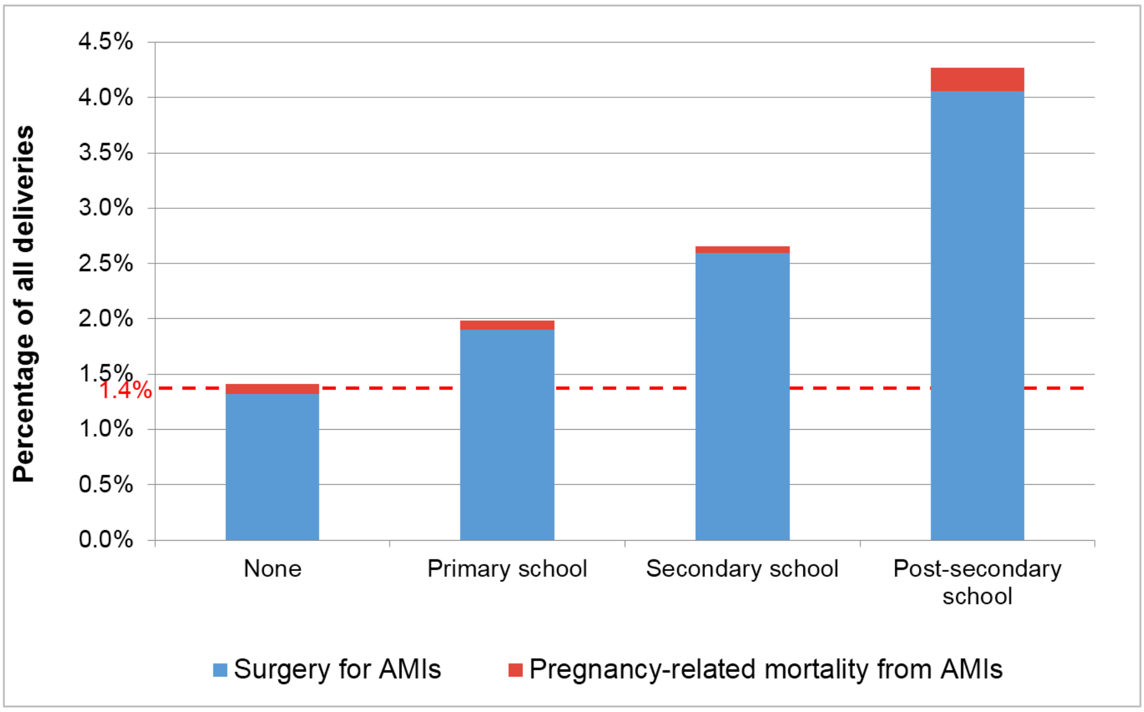


Figure 5.4 Among all deliveries, percentage with surgery for AMIs and pregnancy-related deaths from AMIs, stratified by maternal education – Broad definition (N=50,148)



The type of AMIs varied according to educational level (Figure 5.5 and Figure 5.6). Notably, the percentage of deliveries receiving surgery for major cephalopelvic disproportion increased from 0.24% among women with no education to 1.49% in the post-secondary group using the strict definition ($p<0.001$), and from 0.81% to 2.99% using the broad definition ($p<0.001$). The differences in the overall percentage of surgeries for AMIs is almost entirely explained by differences in surgeries for major cephalopelvic disproportion, while the proportion of surgeries for the four other AMIs combined was almost constant, varying between 0.27-0.43% for the strict definition ($p=0.114$) and 0.50-1.07% for the broad definition ($p=0.001$).

Figure 5.5 Among all deliveries, percentage receiving surgery for each type of strict AMI, stratified by maternal education

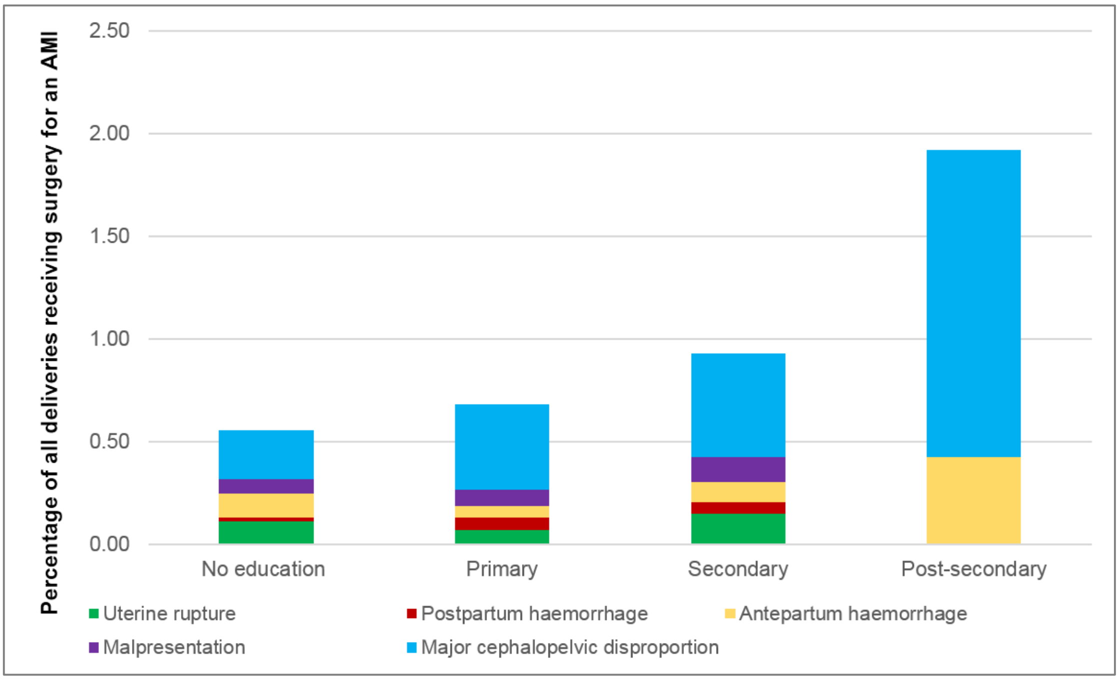
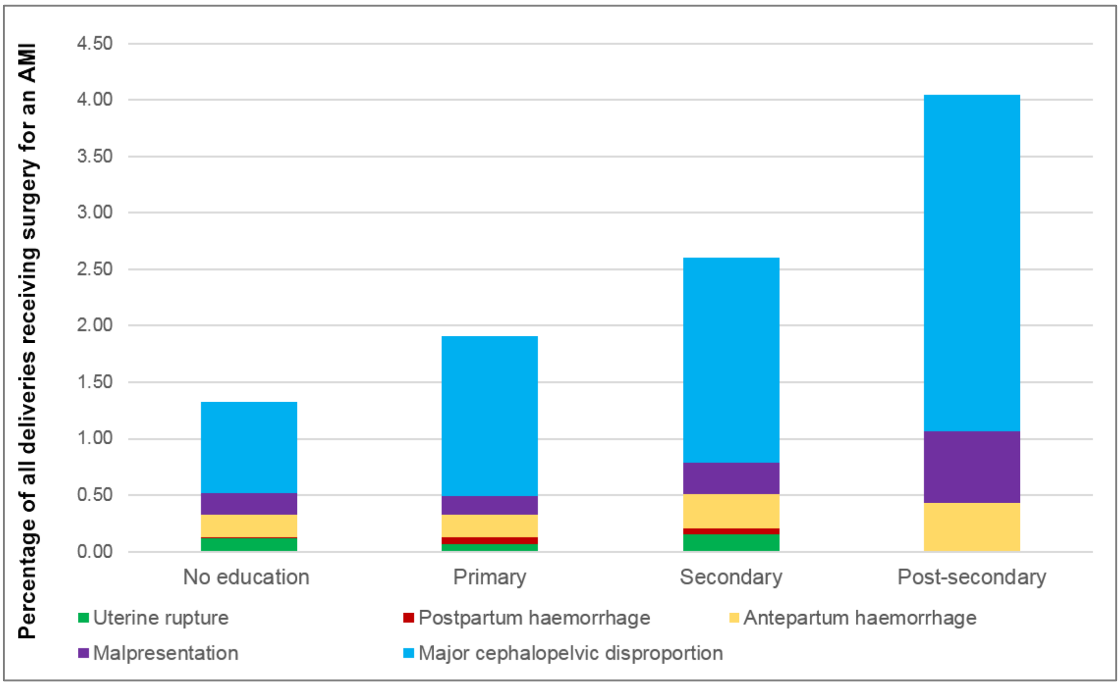


Figure 5.6 Among all deliveries, percentage receiving surgery for each type of broad AMI, stratified by maternal education



5.3.4. Sensitivity analyses

I repeated the calculation of the percentage of deliveries with surgery for AMIs or pregnancy-related deaths for 6 different scenarios, taking into account the three different mortality definitions outlined in section 5.2.3, and two AMI definitions including and excluding major cephalopelvic disproportion (Table 5.7). Pregnancy-related mortality after 22 weeks gestation (298 per 100,000 deliveries) was lower than the total pregnancy-related mortality (404 per 100,000), and both were substantially higher than mortality from AMIs. Contrary to mortality from AMIs, pregnancy-related mortality from all causes and after 22 weeks were highest among women with no education and lowest among women with post-secondary education. As expected based on the distribution of AMI categories in section 5.3.1, excluding major cephalopelvic disproportion from the definition of AMIs more than halved the percentage of surgeries for AMIs across educational groups.

In all six scenarios, the percentage of deliveries with surgery for AMIs or pregnancy-related death increased substantially with educational level, and pregnancy-related mortality did not account for the shortfall in surgeries for AMIs among less educated women. This pattern was found for both the strict and broad definitions of AMIs. In addition, most confidence intervals did not include the 1.4% threshold suggested by the

UON Network, and they did not overlap for the highest and lowest educational levels when including all AMIs, suggesting that no other threshold is compatible with the assumptions of the UON indicator. The confidence intervals overlapped when excluding surgeries for cephalopelvic disproportion, where numbers were very small.

Table 5.7 Sum of Major Obstetric Interventions for AMIs and pregnancy-related mortality ratio (PRMR) - Sensitivity analyses

Maternal education	% surgery for AMIs		All pregnancy-related deaths (denominator=50,349)			Pregnancy-related deaths after 22 weeks (denominator=50,289)			Pregnancy-related deaths from AMIs (denominator=50,289)		
	Strict	*Broad*	*PRMR[a]*	*% deliveries with surgery or death (strict)*	*% deliveries with surgery or death (broad)*	*PRMR[a]*	*% deliveries with surgery or death (strict)*	*% deliveries with surgery or death (broad)*	*PRMR[a]*	*% deliveries with surgery or death (strict)*	*% deliveries with surgery or death (broad)*
ALL ABSOLUTE MATERNAL INDICATIONS											
None	0.56	1.33	417	0.97 (0.84-1.12)	1.74 (1.56-1.94)	303	0.86 (0.73-1.00)	1.62 (1.45-1.82)	92	0.64 (0.54-0.77)	1.41 (1.25-1.59)
Primary	0.68	1.91	376	1.05 (0.87-1.27)	2.25 (1.98-2.56)	267	0.94 (0.77-1.15)	2.15 (1.88-2.45)	79	0.75 (0.60-0.94)	1.98 (1.73-2.27)
Secondary	0.93	2.61	388	1.31 (1.16-1.47)	2.98 (2.76-3.22)	303	1.22 (1.08-1.38)	2.90 (2.68-3.13)	62	0.98 (0.86-1.12)	2.66 (2.45-2.88)
Post-secondary	1.92	4.05	213	2.13 (1.15-3.92)	4.26 (2.77-5.62)	213	2.13 (1.15-3.92)	4.26 (2.77-6.52)	213	2.13 (1.15-3.92)	4.26 (2.77-6.52)
ABSOLUTE MATERNAL INDICATIONS EXCLUDING MAJOR CEPHALOPELVIC DISPROPORTION											
None	0.32	0.52	417	0.73 (0.62-0.86)	0.93 (0.80-1.08)	303	0.62 (0.51-0.74)	0.82 (0.70-0.96)	92	0.41 (0.32-0.51)	0.61 (0.50-0.73)
Primary	0.27	0.50	376	0.63 (0.50-0.81)	0.86 (0.70-1.06)	267	0.52 (0.40-0.69)	0.75 (0.60-0.94)	79	0.34 (0.24-0.47)	0.56 (0.44-0.73)
Secondary	0.43	0.79	388	0.80 (0.69-0.93)	1.16 (1.03-1.32)	303	0.72 (0.61-0.84)	1.08 (0.95-1.23)	62	0.48 (0.39-0.58)	0.84 (0.72-0.97)
Post-secondary	0.43	1.07	213	0.64 (0.21-1.97)	1.28 (0.58-2.82)	213	0.64 (0.21-1.97)	1.28 (0.58-2.82)	213	0.64 (0.21-1.97)	1.28 (0.58-2.82)

[a]PRMR: pregnancy-related mortality ratio

5.4. Discussion

5.4.1. Summary of main findings

In total, 3% of hospital deliveries had an absolute maternal indication (AMI) based on the strict definition, and 8% based on the broad definition. Though uterine rupture was less prevalent among deliveries with higher education in hospitals (chapter 4), the prevalence of AMIs among hospital deliveries was similar across educational levels. Major cephalopelvic disproportion was the most common type of AMI, accounting for more than half of AMIs.

The percentage of all deliveries in the population receiving surgery for AMIs was 0.76% using the strict definition and 2.01% with the broad definition. The strict estimate is close to previous findings by the UON Network in West Africa (ranging between 0.23% in Niger and 1.03% in Benin) [41]. Similar to the caesarean rate, the percentage of surgeries for AMIs increased substantially with maternal education, between 0.56-1.92% for surgeries for strict AMIs; this socio-economic variation was larger than that found across districts in Mali [45], Morocco [46] or Tanzania [43].

The absoluteness of AMIs – that is, whether they inevitably result in a maternal death without surgery – was tested among hospital deliveries and at the population level. In district hospitals in the study area, almost all AMIs (98% of strict AMIs and 90% of broad AMIs) received surgery, suggesting that obstetric care providers consider these complications to be absolute. However, only two deliveries classified as AMIs that did not receive surgery resulted in death before discharge, compared with the seven and 155 deaths expected for strict and broad AMIs, respectively.

At the population level, the absoluteness of AMIs was validated by determining whether mortality from these complications is higher among groups with a lower rate of surgeries for AMIs. Pregnancy-related mortality from AMIs was not inversely associated with the percentage of surgeries for AMIs across all groups, and did not compensate for the shortfall in obstetric surgeries among groups with fewer surgeries for AMIs. The educational gradient in the percentage of deliveries with AMI-related deaths or surgeries persisted regardless of the definition of pregnancy-related deaths or whether surgeries for major cephalopelvic disproportion were included.

The validity of the 1.4% expected prevalence of AMIs was tested by determining whether the sum of AMI-related deaths and surgeries accounted for 1.4% of deliveries across educational groups. This was the case in one group only (women with no education) using the broad definition of AMIs, and the 95% confidence interval included 1.4% in only one group for each definition of AMIs (the lowest educational level using the broad definition, and the highest using the strict definition). The confidence intervals between the highest and lowest educational levels did not overlap (except when excluding surgeries for cephalopelvic disproportion due to small numbers), suggesting there is no other possible percentage of deliveries with AMI-related surgery or death that is constant across groups.

5.4.2. Interpretation

The findings from this study suggest that the UON indicator is not valid in central Ghana, and that groups with low rates of surgery for AMIs cannot be interpreted as having excess mortality from these causes in this setting. A previous study in Bangladesh similarly found that the sum of AMI-related deaths and surgeries increased with maternal education and wealth, and ranged between 0.25% and 2.41% [50].

There are several possible explanations as to why deaths from AMIs and surgeries for AMIs were not found to add up to a constant percentage of deliveries across educational groups. First, deaths from AMIs could have been underestimated among less educated women. However, assuming that the estimated AMI prevalence among post-secondary women (2.13% strict AMIs and 4.26% broad AMIs) is real, the observed rates of surgeries for AMIs among women with no education (0.56% and 1.14% respectively) would lead us to expect pregnancy-related mortality from AMIs of 1,570 and 2,850 per 100,000 deliveries, based on the strict and broad estimates respectively. These mortality rates are higher than most observed all-cause pregnancy-related mortality estimates, and it is unlikely that deaths from AMIs would have been underestimated to this extent.

A second hypothesis would be that the number of surgeries for AMIs is overestimated among more educated women. The excess of surgeries among women with post-secondary education was primarily explained by more caesareans for cephalopelvic disproportion. It is unlikely that an association of this magnitude reflects true differences in the prevalence of AMIs, since there is no reason that more educated women would be more likely to develop major cephalopelvic disproportion than less educated women. It is more likely that surgeries for prolonged labour are misclassified as surgeries for AMIs, thereby overestimating the prevalence of AMIs among more educated women. In Brong-Ahafo, the percentage of surgeries for AMIs increased parallel to the caesarean rate, and it is known that even in settings with very high caesarean rates, many interventions continue to have a medical indication recorded: in 120 facilities in Latin America with a median caesarean rate of 33%, less than 1% of caesareans were recorded as maternal requests without any other indication, and all other caesareans had at least one recorded medical indication [125]. This suggests that doctors may overestimate the severity of the condition in order to justify the caesarean [85], and that the ascertainment of AMIs according to socio-economic status is biased. Financial incentives for caesareans may also encourage doctors to misrecord the indication, if insurance companies only reimburse “necessary” caesareans, though it was unclear whether payment was dependent on documenting complications in Ghana [168]. The Bangladesh study similarly found that the higher rate of surgeries for AMIs among richer and more educated women was almost entirely explained by additional caesareans for cephalopelvic disproportion [50], indicating that misclassification of surgeries for cephalopelvic disproportion may be an issue in other settings. The percentage of surgeries for other types of AMIs was a lot more similar across groups (between 0.3-0.4%), suggesting that misclassification is less likely to be a concern for these conditions. Due to the bias in ascertainment of surgeries for major cephalopelvic disproportion, this study cannot test whether the true prevalence of AMIs varies across educational groups.

Third, AMIs may not be absolute, i.e. may not necessarily result in death without surgery. Hospital deliveries recorded as having an AMI almost always survived even without surgery. However, the bias in the ascertainment of AMIs suggests that these cases may not have been true AMIs, and that doctors successfully identified true AMIs and ensured they received surgery in hospitals. A study with a case definition of AMIs based on clinical criteria would be necessary to evaluate whether AMIs necessarily result in death without surgery, or whether women can survive (even if with severe morbidity); however, there is no gold standard clinical definition of major cephalopelvic disproportion [48, 199], hindering the evaluation for this type of AMI.

Though the misclassification issues outlined above prevent us from determining the true prevalence of AMIs in the study population, findings from this study may still help inform this prevalence. It is likely that the sum of AMI-related deaths and surgeries overestimates this prevalence among women with post-secondary education. However, if we assume that AMIs are not misclassified among women with no education, then the true prevalence of AMIs would be expected to lie between the strict and broad estimated prevalence in this group (0.64% to 1.41% of all deliveries). This would suggest that 1% may be a valid estimate of the minimum absolute threshold for the caesarean rate, and that caesarean rates below 1% indicate an unmet need for life-saving surgery.

In the four district hospitals in the study area, diagnosis data identified most AMIs, while indications for surgery contributed very few additional AMIs to the combined AMI definition. Surgeries for AMIs may thus be underestimated by relying on indications data only, as has been the case in most previous studies [43, 44, 46].

5.4.3. Strengths and limitations

The availability of hospital data linked to population-based socio-economic and mortality data allowed for validating the UON indicator, and was a major strength of this study. Most studies to date have compared the UON indicator according to district or area of residence (rural/urban) [43-46], this study confirmed that these differentials also exist for maternal education. There were few missing data for educational level among pregnancy-related deaths (2%).

Information on obstetric complications and indications for surgery were missing for women who sought care in hospitals outside of the study area, which may have resulted in underestimating the percentage of all deliveries receiving surgery for AMIs. However, only 328 of the 50,289 deliveries in the sample (0.6%) occurred in hospitals outside of the four study districts and the percentage of deliveries in these hospitals was higher among more educated women, indicating that the observed educational gradient in surgeries for AMIs would not disappear if information were available for these deliveries.

In the ObaapaVitA study, clinical data were extracted from medical records prospectively in a standardised way, and data collection for women with complications was further reviewed by research managers. The quality of clinical data in this study is therefore very likely to be considerably better than in other facilities in sub-Saharan Africa or South Asia, particularly since most studies rely on retrospective data extraction. This study found evidence of misclassification of AMI-related surgeries in Brong-Ahafo, however the extent of misclassification is probably lower than in other settings. Therefore, since the UON indicator is not valid in Ghana, it is highly unlikely that the data will be good enough for it to be valid in most other settings in sub-Saharan Africa and South Asia.

5.5. Conclusion

The sum of surgeries for AMIs and deaths from AMIs did not represent a constant percentage of deliveries (whether 1.4% or another benchmark) across educational levels, and the UON indicator was found not to be valid in this setting. The excess in surgeries for AMIs among more educated women was predominantly accounted for by additional caesareans for major cephalopelvic disproportion, suggesting that the indicator is not valid because surgeries for less severe complications are probably misclassified as surgeries for AMIs. Considering the high quality data of the ObaapaVitA study, misclassification of AMI-related surgeries is likely to be an issue in other settings, and thus validation studies elsewhere are unlikely to confirm its validity elsewhere. Assuming that the prevalence of AMIs among women with no education (0.64-1.41%) is unbiased, the 1% threshold used as the minimum necessary rate for life-saving caesareans may be valid.

Chapter 6. Contribution of hospital data to assessing the unmet need for caesareans

Chapter 6 addresses objective 3.3 of this thesis by presenting the caesarean rate and indications for caesareans among hospital deliveries. This chapter begins by describing the urgency of and clinical indications for caesareans in central Ghana. It then investigates whether the caesarean rate varies according to the type of obstetric complication and Robson category. It lastly assesses whether less educated women are less likely to receive a caesarean within hospitals by examining variations in the caesarean rate among complicated deliveries according to maternal education.

6.1. Introduction

Data on indications for caesareans are routinely collected in most maternity services and presented frequently. However, as discussed in chapter 1, the distribution of the urgency of and indications for caesareans does not appear to be useful for measuring the unmet need for caesareans, since they do not have validated benchmarks. The Robson classification may be useful for identifying unmet need in one category (transverse or oblique lies), since these are absolute maternal indications (AMIs) with a clear minimum caesarean rate of 100%, however its usefulness for other groups is limited without validated minimum rates.

However, even if clinical data cannot be used to measure the unmet need directly, other approaches to analysing hospital data on caesareans may provide insights into patterns of access to care, both in reaching health facilities and in the care received within them. Indeed, groups with differing utilisation of delivery care are predicted to have different distributions of urgency of and indications for caesareans among hospital deliveries: for example, women with no education (who have low facility delivery and caesarean rates, see chapter 4) are hypothesised to have more emergency caesareans and more caesareans for severe indications than more educated women, who have better access to care. Within facilities, the unmet need for caesareans cannot be calculated among non-absolute complications since the minimum optimal caesarean rate is unknown in these groups, though it is possible to determine whether variations in the caesarean rate across complications is consistent with the predicted level of need for caesareans. Furthermore, comparing the caesarean rate among each type of complication across educational groups can help understand whether less educated women are less likely to receive a caesarean within facilities.

6.1.1. Objectives

The objective of this chapter is to examine whether hospital data on caesareans can be presented in a useful way to inform our understanding of the unmet need for caesarean sections and access to care among hospital deliveries.

Specifically, in this chapter I will:

1. Describe the urgency status and clinical indications for caesareans;
2. Examine variations in the caesarean rate among deliveries with different complication types and among Robson categories;

3. Determine whether the urgency of and indications for caesareans vary according to educational groups known to have different access to delivery care; and
4. Assess whether access to caesareans within facilities varies with education by determining whether less educated women have lower caesarean rates than more educated women with the same complication types.

6.2. Methods

In this analysis, I use the hospital subsample from the ObaapaVitA trial, which includes information on more than 90% of women who reported delivering at one of the four district hospitals in the study area. The selection of hospital deliveries and construction of mode of delivery and socio-economic variables are detailed in chapter 4 (sections 4.2.6 and 4.2.7). I exclude from this analysis 380 postpartum admissions, leaving a total sample of 13,506 deliveries in hospitals.

Additional methods specific to this analysis are described below.

6.2.1. Definition of outcomes

Emergency vs. elective caesareans

Caesareans were categorised in the hospital data extraction form as emergency or elective based on the mode of delivery recorded by hospital-based data supervisors ("How was the baby delivered?"; response options: "Normally through the vagina", "Forceps", "Vacuum", "Emergency caesarean section" and "Elective caesarean section"). The ObaapaVitA trial used a definition of emergency caesarean based on decision time (where the decision to perform the caesarean is made after the onset of labour), rather than operation time (where the caesarean itself is performed after the onset of labour) [127]. Caesareans were classified as emergencies based on information in the hospital notes regarding whether women were in labour at the time of the decision.

Classification of clinical indications for caesareans

The hospital data collection form recorded indications for caesareans and other obstetric surgeries. The code list consisted of 40 individual indications for obstetric surgery as well as an “Unknown” code, of which 7 were postpartum conditions not relevant for caesareans.

The classification proposed by Stanton et al. was used to classify indications for caesareans [49]. The WHO systematic review of classifications of caesareans [75] mentioned in section 1.5 did not highly rate this classification because it did not provide clear definitions for each group and it had not been tested on real patients. Nonetheless, the Stanton classification was used in this study because it was one of the most detailed classifications and enabled for distinguishing between absolute maternal and non-absolute indications. I used data on recorded diagnoses in order to sub-categorise some indications categories (for instance, caesareans for “antepartum haemorrhage from placenta praevia” were classified as “major antepartum haemorrhage” if the delivery had a diagnosis of placenta praevia type III or IV, and as “antepartum haemorrhage (excluding AMIs)” otherwise). There were no available indications that were classifiable as “genitourinary fistula” or “psychosocial indications”, and these categories were omitted from the classificiation. Three categories could not be mapped onto Stanton et al.’s classification and were added as separate categories (“multiple pregnancy”, “other”, and “unknown”). Table 6.1 presents the classification of indications for caesarean used in this chapter.

Dealing with multiple indications

The hospital form allowed for up to three indications to be recorded. Caesareans with at least one AMI were classified as caesareans for AMIs; among AMIs, indications are not hierarchical, and therefore all indications recorded for caesareans for AMIs are reported. Caesareans with no AMIs were categorised as caesareans for non-absolute indications, and similarly all recorded indications are reported among these caesareans (including multiple indications). The indications categories are therefore not mutually exclusive.

Table 6.1 Classification of indications for caesarean

Category	Indications	Complication
ABSOLUTE MATERNAL INDICATIONS		
Obstructed labour	Cephalopelvic disproportion (CPD)	Obstructed labour
	Macrosomia	Obstructed labour
Major antepartum haemorrhage	Antepartum haemorrhage due to placenta praevia	Partial placenta praevia, placenta praevia type III
		Complete placenta praevia, placenta praevia type IV
Malpresentation	Transverse lie	
	Brow presentation	
	Face presentation	
	Oblique lie	
Uterine rupture	Uterine rupture	
	Pre-uterine rupture or Bandl's ring	
NON-ABSOLUTE INDICATIONS		
Failure to progress	Cephalopelvic disproportion (CPD)	No diagnosis of obstructed labour
	Macrosomia	No diagnosis of obstructed labour
	Cervical stenosis/dystocia	
	Vaginal stenosis/dystocia	
	Premature rupture of membranes	
	Prolonged labour	
Previous caesarean	Previous caesarean section/Scarred uterus	
Genitourinary fistula or third-degree tear repair	-	
Antepartum haemorrhage (excluding AMIs)	Antepartum haemorrhage due to placenta praevia	No diagnosis of partial placenta praevia type III type IV
	Antepartum haemorrhage due to placental abruption	
	Antepartum haemorrhage, cause unspecified	
Maternal medical diseases	Medical conditions in the mother	
Severe pre-eclampsia or eclampsia	Pregnancy-induced hypertension	
	Pre-eclampsia	
	Eclampsia	
Psychosocial indications	-	
Fetal compromise	Fetal distress	
	Cord prolapse	
	Cord around the neck	
	Congenital malformation (baby)	
	Hydramnios	
	Oligoamnios	
	Hydrocephalus	
Breech presentation	Breech presentation	
	Footling breech	
Multiple pregnancy	Multiple pregnancy	
Other	Other	
Unknown/no information	Not known	

Robson classification

The Robson classification was described in chapter 1 (Table 6.2). I modified the Robson classification for this analysis (Table 6.3) because induction of labour was not recorded in the ObaapaVitA hospital form: I grouped all nullipara with singleton cephalic delivery (groups 1 and 2), and all multipara with singleton cephalic delivery and no previous caesarean (groups 3 and 4) together, respectively.

Table 6.2 Robson classification [64]

1 - Nulliparous, singleton cephalic, ≥ 37 weeks, in spontaneous labour
2 - Nulliparous, singleton cephalic, ≥ 37 weeks, induced or caesarean before labour
3 - Multiparous (excluding previous caesarean), singleton cephalic, ≥ 37 weeks, in spontaneous labour
4 - Multiparous (excluding previous caesarean), singleton cephalic, ≥ 37 weeks, induced or caesarean before labour
5 - Previous caesarean, singleton cephalic, ≥ 37 weeks
6 - All nulliparous breeches
7 - All multiparous breeches (including previous caesarean)
8 - All multiple pregnancies (including previous caesarean)
9 - All abnormal lies (including previous caesarean)
10 - All singleton cephalic, ≤ 36 weeks (including previous caesarean)

Table 6.3 Modified Robson classification used in this analysis

1/2 - Nulliparous, term singleton cephalic
3/4 - Multiparous (no previous caesarean), term singleton cephalic
5 - Previous caesarean, term singleton cephalic
6 - All nulliparous breeches
7 - All multiparous breeches (including previous caesarean)
8 - All multiple pregnancies (including previous caesarean)
9 - All abnormal lies (including previous caesarean)
10 - Pre-term singleton cephalic (including previous caesarean)

Singleton cephalic deliveries with an estimated gestational age of less than 37 weeks or less than 9 months were classified as pre-term singleton cephalic deliveries (group 10). Previous caesarean section was not recorded for all deliveries, so I used maternal self-report from the profile form to identify women with a previous caesarean. For a number of women, this information was collected after delivery: 112 women delivered by caesarean and stated having a previous caesareans after the index delivery, making it impossible to ascertain whether they had received a caesarean before the most recent delivery. These women account for 14% of the 774 women who reported a previous caesarean and delivered by caesarean at the index pregnancy, and they were classified as having a previous caesarean.

Classification of delivery complications

The classification of delivery complications was described in chapter 4 (Table 4.2 on page 117). Women admitted postpartum were excluded from this analysis, though women who were admitted before or during delivery may have developed postpartum complications (such as postpartum haemorrhage and infection). In this analysis I do not present information on postpartum complications or non-obstetric complications from the classification, since caesareans are not used to treat these conditions.

6.2.2. Statistical analyses

I first described the indications for all caesareans among hospital deliveries, including the percentage of emergency caesareans and caesareans performed for AMIs, as well as for each clinical indication. Hospital deliveries were further classified into Robson groups, and the caesarean rate calculated in each category.

Second, I calculated the caesarean rate among hospital deliveries with different obstetric complications, in order to assess whether the caesarean rate varies according to the hypothesised level of need for caesareans (for example, whether more severe dystocic complications have higher caesarean rates than deliveries with less severe dystocia).

Lastly, I examined whether indications for caesareans and the caesarean rate in hospitals (for all deliveries and stratified by complication) vary according to maternal education, in order to assess whether less educated women are less likely to receive a caesarean than more educated women. As in the previous chapter, maternal education was chosen because it had the widest variation in facility delivery and caesarean rates (see chapter 4), which allowed for examining how differences in access affect the distribution of indications for caesareans and whether population-based differences in caesarean rates are partly explained by differential access to caesareans within hospitals. Chi-square tests were used to test for differences in indications and the caesarean rate according to maternal education.

6.3. Results

The sample used for this analysis consisted of 13,506 women with a record of admission during pregnancy or labour (but excluding postpartum admissions) in the district hospitals of the study area, of which 2,306 delivered by caesarean. The analyses according to maternal education excluded 30 hospital deliveries with missing information (including six by caesarean).

6.3.1. Indications for caesareans

Emergency status

Caesareans accounted for 17% (n=2,306) of hospital deliveries. Overall, 90.1% (n=2,078) of caesareans were emergency interventions (where the decision was made after the onset of labour), and 9.9% were elective caesareans. The emergency caesarean rate (percentage of hospital deliveries with emergency caesareans) was 15.4%.

Clinical indications

Of the 2,306 caesareans, 1,498 (65%) had one recorded indication, 682 (30%) had two recorded indications and 93 (4%) had three recorded indications. The indication was unknown in 33 caesareans (1.4%).

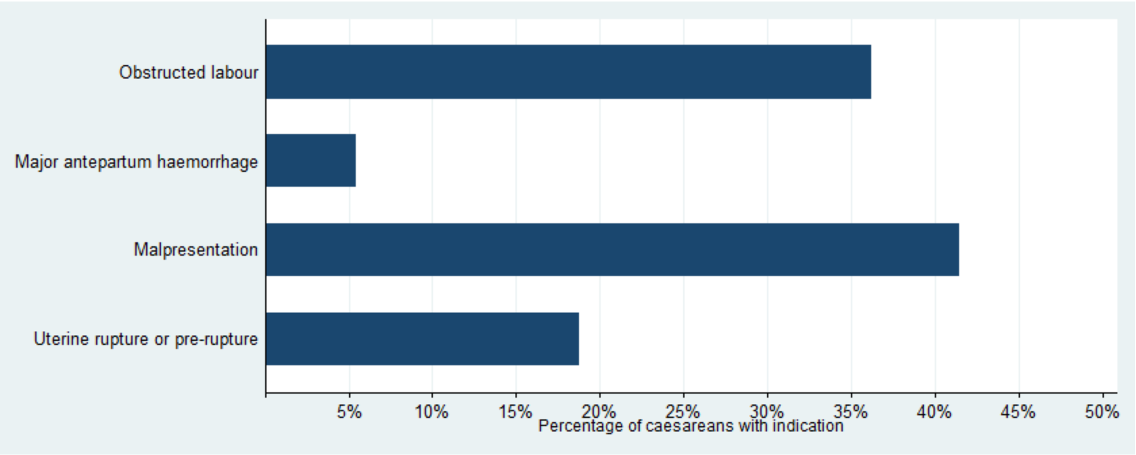
Table 6.4, Figure 6.1 and Figure 6.2 present the recorded indications for caesareans among hospital deliveries, stratified according to absolute maternal and non-absolute indications. Of the 2,306 caesareans, 9.7% (n=224) were performed for AMIs, among which malpresentation and obstructed labour were the most common indications (42% and 32% of caesareans for AMIs, respectively). Eighty-nine percent (n=2,049) of all caesareans were performed for non-absolute indications; among these, failure to progress was recorded as an indication in more than half (55%) of procedures. One quarter (26%) of caesareans for non-absolute indications had an indication of previous caesarean, and 18% of fetal compromise. In total, 447 caesareans for non-absolute indications (22%) had at least one indication coded as “other”.

Table 6.4 Indications for caesarean sections among hospital deliveries

Indication	N	%
Absolute Maternal Indications	224	9.7
Obstructed labour	81	36.2
Major antepartum haemorrhage	12	5.4
Malpresentation	93	41.5
Uterine rupture or pre-rupture	42	18.8
Non-absolute indications	2,049	88.9
Failure to progress	1,118	54.6
Previous caesarean	537	26.2
Antepartum haemorrhage (excluding AMIs)	95	4.6
Maternal medical diseases	15	0.7
Severe pre-eclampsia or eclampsia	120	5.9
Fetal compromise	365	17.8
Breech presentation	136	6.6
Multiple pregnancy	43	2.1
Other	447	21.8
Unknown indication	33	1.4
Total	**2,306**	**-**

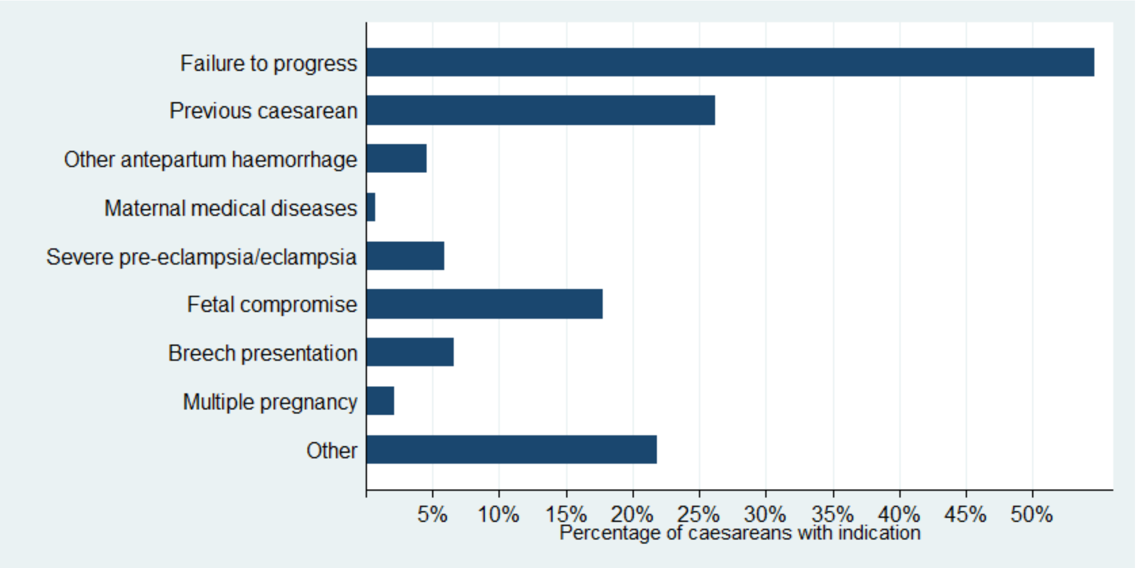
Note: the indications presented in this table include multiple indications, and therefore the sum of all absolute maternal and non-absolute indications adds up to over 100%.

Figure 6.1 Distribution of indications among caesareans performed for absolute maternal indications – hospital deliveries (N=224)



Note: some caesareans had multiple absolute maternal indications, and therefore the sum of all indications adds up to over 100%.

Figure 6.2 Distribution of indications among caesareans performed for non-absolute indications – hospital deliveries (N=2,049)



Note: some caesareans had multiple non-absolute indications, and therefore the sum of all indications adds up to over 100%.

6.3.2. Caesarean rates among Robson categories

Table 6.5 presents the distribution of deliveries and caesareans according to the modified Robson classification. Multiparous women with a singleton cephalic delivery and no previous caesarean represented the largest group of hospital deliveries (41%), followed by pre-term singleton cephalic deliveries (29%). The caesarean rate was almost twice as high among nullipara as multipara with a singleton cephalic delivery (19% compared with 10%), and half of all caesareans (47%) occurred in these two groups. Almost all transverse and oblique lies had a caesarean (96%), suggesting there is very little or no unmet need for caesareans in this group. The caesarean rate was similar among singleton breech deliveries for nullipara (100%) and multipara (93%), while less than one third of multiple births and 58% of women with a previous caesarean had a surgical delivery; it is not possible to interpret these findings in relation to the unmet need for caesareans, since the minimum caesarean rate in these categories is not known.

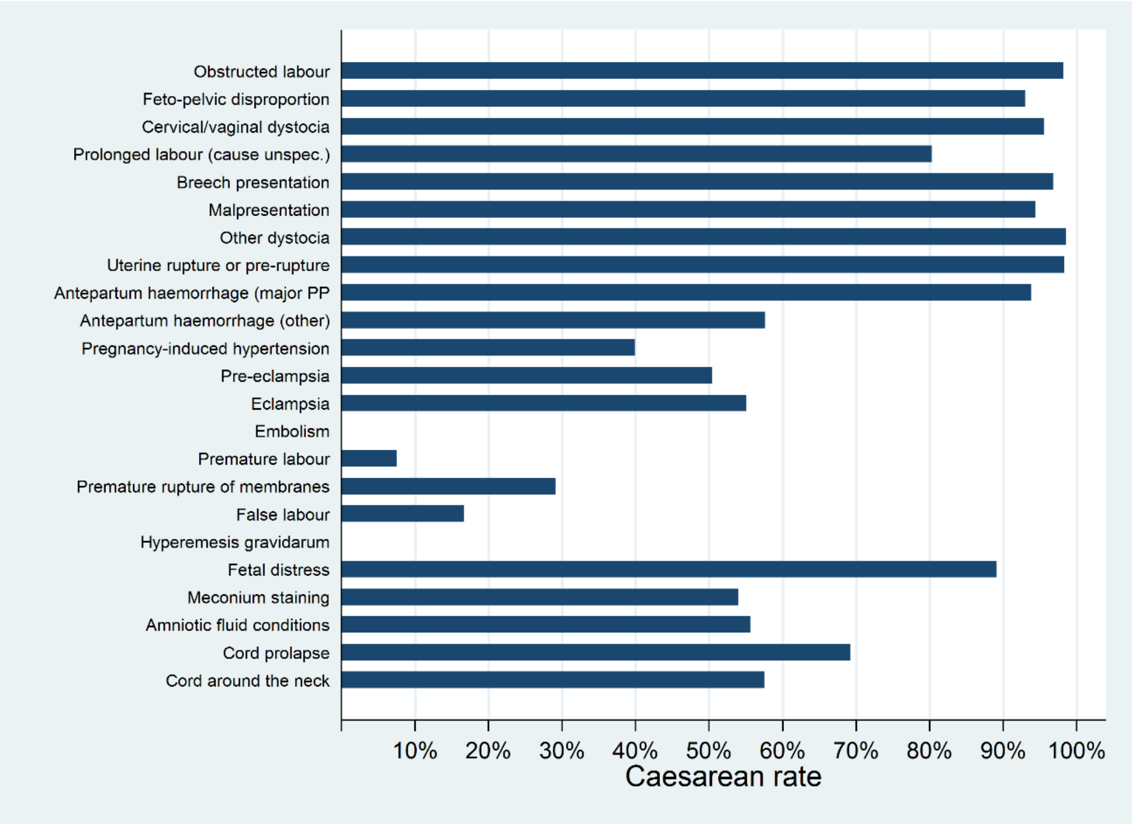
Table 6.5 Distribution of hospital deliveries and caesareans according to modified Robson categories

	Robson category	N (%)	Caesarean rate	Percentage of all caesareans in category
1/2	Nullipara, singleton cephalic delivery	2798 (20.8)	18.9	23.0
3/4	Multipara (no previous caesarean), singleton cephalic delivery	5452 (40.5)	10.0	23.7
5	Multipara with previous caesarean, singleton cephalic delivery	771 (5.7)	58.1	19.5
6	Nullipara singleton breech delivery	45 (0.3)	100.0	2.0
7	Multipara singleton breech delivery (including previous caesarean)	58 (0.4)	93.1	2.3
8	Multiple pregnancy (including previous caesarean)	442 (3.3)	31.4	6.0
9	Singleton transverse or oblique delivery (including previous caesarean)	51 (0.4)	96.1	2.1
10	All pre-term singleton cephalic (including previous caesarean)	3868 (28.7)	12.7	21.4

6.3.3. Caesarean rate among deliveries with complications

Table 6.6 and Figure 6.3 present the caesarean rate among hospital deliveries with complications. Almost two thirds (65%) of deliveries with any complication were by caesarean, compared with only 2% of deliveries with no recorded complication. The caesarean rate was broadly consistent with the expected level of need for caesareans: it was highest for deliveries with dystocia (90%), and lower for deliveries with hypertension (45%) and other obstetric complications (21%), among which caesareans are not the most common treatment. Among specific complications, the caesarean rate was almost 100% among deliveries with obstructed labour and uterine rupture, two AMIs, and it was lower among less severe complications (such as pre-eclampsia compared with eclampsia, and antepartum haemorrhage from major placenta praevia compared with other antepartum haemorrhage). However, the caesarean rate among breech deliveries was higher than among malpresentations (97% compared with 94%), which is inconsistent with the fact that the latter are AMIs while breech is not.

Figure 6.3 Caesarean rates among deliveries with complications (N=3,234)



Note: "Antepartum haemorrhage (major PP)" refers to antepartum haemorrhage from major placenta praevia

Table 6.6 Caesarean section rate among hospital deliveries, stratified according to obstetric complication (n=13,506 hospital deliveries)

Complication	N	Caesarean rate (%)
Dystocia	1,844	89.6
Obstructed labour	216	98.2
Cephalopelvic disproportion	657	93.0
Cervical/vaginal dystocia	513	95.5
Prolonged labour (cause unspecified)	497	80.3
Breech presentation	155	96.8
Malpresentation	108	94.4
Other dystocia	363	94.2
Haemorrhage	275	66.9
Uterine rupture or pre-rupture	57	98.3
Antepartum haemorrhage from major placenta praevia	16	93.8
Other antepartum haemorrhage	212	57.6
Hypertension	458	45.2
Pregnancy-induced hypertension	258	39.9
Pre-eclampsia	137	50.4
Eclampsia	78	55.1
Other obstetric complications	340	20.6
Embolism	1	0.0
Premature labour	146	7.5
Premature rupture of membranes	206	29.1
False labour	6	16.7
Hyperemesis gravidarum	2	0.0
Fetal complications	1,170	60.3
Fetal distress	394	89.1
Meconium staining	780	54.0
Amniotic fluid conditions	36	55.6
Cord prolapse	52	69.2
Cord around the neck	153	57.5
Any complication	**3,234**	**64.9**
No complication	**10,270**	**2.1**

6.3.4. Variation in indications and caesarean rates according to maternal education

Caesarean rate among hospital deliveries

There was little variation in the hospital caesarean rate according to maternal education (see Table 6.7). The rate was slightly higher among women with secondary school education or higher (18%), compared to 15-16% among less educated women ($p<0.001$). The percentage of caesareans that were emergency procedures was lower among women with post-secondary education, though there was no evidence that this difference was significant (85% compared with 90-91% among women with no, primary or secondary education, p=0.724). However, the emergency caesarean rate increased from 13% among women with no education to 17% among women with secondary education, and declined slightly in the post-secondary education group (p<0.001).

Table 6.7 Hospital caesarean rate and emergency status of caesareans according to household wealth and maternal education (hospital deliveries)

Maternal education	Hospital deliveries (N)	Hospital caesarean rate		Emergency caesarean rate		% Emergency caesareans	
		%	*p-value*	%	*p-value*	%	*p-value*
None	3,263	14.5	<0.001	13.1	<0.001	90.5	0.724
Primary	2,561	16.4		14.7		90.0	
Secondary	7,383	18.4		16.6		90.2	
Post-secondary	269	17.8		15.2		85.4	
All hospital deliveries	**13,506**	**17.1**	**-**	**15.4**	**-**	**90.1**	**-**

Indications for caesareans

Table 6.8 presents clinical indications for caesareans stratified by maternal education. Six caesarean deliveries following admission during labour were excluded because of missing data on education (n=2,300). There was weak evidence that the percentage of caesareans performed for AMIs was higher among women with less education than more education (p=0.065); this percentage was 13% among women with no education and 8% among women with post-secondary education. Among caesareans performed for AMIs, the proportion with an indication of obstructed labour was highest among women with primary and post-secondary education (p=0.016). There was no difference in the proportion of caesareans for AMIs with major antepartum haemorrhage, malpresentation or uterine rupture. Similarly, there was no difference in the percentage of caesareans with most indications among caesareans for non-absolute indications, with the exception of non-AMI antepartum haemorrhage which decreased from 7% among women with no education to 2% among women with post-secondary education (p=0.036). There was weak evidence that multiple pregnancy was a more common indication among less educated than more educated women (p=0.086).

Table 6.8 Percentage of caesareans with indications (including multiple indications), stratified by maternal education (n=2,300)

Indication	***No education (n=473)***	***Primary (n=419)***	***Secondary (n=1,360)***	***Post-secondary (n=48)***	**Chi-square p-value**
Absolute Maternal Indications	12.9	9.8	8.7	8.3	-
Obstructed labour	21.3	51.2	38.1	50.0	0.016
Major antepartum haemorrhage	8.2	2.4	5.1	0.0	0.593
Malpresentation	45.9	34.1	41.5	50.0	0.678
Uterine rupture or pre-rupture	24.6	14.6	17.8	0.0	0.421
Non-absolute indications	85.6	89.2	89.8	89.6	-
Failure to progress	53.6	57.7	52.8	45.5	0.262
Previous caesarean	24.5	29.9	25.3	15.9	0.107
Antepartum haemorrhage (excluding AMIs)	7.0	4.8	3.7	2.3	0.036
Maternal medical diseases	1.0	0.8	0.6	0.0	0.848
Severe pre-eclampsia or eclampsia	4.1	5.3	6.3	11.4	0.150
Fetal compromise	19.7	14.6	17.6	15.9	0.295
Breech presentation	5.6	5.8	6.8	13.6	0.196
Multiple pregnancy	3.4	0.8	2.0	2.3	0.084
Other	23.3	22.2	20.2	29.5	0.281
Unknown	1.5	1.0	1.5	2.1	-

Caesarean rate among deliveries with complications

Table 6.9 and Figure 6.4 present the caesarean rate for deliveries with complications, stratified by maternal education. There was a significant rise in the caesarean rate across educational levels among women with any complication, ranging from 60% among women with no education to 71% among women with post-secondary education (p=0.004). There was only weak evidence that the caesarean rate also increased with educational level among deliveries with no complications (p=0.059).

Women with dystocia, haemorrhage, and other obstetric complications had similar caesarean rates across educational levels (including three AMI categories: uterine rupture, obstructed labour and malpresentation). The caesarean rate among deliveries with hypertension increased from 35% in the lowest educational group to 67% in the highest, as well as within each type of hypertensive complication, though there was only weak evidence that this trend was significant (p=0.086). However, more educated women with fetal complications were more likely to deliver by caesarean than less educated women (75% of women with post-secondary education compared with 52% of women with no education, p<0.001), driven by caesarean rate differences in deliveries with fetal distress and meconium staining. There was no educational difference in the caesarean rate for complicated deliveries after excluding fetal complications (p=0.336, data not shown).

Figure 6.4 Caesarean rate among deliveries with complications, stratified by maternal education (N=2,300)

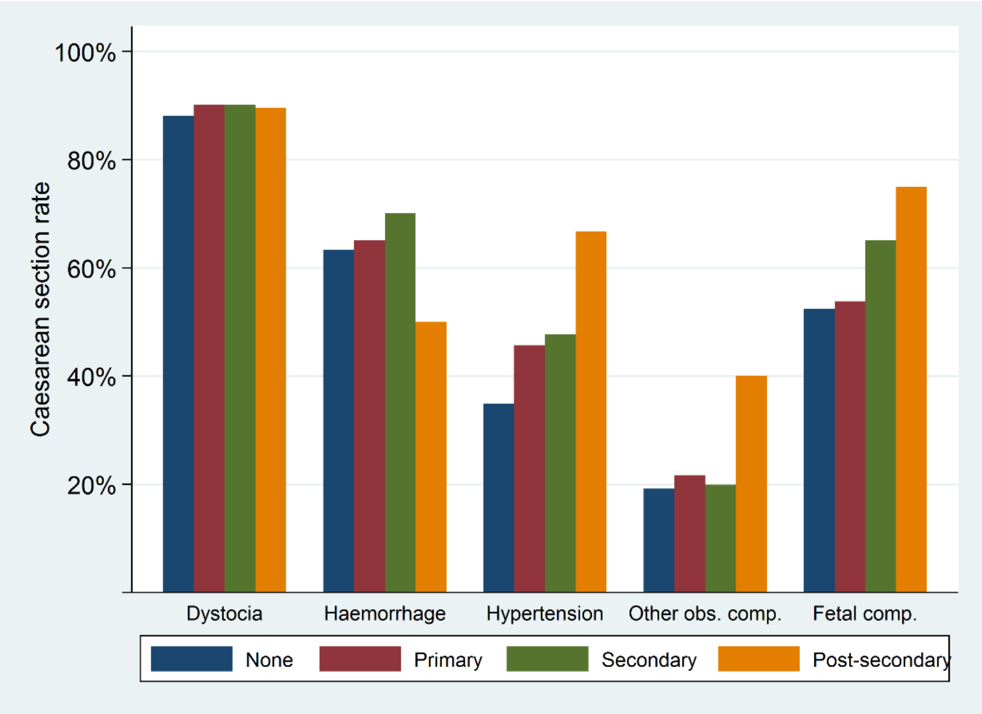


Table 6.9 Percentage of caesareans among deliveries with complications, stratified by maternal education

Complication	N	Caesarean rates by educational level				P-value
		No education	*Primary*	*Secondary*	*Post-secondary*	
Dystocia	1,839	88.1	90.1	90.1	89.5	0.744
Obstructed labour	214	98.0	100.0	97.4	100.0	0.730
Feto-pelvic disproportion	653	89.3	94.1	94.4	83.3	0.100
Cervical/vaginal dystocia	513	91.2	96.8	95.9	100.0	0.276
Prolonged labour (cause unspecified)	493	80.6	82.4	79.6	81.8	0.948
Breech presentation	154	93.3	96.0	97.8	100.0	0.633
Malpresentation	108	100.0	85.0	94.5	100.0	0.148
Other dystocia	362	97.8	92.6	92.6	100.0	0.266
Haemorrhage	273	63.3	65.1	70.1	50.0	0.634
Uterine rupture or pre-rupture	57	95.2	100.0	100.0	-	0.418
Antepartum haemorrhage from major placenta praevia	16	100	100	87.5	100	0.785
Other antepartum haemorrhage	210	51.5	59.5	61.2	33.3	0.503
Hypertension	455	34.9	45.7	47.7	66.7	0.086
Pregnancy-induced hypertension	255	30.0	45.8	40.9	55.6	0.294
Pre-eclampsia	137	42.1	40.0	53.3	100.0	0.182
Eclampsia	78	38.9	53.8	61.7	-	0.253
Other obstetric complications	340	19.2	21.7	19.9	40.0	0.720
Embolism	1	-	0.0	-	-	-
Premature labour	146	2.9	3.4	11.3	0.0	0.315
Premature rupture of membranes	206	30.4	35.5	25.6	66.7	0.326
False labour	6	0.0	50.0	0.0	-	0.301

Complication	N	Caesarean rates by educational level				P-value
		No education	*Primary*	*Secondary*	*Post-secondary*	
Hyperemesis gravidarum	2	0.0	-	0.0	-	-
Fetal complications	1,165	52.4	53.8	65.1	75.0	<0.001
Fetal distress	393	82.0	90.0	91.1	100.0	0.090
Meconium staining	775	46.1	48.1	58.5	68.4	0.008
Amniotic fluid conditions	36	42.9	62.5	64.3	-	0.472
Cord prolapse	52	70.6	70.0	68.0	-	0.983
Cord around the neck	152	57.1	37.0	61.6	100.0	0.043
Any complication	**3,215**	**59.7**	**64.5**	**67.0**	**70.5**	**0.004**
No complication	**10,250**	**1.4**	**2.0**	**2.3**	**2.4**	**0.059**

6.4. Discussion

6.4.1. Summary of main findings

Caesarean rates were consistent with the predicted level of need for caesareans: they were highest among dystocic complications, and lowest for "other obstetric complications" which infrequently require a caesarean. The caesarean rate among deliveries with eclampsia was similar to that found in a systematic review of caesarean rates in hospitals in sub-Saharan Africa (median across studies: 64%, compared with 55% in Brong-Ahafo), though it was much higher for women with prolonged labour (median: 22%, compared with at least 80% in Ghana) [86], probably partly because of different case definitions. As shown in the previous chapter, almost 100% of obstructed labours, uterine ruptures and malpresentations had a surgical delivery, suggesting the need for caesareans in these AMIs is met among hospital deliveries.

Overall, the caesarean rate among complicated deliveries increased with education, driven by the trend among deliveries with fetal complications (and a borderline trend among deliveries with hypertension). For most individual complications, including the three AMIs, women were equally likely to deliver by caesarean regardless of their education.

Ninety percent of caesareans were emergency operations. Women with post-secondary education had a lower percentage (though not significantly) of emergency procedures among caesarean deliveries (85%), however the percentage of emergency caesareans among all hospital deliveries increased with education ($p<0.001$). Failure to progress was the most common indication for caesareans, as has previously been found in other settings in sub-Saharan Africa [79, 81, 83] and Asia [80, 82]. One quarter of caesareans were performed for previous caesarean, which is within the 12-43% range observed across 8 sites in sub-Saharan Africa [85]. There was no difference in the percentage of caesareans with each indication by education, except for antepartum haemorrhage other than AMIs which were less common with higher education.

6.4.2. Interpretation

As expected, analysing the distribution of emergency caesareans and indications for caesareans was not useful for assessing the unmet need for caesareans within facilities, including when stratified according to education. The very high caesarean rates observed among AMIs indicates that the need for caesareans is met for these complications among hospital deliveries. However, without benchmarks for minimum necessary caesarean rates among “non-absolute” complications, it is not possible to conclude whether the need for caesareans is met in these groups, or among all but one Robson category (transverse and oblique lies). The variation in caesarean rates was nonetheless broadly consistent with the predicted level of need for caesareans, with the exception that caesarean rates among breech deliveries was higher than among malpresentations. Though the minimum optimal caesarean rate for breech is not known, it is likely to be less than 100% since all breeches do not require surgery to avert poor maternal or perinatal outcomes: the caesarean rate of almost 100% suggests that there is no unmet need for caesareans among breech deliveries, though it is not possible to assess whether unnecessary caesareans were performed in this group.

To my knowledge, this was the first study to analyse variations in the caesarean rate among obstetric complications stratified by education. For all types of complications except fetal complications, women were equally likely to receive a caesarean regardless of their educational level. Though the minimum optimal caesarean rate is not known for most complications, and therefore the magnitude of unmet need for caesareans cannot be calculated, the results from this study suggest that the unmet need among hospital deliveries (if any) is similar across educational levels in the ObaapaVitA study area. This further indicates that discrepancies in the population-based caesarean rate are primarily driven by differences in access to deliveries in facilities performing caesareans, rather than in access to caesareans within facilities.

The increase in caesarean rate with education among women with fetal complications is unlikely to be due to chance ($p<0.001$) or to bias in the ascertainment of caesareans, since data were collected prospectively and supervised by the study team. The diagnosis of fetal distress relies on a subjective assessment by obstetric care providers [205], however it is improbable that less severe fetal distress would be more likely to be recorded among less educated women, and hence this association is unlikely to be explained by bias in this diagnosis. Confounding due to the severity of fetal complications is also unlikely, since more educated women were equally likely to experience severe fetal complications such as cord prolapse or cord around the neck as less educated women (see chapter 4). The educational gradient in the caesarean rate among women with fetal complications may be real, and if so would suggest that either less educated women are not receiving the care they need, or that more educated women are receiving unnecessary caesareans (or both). It is not possible to determine which of these alternatives is true without knowing the optimal caesarean rate for fetal complications. The barriers faced in accessing care for fetal complications by women with less education may be financial (the extent of user fees for caesareans and National Health Insurance Scheme coverage throughout the study period is uncertain [168]), though these would be expected to affect all complications rather than just fetal ones. They may also be communication- or discrimination-related barriers, echoing findings elsewhere in Ghana where patients from rural areas were found to receive differential treatment from providers in hospitals [206].

6.4.3. Strengths and limitations

This is the first study to analyse clinical data on caesareans according to maternal education. The major strength of this study is that both clinical data on caesareans and delivery complications, as well as maternal socio-economic information, were available for hospital deliveries. Though available indications codes were not detailed enough, the availability of complications data enabled me to use Stanton et al.'s indications classification and distinguish between caesareans performed for absolute maternal and non-absolute indications [49]. Information on induction of labour was not available and therefore it was not possible to classify deliveries into all ten original Robson categories. Moreover, the assessment of gestational age was made on the basis of last menstrual period rather than early pregnancy ultrasound, raising concerns about misclassification which are supported by the relatively high proportion of deliveries in the pre-term group (29%, compared with the 12.3% estimate for sub-Saharan Africa based on a systematic global analysis of available data [207]).

The limitations of indications data have been extensively mentioned in the literature, regarding both completeness and validity, but rarely quantified. An assessment of caesarean records in nine facilities in sub-Saharan Africa and Bangladesh found that 20% of caesarean records could not be located in more than half the sites [85]. The authors also argued that doctors may misclassify the indication in order to make the caesarean seem medically justified [85]. In Tanzania, Maaløe et al. found that over one third of caesareans for prolonged labour were inappropriate because either the partograph showed timely progression of labour or the membranes were still intact (indicating that induction of labour had not been attempted) [202]. Overall, one quarter of caesareans had an inappropriate indication and 38% had unclear indications [202]. Though less documented, information on obstetric complications may also be misrecorded. In Brong-Ahafo, data were collected prospectively, and the great majority of caesareans are likely to have been captured. Only 2% of caesareans had no recorded indication.

6.5. Conclusion

The need for caesareans to treat uterine rupture, obstructed labour and transverse/oblique lies appears to be largely met among hospital deliveries in Brong-Ahafo, regardless of the woman's education. For most other complications, the likelihood of receiving a caesarean was not affected by education, but it was not possible to determine whether there was an unmet need for caesareans. More educated women experiencing fetal distress were more likely to receive a caesarean than less educated women, but similarly it was not possible to state whether this trend represents an unmet need among less educated women or an excess among more educated women. These findings suggest that population-based differences in the caesarean rate are predominantly explained by differences in access to hospital deliveries, rather than by differential access to caesareans within hospitals.

Indications data were not useful for assessing the unmet need for caesareans, including when stratified by socio-economic status. The Robson classification was informative for one group (transverse and oblique lies), but could not inform our understanding of the unmet need in other groups with unknown minimum caesarean rates.

Chapter 7. Discussion

The overall aim of this thesis was to explore existing and novel approaches to measuring the unmet need for caesarean sections in sub-Saharan Africa and South Asia. This chapter consists of two broad sections: I first synthesise the findings of this thesis, and second, I outline the implications for measuring the unmet need for caesareans in sub-Saharan Africa and South Asia, as well as making recommendations for future research.

7.1. Summary of findings

Caesareans are an essential, and sometimes life-saving, component of emergency obstetric care [7]. The rise in caesarean rates worldwide has raised concerns over the excessive use of this procedure [11-14, 125]; however many women in sub-Saharan Africa and South Asia, particularly poor rural women, still face obstacles in accessing emergency obstetric care – including caesareans – when they need it [107, 108, 116, 154, 208].

Measuring the unmet need for caesareans is important to monitor progress in access to emergency obstetric care. The main difficulty of measuring this unmet need lies in defining who needs a caesarean. For most interventions in maternal and child health (such as facility delivery or vaccinations), the great majority of women and children are expected to benefit from the intervention. However, because of the risks associated with caesareans [8, 62, 63], as well as the additional cost of surgical compared to vaginal deliveries [1], caesareans should not be performed routinely. Researchers have attempted to define the need for caesareans at the population level and within subgroups of deliveries, but there remains no consensus on how to measure the unmet need for caesareans.

This thesis aimed to address this knowledge gap by examining how best to measure the unmet need for caesarean sections in sub-Saharan Africa and South Asia. The following research questions were addressed:

1. Is there a minimum caesarean rate at the population level, below which women and babies are known to die?
2. Does the concept of absolute maternal indications help identify a threshold of met need for caesarean sections?
3. Is an analysis of the caesarean rate in subgroups of women useful for assessing the unmet need for caesareans?

7.1.1. Is there a minimum caesarean rate at the population level, below which women and babies are known to die?

Ecological studies have not identified a valid threshold for the minimum optimal caesarean rate necessary to achieve low maternal and perinatal mortality. The reported threshold beyond which maternal mortality ceases to decline varied between 10% and 15-20% for low-income or developing countries, and was 15-20% for early neonatal mortality and 13% for stillbirths. The ecological evidence indicates the minimum optimal caesarean rate is likely to be above the WHO 5% lower threshold, suggesting rates below 5% may indicate an unmet need, though low maternal mortality has been observed historically in high-income countries with caesarean rates below this benchmark. Similarly, there was no consensus on the optimal caesarean rate among clinicians: though three quarters of Optimal Caesarean Rates Survey respondents reported the optimal rate to be above the 15% upper limit suggested by the WHO, the substantial variation in responses highlighted a lack of agreement between obstetric care providers. The sample was not representative of doctors who perform caesareans worldwide, which may have biased the median optimal rate, however the variation in responses would have been unlikely to be completely eliminated with a representative sample. There is no other data source which can be used to validate the optimal caesarean rate at the population level, and therefore efforts to estimate it are unhelpful. Even if there had been agreement between ecological evidence and obstetricians' opinions, conceptual issues remain: as mentioned in section 1.3.1, the relationship between the population-based caesarean rate and maternal or perinatal mortality may be confounded by other factors, such as access to delivery care, and it may also be modified by the quality of care. These issues raise the question of whether there is such a thing as an optimal caesarean rate across populations, and whether this concept is valid for monitoring access to emergency obstetric care. These limitations indicate that the optimal caesarean rate is not useful as a benchmark for calculating the unmet need for caesareans.

There is evidence to support an absolute minimum caesarean rate indicative of high maternal and perinatal mortality. The 1% and 2% thresholds used in the literature have not been validated, but the review of ecological evidence presented in chapter 1 found that rates below these thresholds (particularly below 1%) were almost always associated with high maternal and neonatal mortality. Furthermore, the estimated prevalence of absolute maternal indications (AMIs) among women with no education was between 0.64 and 1.41%, suggesting that the true prevalence of AMIs may be close to 1% (assuming this estimate is unbiased). These findings suggest that caesarean rates below 1% almost certainly indicate that women are dying because of lack of access to surgical delivery; the evidence to support the 2% threshold as an indicator of high maternal mortality is weaker. It is therefore known that maternal and perinatal mortality is higher at very low caesarean rates, however above these thresholds it is difficult to make inferences about the unmet need – it is likely that the magnitude of life-saving need is lower with higher caesarean rates, but the burden of unmet need cannot be quantified and it is unknown at what level of caesarean rates maternal and perinatal outcomes begin to improve.

The analysis of Demographic and Health Survey data in chapter 2 showed that a large proportion of women have caesarean rates below 1% and 2% in low-income settings, suggesting there is a critical unmet need for caesareans in these populations. In most countries in sub-Saharan Africa and South Asia, caesarean rates were extremely low among the poor and less educated. In 21 of 26 countries, the caesarean rate was below 2% in the poorest quintile and eight countries showed evidence of large-scale unmet need at the population level, with 80% or more of the population below 1%. These findings suggest that poor women in these countries are dying due to lack of access to caesareans.

7.1.2. Does the concept of absolute maternal indications help identify a threshold of met need for caesarean sections?

The UON indicator was found not to be valid in central Ghana: pregnancy-related mortality from AMIs did not make up the shortfall between the observed and expected percentage of surgeries for AMIs. I argued that this finding is probably caused by misclassification of the severity of complications, particularly major cephalopelvic disproportion, leading to an overestimation of the number of surgeries for AMIs among more educated women. Similarly, a validation study in Bangladesh found that mortality from AMIs did not compensate for the socio-economic gradient in the percentage of surgeries for AMIs, and attributed these findings to an excess of surgeries for major cephalopelvic disproportion among wealthy and more educated women [50]. These findings suggest that groups with less than 1.4% surgery for AMIs cannot be interpreted as having excess mortality due to lack of access to surgery. The UON indicator has been used to calculate the absolute number of maternal deaths attributed to a deficit in surgeries for AMIs [41, 46]; the validation studies indicate this interpretation is not valid.

7.1.3. Is an analysis of caesarean rates in subgroups of women useful for assessing the unmet need for caesareans?

The caesarean rate among subgroups of deliveries is only useful for quantifying the unmet need for caesareans among groups with known optimal caesarean rates. In practice, this is restricted to conditions with an absolute need for caesareans – that is, where caesareans are required in all cases to avert severe morbidity or mortality in the mother or baby. Obstetricians agreed that AMIs constitute an absolute need for surgical delivery, reporting optimal caesarean rates of 91-100% with very little variation in responses (except for antepartum haemorrhage from placental abruption and face/brow presentation). In Ghana, the great majority of AMIs received surgery in hospitals, indicating that clinical practice is aligned with obstetric care providers' opinions in this setting. However, of the few women classified as having an AMI who did not receive surgery most survived, either because they are not "absolute" (i.e. they do not necessarily result in death without surgery) or because less severe complications were misclassified as AMIs. Even if they do not always lead to death without surgery, obstetricians' opinions and practices suggest that AMIs would lead to extremely severe morbidity without surgery, and that AMIs nonetheless constitute a critical need for caesareans. Therefore, caesarean rates below 100% among deliveries with AMIs are an indicator of unmet need for caesareans.

The unmet need for caesareans cannot be quantified in other subgroups of deliveries, among which the optimal caesarean rate is unknown. However, analysing caesarean rates across different obstetric complications or Robson categories may still be useful for understanding patterns of access to care. First, it can be used to investigate whether the caesarean rate in hospitals varies according to the hypothesised level of need for caesareans. In Ghana, the caesarean rate among deliveries with non-absolute complications was consistent with the predicted need for caesareans, with the exception of breech deliveries which had a higher caesarean rate than some AMI categories. The caesarean rate among Robson categories was lowest in the lowest risk group (multiparas with term singleton cephalic delivery and no previous caesarean); and it was above 95% among nulliparas with singleton breech delivery and transverse/oblique lies.

More importantly, comparing hospital caesarean rates by socio-economic status is useful for understanding whether low population-based caesarean rates among the poor or less educated are partly driven by lower access to caesareans within hospitals. In hospitals in the Brong-Ahafo region of Ghana, women were equally likely to receive a caesarean for most complications regardless of their educational level, with the exception of fetal complications, for which more educated women were more likely to receive a caesarean. The limited variation in caesarean rates by education among hospital deliveries highlights that the lower population-based caesarean rates among women with no education primarily reflect poorer access to facilities equipped to perform caesareans, rather than poorer access to caesareans within these facilities. This finding is reassuring, and raises the question of whether the observed apparent equity in caesareans within district hospitals may have improved with the introduction of the fee exemption and NHIS policies in Ghana. A systematic review found evidence that the facility delivery rate and the percentage of complicated deliveries receiving treatment increased in Ghana following the removal of maternity care fees [209], though socio-economic inequalities in the facility delivery rate were not consistently reduced across districts in Ghana [210].

7.1.4. Limitations

Specific limitations to each of the analyses have been noted in the relevant chapters (sections 2.1.5, 3.4.3, 4.4.3, 5.4.3, and 6.4.3). Overall, the main limitation faced in this thesis lies in the fact that the concept of unmet need for caesareans is difficult to operationalise in practice. Conceptually, as outlined by the definition of unmet need used in this thesis (see section 1.2), it refers to women who need a caesarean but do not receive one. In practice, the work presented in this thesis has shown that identifying women who need a caesarean at the individual level requires clinical judgment and cannot be based on simple algorithms, while at the population level, the optimal caesarean rate is not a valid benchmark for calculating the unmet need. Without a valid definition of the need for caesareans, it is not possible to estimate the magnitude of unmet need.

7.2. Implications and recommendations for future research: how should we measure the unmet need for caesarean sections in sub-Saharan Africa and South Asia?

In the following section, I make recommendations for how to measure the unmet need for caesareans as well as suggestions for future research, on the basis of the findings presented in this thesis. In light of the fact that the main method to measuring the unmet need for caesareans – based on the optimal caesarean rate – was found not to be valid, what approaches can be used instead?

7.2.1. Caesarean rates below 1% and 2%

Based on the evidence from ecological studies and the estimate of the true prevalence of AMIs, caesarean rates below 1% and 2% are likely to indicate a critical unmet need for caesareans at the population level (though there is less evidence to support the 2%

threshold). I recommend that caesarean rates be monitored, at the national level and stratified according to maternal education and wealth quintile, as part of global efforts to examine equity in access to caesareans and identify groups of women with a critical unmet need. Caesareans are well documented in comparison to other emergency obstetric care signal functions, with representative data available for 90% of births in developing countries [211], making caesarean rates a useful indicator of emergency obstetric care coverage. The percentage of the population with rates below 1% (based on cumulative caesarean rates across wealth quintiles) is a useful summary indicator to capture coverage of this critical intervention, and it should be included in global efforts to monitor maternal and perinatal health such as the Countdown to 2015 Initiative [110] and Sustainable Development Goals 3.1 and 3.2 [212].

Few countries included in the ecological studies had caesarean rates below 1% or 2%, or even below 5%. It would be useful to conduct other ecological analyses at the sub-national level, where the corresponding maternal mortality data are also available, in order to validate these absolute minimum thresholds. More detailed historical data from high-income countries might further confirm that maternal and neonatal mortality is always high below these thresholds, though there are unlikely to be reliable historical measures of stillbirths or perinatal mortality. The 1% and 2% thresholds are likely to become less useful over time considering the rise in caesarean rates worldwide. In central Ghana, no socio-demographic or residential subgroup had caesarean rates below 2%, yet a non-negligible proportion of pregnancy-related deaths were caused by complications which might have been treated by caesareans (including uterine rupture, obstructed labour and antepartum haemorrhage). A key limitation of the 1% and 2% thresholds is that caesarean rates above these benchmarks do not necessarily imply that the critical unmet need for caesareans has been eliminated.

It is also important for countries to analyse the regional and urban-rural distribution of caesarean rates, in order to identify groups with poor access and target interventions for improving access to obstetric surgery. Monitoring equity trends over time can also help identify countries with rapid improvements in access to caesareans among the poor, such as Rwanda, where the proportion of the population with a caesarean rate below 2% declined from 80% to 0% between 2000 and 2010 (chapter 2). Lessons can be drawn from case-studies of these countries to inform strategies for improving access among underserved populations, as well as yield insights into preventing unnecessary interventions rising with improved access to care.

7.2.2. Analysis of caesarean rates among subgroups of hospital deliveries

Caesarean rates among complicated deliveries in facilities should be stratified by maternal socio-economic status, in order to identify any differential access to caesareans within health facilities. I recommend that facilities routinely collect socio-economic information on women who deliver: education is probably the easiest marker of socio-economic status for this purpose, since it requires a single question, there is little misclassification and it is more informative than occupation in contexts where many women do not work outside the home or work in the informal sector. While wealth quintiles based on household assets are useful for stratifying caesarean rates at the national level, the data collection required to calculate the wealth index is onerous and less appropriate for clinical settings.

Caesarean rates among deliveries with different complications should be regularly reviewed at the facility level to monitor clinical practice. Rates below 100% among AMIs are indicative of an unmet need for caesareans. It is not possible to quantify the unmet need for other conditions, but comparing the caesarean rate among different complications can help assess whether the rates vary according to the predicted level of need for caesareans. Similarly, facilities should monitor caesarean rates over time among the Robson categories in order to assess whether clinical management is consistent with the hypothesised need for caesareans. Robson analyses at a single point in time can yield only limited insights, considering differences in case mix across facilities.

The variation in caesarean rates among deliveries with complications and corresponding case-fatality rates is unknown across facilities. The WHO Global Survey on Maternal and Perinatal Health found that rising institutional caesarean rates were associated with increased maternal and perinatal mortality rates in Latin America [125], however it is unclear whether the models controlled for all confounding due to differences in case-mix. The minimum optimal caesarean rate for specific complications may vary according to quality of care provided in facilities, and there would be difficulties in standardising case definitions across facilities. It is therefore unlikely that the optimal rate for specific complications could be ascertained confidently with ecological studies at the facility level. However ecological studies may help identify absolute minimum caesarean rates for specific complications (such as breech delivery) which could then be used as benchmarks of critical unmet need for caesareans within facilities.

7.2.3. The Unmet Obstetric Need indicator

The UON indicator is unlikely to be useful for measuring the unmet need for obstetric surgery. Both its 1.4% threshold and interpretation were shown not to be valid in central Ghana, probably because of misclassification of the severity of complications in hospital records (particularly major cephalopelvic disproportion). Though the extent to which they are misclassified in other settings is unknown, data in other settings are probably less standardised and less valid than in Brong-Ahafo during the ObaapaVitA trial. In addition, no clear case definition of major cephalopelvic disproportion exists [48, 199], or for other AMIs such as incoercible postpartum haemorrhage. Thus, the UON indicator is unlikely to be valid elsewhere in sub-Saharan Africa and South Asia, and I recommend that validation studies should not be repeated in other settings. Building up a picture of the unmet need for caesareans

The work presented in this thesis indicates that there is no single indicator that can capture the magnitude of unmet need, and it is a limitation of this research that there is no clear-cut alternative indicator that can be recommended based on these findings. As stated previously, I recommend that countries examine which sub-populations have rates below 1% and 2%, and that facilities review their caesarean rates, but it appears that we will need multiple types of information in order to gauge the presence and extent of unmet need for caesareans within sub-Saharan Africa and South Asia. Complementary information would include quantitative indicators – such as the proportion of deliveries occurring in facilities equipped to provide emergency obstetric care, the duration of delays before emergency caesareans, use of partographs and other interventions to monitor labour and identify women in need of a caesarean – as well as qualitative information from audits of adverse maternal and perinatal events (in facilities and in the community). The magnitude of unmet need cannot be unambiguously deduced from a single piece of information, though together they can help build an understanding of access to emergency obstetric care for women in sub-Saharan Africa and South Asia.

7.3. Conclusion

In conclusion, the work presented in this thesis has contributed to knowledge of how to measure the unmet need for caesareans in sub-Saharan Africa and South Asia. I have shown that the minimum optimal caesarean rate and the UON indicator cannot be used to estimate the unmet need, but that caesarean rates below 1% probably indicate a critical unmet need for caesareans. Among subgroups, rates of surgery below 100% among absolute maternal indications reveal an unmet need for caesareans, but the unmet need cannot be quantified among less severe complications.

References

1. Gibbons L, Belizan JM, Lauer JA, Betran AP, Merialdi M, Althabe F. Inequities in the use of cesarean section deliveries in the world. American Journal of Obstetrics and Gynecology. 2012;206(4):331.e1-.e19.

2. WHO. Global Health Observatory (WHO) - Country statistics [Accessed: 15th April 2014]. Available from: http://www.who.int/gho/countries/en/.

3. Institut National de la Statistique (INS) et ICF International. Enquête Démographique et de Santé et à Indicateurs Multiples du Niger 2012. Calverton, Maryland, USA: INS et ICF International, 2013.

4. Stanton CK, Holtz SA. Levels and Trends in Cesarean Birth in the Developing World. Studies in Family Planning. 2006;37(1):41-8.

5. Betran AP, Merialdi M, Lauer JA, Bing-Shun W, Thomas J, Van Look P, et al. Rates of caesarean section: analysis of global, regional and national estimates. Paediatr Perinat Epidemiol. 2007;21(2):98-113.

6. Ronsmans C, Holtz S, Stanton C. Socioeconomic differentials in caesarean rates in developing countries: a retrospective analysis. Lancet. 2006;368(9546):1516-23.

7. WHO, UNFPA, UNICEF, AMDD. Monitoring emergency obstetric care: a handbook. Geneva, Switzerland: World Health Organisation. 2009.

8. Souza J, Gulmezoglu A, Lumbiganon P, Laopaiboon M, Carroli G, Fawole B, et al. Caesarean section without medical indications is associated with an increased risk of adverse short-term maternal outcomes: the 2004-2008 WHO Global Survey on Maternal and Perinatal Health. BMC Medicine. 2010;8(1):71.

9. Ronsmans C, Campbell OMR, McDermott J, Koblinsky M. Questioning the indicators of need for obstetric care. Bulletin of the World Health Organization. 2002;80(4):317-24.

10. Gichangi P, Apers L, Temmerman M. Rate of caesarean section as a process indicator of safe-motherhood programmes: the case of Kenya. J Health Popul Nutr. 2001;19(2):52-8.

11. Feng XL, Xu L, Guo Y, Ronsmans C. Factors influencing rising caesarean section rates in China between 1988 and 2008. Bulletin of the World Health Organization. 2012;90:30-9A.

12. Belizán JM, Althabe F, Cafferata ML. Health Consequences of the Increasing Caesarean Section Rates. Epidemiology. 2007;18(4):485-6 10.1097/EDE.0b013e318068646a.

13. Leone T, Padmadas SS, Matthews Z. Community factors affecting rising caesarean section rates in developing countries: An analysis of six countries. Social Science & Medicine. 2008;67(8):1236-46.

14. Niino Y. The increasing cesarean rate globally and what we can do about it. Biosci Trends. 2011;5(4):139-50.

15. Cyr RM. Myth of the ideal cesarean section rate: Commentary and historic perspective. American Journal of Obstetrics and Gynecology. 2006;194(4):932-6.

16. Schneid-Kofman N, Sheiner E, Levy A, Holcberg G. Risk factors for wound infection following cesarean deliveries. International Journal of Gynecology & Obstetrics. 2005;90(1):10-5.

17. Burrows LJ, Meyn LA, Weber AM. Maternal Morbidity Associated With Vaginal Versus Cesarean Delivery. Obstetrics & Gynecology. 2004;103(5, Part 1):907-12 10.1097/01.AOG.0000124568.71597.ce.

18. Gungorduk K, Asicioglu O, Celikkol O, Sudolmus S, Ark C. Iatrogenic bladder injuries during caesarean delivery: A case control study. Journal of Obstetrics & Gynaecology. 2010;30(7):667-70.

19. Chu K, Cortier H, Maldonado F, Mashant T, Ford N, Trelles M. Cesarean section rates and indications in sub-Saharan Africa: a multi-country study from Medecins sans Frontieres. PLoS One. 2012;7(9):e44484.

20. Gebremedhin S. Trend and socio-demographic differentials of Caesarean section rate in Addis Ababa, Ethiopia: analysis based on Ethiopia demographic and health surveys data. Reprod Health. 2014;11(1):14.

21. Jurdi R, Khawaja M. Caesarean section rates in the Arab region: a cross-national study. Health Policy Plan. 2004;19(2):101-10.

22. Belizán JM, Showalter E, Castro A, Bastian H, Althabe F, Barros FC, et al. Rates and implications of caesarean sections in Latin America: ecological study. 1999;319(7222):1397-402.

23. WHO. Appropriate technology for birth. Lancet. 1985;2(8452):436-7.

24. UNICEF, WHO, UNFPA. Guidelines for Monitoring the Availability and Use of Obstetric Services. New York: United Nations Children's Fund, 1997.

25. Nordberg E. Incidence and estimated need of caesarean section, inguinal hernia repair, and operation for strangulated hernia in rural Africa. British Medical Journal. 1984;289:92-3.

26. Nirupam S. Availability of emergency obstetric care in three districts: Current status and next steps. Government of India/UNICED, 1992.

27. Nirupam S, Yuster EA. Emergency obstetric care: measuring availability and monitoring progress. International Journal of Gynecology & Obstetrics. 1995;50, Supplement 2(0):S79-S88.

28. Notzon F. INternational differences in the use of obstetric interventions. JAMA. 1990;263(24):3286-91.

29. Althabe F, Sosa C, Belizan JM, Gibbons L, Jacquerioz F, Bergel E. Cesarean section rates and maternal and neonatal mortality in low-, medium-, and high-income countries: an ecological study. Birth. 2006;33(4):270-7.

30. Unmet Obstetric Need Network. Tackling Unmet Need for Major Obstetric Interventions. Concepts, General Principles and International Network. 2000.

31. Paxton A, Bailey P, Lobis S, Fry D. Global patterns in availability of emergency obstetric care. International Journal of Gynecology & Obstetrics. 2006;93(3):300-7.

32. Okong P, Byamugisha J, Mirembe F, Byaruhanga R, Bergstrom S. Audit of severe maternal morbidity in Uganda - implications for quality of obstetric care. Acta Obstetricia Et Gynecologica Scandinavica. 2006;85(7):797-804.

33. Kaye D, Kakaire O, Osinde M. Systematic review of the magnitude and case fatality ratio for severe maternal morbidity in sub-Saharan Africa between 1995 and 2010. BMC Pregnancy and Childbirth. 2011;11(1):65.

34. Zizza A, Tinelli A, Malvasi A, Barbone E, Stark M, De Donno A, et al. Caesarean section in the world: a new ecological approach. J Prev Med Hyg. 2011;52(4):161-73.

35. McClure EM, Goldenberg RL, Bann CM. Maternal mortality, stillbirth and measures of obstetric care in developing and developed countries. International Journal of Gynecology & Obstetrics. 2007;96(2):139-46.

36. Volpe FM. Correlation of Cesarean rates to maternal and infant mortality rates: an ecologic study of official international data. Rev Panam Salud Publica. 2011;29(5):303-8.

37. Ronsmans C, Etard JF, Walraven G, Hoj L, Dumont A, de Bernis L, et al. Maternal mortality and access to obstetric services in West Africa. Trop Med Int Health. 2003;8(10):940-8.

38. Jonsdottir G, Smarason AK, Geirsson RT, Bjarnadottir RI. No correlation between cesarean section rates and perinatal mortality of singleton infants over 2,500 g. Acta Obstetricia et Gynecologica Scandinavica. 2009;88(5):621-3.

39. Ye J, Betrán AP, Guerrero Vela M, Souza JP, Zhang J. Searching for the Optimal Rate of Medically Necessary Cesarean Delivery. Birth. 2014;41(3):237-44.

40. Chalmers BE, McIntyre JA, Meyer D. South African obstetricians' views on caesarean section. S Afr Med J. 1992;82(3):161-3.

41. Unmet Obstetric Need Network. L'approche des Besoins Obstétricaux Non Couverts pour les Interventions Obstétricales Majeures - Etude comparative Bénin, Burkina-Faso, Haïti, Mali, Maroc, Niger, Pakistan et Tanzanie. Antwerp, Belgium: Institut de Medecine Tropicale (IMT).

42. Say L, Chou D, Gemmill A, Tunçalp Ö, Moller A-B, Daniels J, et al. Global causes of maternal death: a WHO systematic analysis. The Lancet Global Health. 2014;2(6):e323-e33.

43. Prytherch H, Massawe S, Kuelker R, Hunger C, Mtatifikolo F, Jahn A. The unmet need for Emergency Obstetric Care in Tanga Region, Tanzania. BMC Pregnancy and Childbirth. 2007;7(1):16.

44. Hunger C, Kulker R, Kitundu H, Massawe S, Jahn A. Assessing unmet obstetric need in Mtwara Region, Tanzania. Trop Med Int Health. 2007;12(10):1239-47.

45. Guindo G, Dubourg D, Marchal B, Blaise P, De Brouwere V. Measuring unmet obstetric need at district level: how an epidemiological tool can affect health service organization and delivery. Health Policy Plan. 2004;19 Suppl 1:i87-i95.

46. Belghiti A, De Brouwere V, Kegels G, Van Lerberghe W. Monitoring unmet obstetric need at district level in Morocco. Trop Med Int Health. 1998;3(7):584-91.

47. Bossyns PBM, Miyé H, Depoorter AM, Van Lerberghe W. Unmet need for obstetric interventions in Niger: between failing referral systems and inadequate management of human resources. [Unpublished].

48. Ronsmans C, De Brouwere V, Dubourg D, Dieltiens G. Measuring the need for life-saving obstetric surgery in developing countries. BJOG. 2004;111(10):1027-30.

49. Stanton C, Ronsmans C. Recommendations for routine reporting on indications for cesarean delivery in developing countries. Birth. 2008;35(3):204-11.

50. Dieltiens G, Dewan H, Botlero R, Biswas K, Begum SN, Shahjahan M. Met need for life-saving obstetric surgery in Bangladesh. ICCDR,B Centre for Health and Population Research.

51. Hofmeyr GJ, Hannah ME, Lawrie TA. Planned caesarean section for term breech delivery. Cochrane Database of Systematic Reviews, 2003 27th August 2014. Report No.

52. Hannah ME, Hannah WJ, Hewson SA, Hodnett ED, Saigal S, Willan AR. Planned caesarean section versus planned vaginal birth for breech presentation at term: a randomised multicentre trial. The Lancet. 2000;356(9239):1375-83.

53. Read JS. Efficacy and safety of caesarean delivery for prevention of mother-to-child transmission of HIV-1. Cochrane Database of Systematic Reviews: 2005.

54. Dodd JM, Crowther C, Huertas E, Guise J-M, Horey D. Planned elective repeat caesarean section versus planned vaginal birth for women with a previous caesarean. 2013.

55. Dodd JM, Crowther C. Elective repeat caesarean section versus induction of labour for women with a previous caesarean birth. 2012.

56. Alfirevic Z, Milan SJ, Livio S. Caesarean section versus vaginal delivery for preterm birth in singletons. Cochrane Database of Systematic Reviews. 2013.

57. Hofmeyr G, Barrett JF, Crowther C. Planned caesarean section for women with a twin pregnancy. Cochrane Database of Systematic Reviews. 2011.

58. McIntyre PG, Tosh K, McGuire W. Caesarean section versus vaginal delivery for preventing mother to infant hepatitis C virus transmission. Cochrane Database of Systematic Reviews. 2006.

59. Lavender T, Hofmeyr G, Neilson J, Kingdon C, Gyte G. Caesarean section for non-medical reasons at term. Cochrane Database of Systematic Reviews. 2012.

60. Hall DR, Odendaal HJ, Steyn DW. Delivery of patients with early onset, severe pre-eclampsia. Int J Gynaecol Obstet. 2001;74(2):143-50.

61. Calvert C, Ronsmans C. HIV and the Risk of Direct Obstetric Complications: A Systematic Review and Meta-Analysis. PLoS ONE. 2013;8(10):e74848.

62. Karlström A, Lindgren H, Hildingsson I. Maternal and infant outcome after caesarean section without recorded medical indication: findings from a Swedish case–control study. BJOG: An International Journal of Obstetrics & Gynaecology. 2013;120(4):479-86.

63. Liu S, Liston RM, Joseph KS, Heaman M, Sauve R, Kramer MS, et al. Maternal mortality and severe morbidity associated with low-risk planned cesarean delivery versus planned vaginal delivery at term. Canadian Medical Association Journal. 2007;176(4):455-60.

64. Robson M. Classification of caesarean sections. Fetal and Maternal Medicine Review. 2001;12(01):23-39.

65. Robson M, Hartigan L, Murphy M. Methods of achieving and maintaining an appropriate caesarean section rate. Best Pract Res Clin Obstet Gynaecol. 2013;27(2):297-308.

66. Betran AP, Vindevoghel N, Souza JP, Gulmezoglu AM, Torloni MR. A systematic review of the Robson classification for caesarean section: what works, doesn't work and how to improve it. PLoS One. 2014;9(6):e97769.

67. Minsart AF, De Spiegelaere M, Englert Y, Buekens P. Classification of cesarean sections among immigrants in Belgium. Acta Obstet Gynecol Scand. 2013;92(2):204-9.

68. Florica M, Stephansson O, Nordstrom L. Indications associated with increased cesarean section rates in a Swedish hospital. Int J Gynaecol Obstet. 2006;92(2):181-5.

69. Denk CE, Kruse LK, Jain NJ. Surveillance of cesarean section deliveries, New Jersey, 1999-2004. Birth. 2006;33(3):203-9.

70. Zhang J, Troendle J, Reddy UM, Laughon SK, Branch DW, Burkman R, et al. Contemporary cesarean delivery practice in the United States. Am J Obstet Gynecol. 2010;203(4):326.e1-.e10.

71. Kazmi T, Saiseema St, Khan S. Analysis of Cesarean Section Rate - According to Robson's 10-group Classification. Oman Med J. 2012;27(5):415-7.

72. Chong C, Su LL, Biswas A. Changing trends of cesarean section births by the Robson Ten Group Classification in a tertiary teaching hospital. Acta Obstet Gynecol Scand. 2012;91(12):1422-7.

73. Scarella A, Chamy V, Sepulveda M, Belizan JM. Medical audit using the Ten Group Classification System and its impact on the cesarean section rate. Eur J Obstet Gynecol Reprod Biol. 2011;154(2):136-40.

74. Litorp H, Kidanto HL, Nystrom L, Darj E, Essen B. Increasing caesarean section rates among low-risk groups: a panel study classifying deliveries according to Robson at a university hospital in Tanzania. BMC Pregnancy Childbirth. 2013;13:107.

75. Torloni MR, Betran AP, Souza JP, Widmer M, Allen T, Gulmezoglu M, et al. Classifications for Cesarean Section: A Systematic Review. PLoS ONE. 2011;6(1):e14566.

76. RCOG. Classification of urgency of caesarean section - a continuum of risk. Royal College of Obstetricians and Gynaecologists, 2010.

77. Barros AJD, Santos IS, Matijasevich A, Domingues MR, Silveira M, Barros FC, et al. Patterns of deliveries in a Brazilian birth cohort: almost universal cesarean sections for the better-off. Revista de Saúde Pública. 2011;45:635-43.

78. Maaloe N, Sorensen BL, Onesmo R, Secher NJ, Bygbjerg IC. Prolonged labour as indication for emergency caesarean section: a quality assurance analysis by criterion-based audit at two Tanzanian rural hospitals. Bjog. 2012;119(5):605-13.

79. Fesseha N, Getachew A, Hiluf M, Gebrehiwot Y, Bailey P. A national review of cesarean delivery in Ethiopia. International Journal of Gynecology & Obstetrics. 2011;115(1):106-11.

80. Kim Y-M, Tappis H, Zainullah P, Ansari N, Evans C, Bartlett L, et al. Quality of caesarean delivery services and documentation in first-line referral facilities in Afghanistan: a chart review. BMC Pregnancy and Childbirth. 2012;12(1):14.

81. Igberase GO, Ebeigbe PN, Andrew BO. High caesarean section rate: a ten year experience in a tertiary hospital in the Niger Delta, Nigeria. Niger J Clin Pract. 2009;12(3):294-7.

82. Rafique S, Raana GE. Changing trends in caesarean section rate and indications. Pakistan Journal of Sugery. 2012;28(1):60-4.

83. Buowari YD. Indications for Caesarean Section at a Nigerian District Hospital. Nigerian Health Journal. 2012;12(2):43-6.

84. Geidam AD, Audu BM, Kawuwa BM, Obed JY. Rising trend and indications of caesarean section at the university of Maiduguri teaching hospital, Nigeria. Ann Afr Med. 2009;8(2):127-32.

85. Landry E, Pett C, Fiorentino R, Ruminjo J, Mattison C. Assessing the quality of record keeping for cesarean deliveries: results from a multicenter retrospective record review in five low-income countries. BMC Pregnancy and Childbirth. 2014;14(1):139.

86. Dumont A, de Bernis L, Bouvier-olle M-H, Bréart G. Caesarean section rate for maternal indication in sub-Saharan Africa: a systematic review. The Lancet. 2001;358(9290):1328-33.

87. Ronsmans C, Van Damme W, Filippi V, Pittrof R. Need for caesarean sections in west Africa. Lancet. 2002;359(9310):974; discussion 5.

88. Zhang J, Liu Y, Meikle S, Zheng J, Sun W, Li Z. Cesarean Delivery on Maternal Request in Southeast China. Obstetrics & Gynecology. 2008;111(5):1077-82 10.97/AOG.0b013e31816e349e.

89. Bryce J, Arnold F, Blanc A, Hancioglu A, Newby H, Requejo J, et al. Measuring Coverage in MNCH: New Findings, New Strategies, and Recommendations for Action. PLoS Med. 2013;10(5):e1001423.

90. Requejo JH, Newby H, Bryce J. Measuring Coverage in MNCH: Challenges and Opportunities in the Selection of Coverage Indicators for Global Monitoring. PLoS Med. 2013;10(5):e1001416.

91. WHO, UNICEF, UNFPA, World Bank. Trends in maternal mortality: 1990 to 2008. Geneva: World Health Organisation, 2010.

92. Lawn JE, Lee AC, Kinney M, Sibley L, Carlo WA, Paul VK, et al. Two million intrapartum-related stillbirths and neonatal deaths: where, why, and what can be done? Int J Gynaecol Obstet. 2009;107 Suppl 1:S5-18, S9.

93. Cavallaro FL, Cresswell JA, Franca GV, Victora CG, Barros AJ, Ronsmans C. Trends in caesarean delivery by country and wealth quintile: cross-sectional surveys in southern Asia and sub-Saharan Africa. Bull World Health Organ. 2013;91(12):914-22d.

94. Villar J, Carroli G, Zavaleta N, Donner A, Wojdyla D, Faundes A, et al. Maternal and neonatal individual risks and benefits associated with caesarean delivery: multicentre prospective study. BMJ. 2007;335(7628):1025.

95. Thiery M, Derom R. Review of evaluation studies on caesarean section. Trends in caesarean section and perinatal mortality. In: Kaminski M, Breart G, Buekens P, editors. Perinatal care delivery systems: description and evaluation in European Community countries. London: Oxford University Press; 1986. p. 93-113.

96. Loudon I. Death in childbirth: an international study of maternal care and maternal mortality 1800–1950. Oxford: Clarendon Press; 1992.

97. De Brouwere V, Dubourg D, Richard F, Lerberghe WV. Need for caesarean sections in west Africa. The Lancet. 2002;359(9310):974-5.

98. Lomas J, Enkin M. Variations in operative delivery rates. In: Chalmers I, Enkin M, Kerise MJNC, editors. Effective care in pregnancy and childbirth, volume II. Oxford: Oxford University Press; 1989. p. 1182-95.

99. De Brouwere V, Van Lerberghe W. Les besoins obstétricaux non couverts. Paris: L'Harmattan; 1998.

100. MEASURE DHS. MEASURE DHS - Demographic and Health Surveys Calverton2013 [Accessed: 30 July 2013]. Available from: http://measuredhs.com/.

101. Macro International Inc. Sampling Manual. DHS-III Basic Documentation No. 6. Calverton, Maryland: 1996.

102. The DHS Program. DHS Model Questionnaires [Accessed: 8th October 2010]. Available from: http://www.dhsprogram.com/What-We-Do/Survey-Types/DHS-Questionnaires.cfm.

103. DHS. Demographic and Health Surveys - Phase 2: Model "A" Questionnaire with Commentary for High Contraceptive Prevalence Countries. Columbia, Maryland: Institute for Resource Development/Macro International, Inc., 1990.

104. DHS. Demographic and Health Surveys - Phase 4 Model "A" Questionnaire with Commentary for High Contraceptive Prevalence Countries. Calverton, Maryland, USA: ORC Macro, 2001.

105. ICF International. Demographic and Health Surveys Methodology - Questionnaires: Household, Woman's, and Man's. Calverton, Maryland, USA: MEASURE DHS, 2011.

106. 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. Bull World Health Organ. 2007;85(10):812-9.

107. Gabrysch S, Campbell O. Still too far to walk: Literature review of the determinants of delivery service use. BMC Pregnancy Childbirth. 2009;9(1):34.

108. Moyer C, Mustafa A. Drivers and deterrents of facility delivery in sub-Saharan Africa: a systematic review. Reproductive Health. 2013;10(1):40.

109. Rutstein S, Johnson K. The DHS Wealth Index. DHS Comparative Reports No. 6. Calverton, Maryland: ORC Macro, 2004.

110. Requejo JH, Bryce D, Victora C. Countdown to 2015: building a future for women and children: the 2012 report. Washington: World Health Organisation, 2012.

111. UNICEF. The state of the world's children 2012: children in an urban world. New York: United Nations Children's Fund, 2012.

112. Stanton CK, Dubourg D, De Brouwere V, Pujades M, Ronsmans C. Reliability of data on caesarean sections in developing countries. Bulletin of the World Health Organization. 2005;83(6):449-55.

113. Cummings P. Methods for estimating adjusted risk ratios. Stata J. 2009;9:175-96.

114. Pearson L, Shoo R. Availability and use of emergency obstetric services: Kenya, Rwanda, Southern Sudan, and Uganda. International Journal of Gynecology & Obstetrics. 2005;88(2):208-15.

115. Luboga S, Macfarlane SB, von Schreeb J, Kruk ME, Cherian MN, Bergström S, et al. Increasing Access to Surgical Services in Sub-Saharan Africa: Priorities for National and International Agencies Recommended by the Bellagio Essential Surgery Group. PLoS Med. 2009;6(12):e1000200.

116. Hsia RY, Mbembati NA, Macfarlane S, Kruk ME. Access to emergency and surgical care in sub-Saharan Africa: the infrastructure gap. Health Policy and Planning. 2012;27(3):234-44.

117. Pollock J, Love T, Steffes B, Thompson D, Mellinger J, Haisch C. Is it Possible to Train Surgeons for Rural Africa? A Report of a Successful International Program. World Journal of Surgery. 2011;35(3):493-9.

118. Gartoulla P, Liabsuetrakul T, Chongsuvivatwong V, McNeil E. Ability to pay and impoverishment among women who give birth at a University Hospital in Kathmandu, Nepal. Global Public Health. 2012;7(10):1145-56.

119. Arsenault C, Fournier P, Philibert A, Sissoko K, Coulibaly A, Tourigny C, et al. Emergency obstetric care in Mali: catastrophic spending and its impoverishing effects on households. Bulletin of the World Health Organization. 2013;91:207-16.

120. Meessen B, Hercot D, Noirhomme M, Ridde V, Tibouti A, Tashobya CK, et al. Removing user fees in the health sector: a review of policy processes in six sub-Saharan African countries. Health Policy and Planning. 2011;26(suppl 2):ii16-ii29.

121. Witter S, Dieng T, Mbengue D, Moreira I, De Brouwere V. The national free delivery and caesarean policy in Senegal: evaluating process and outcomes. Health Policy and Planning. 2010;25(5):384-92.

122. Asante F, Chikwama C, Daniels A, Armar-Klemesu M. Evaluating the economic outcomes of the policy of fee exemption for maternal delivery care in Ghana. Ghana Med J. 2007;41:110-7.

123. Montagu D, Yamey G, Visconti A, Harding A, Yoong J. Where Do Poor Women in Developing Countries Give Birth? A Multi-Country Analysis of Demographic and Health Survey Data. PLoS ONE. 2011;6(2):e17155.

124. Parkhurst JO, Rahman SA. Life saving or money wasting?: Perceptions of caesarean sections among users of services in rural Bangladesh. Health Policy. 2007;80(3):392-401.

125. Villar J, Valladares E, Wojdyla D, Zavaleta N, Carroli G, Velazco A, et al. Caesarean delivery rates and pregnancy outcomes: the 2005 WHO global survey on maternal and perinatal health in Latin America. The Lancet. 2006;367(9525):1819-29.

126. Victora CG, Vaughan JP, Barros FC, Silva AC, Tomasi E. Explaining trends in inequities: evidence from Brazilian child health studies. The Lancet. 2000;356(9235):1093-8.

127. Tunçalp Ö, Stanton C, Castro A, Adanu R, Heymann M, Adu-Bonsaffoh K, et al. Measuring Coverage in MNCH: Validating Women's Self-Report of Emergency Cesarean Sections in Ghana and the Dominican Republic. PLoS ONE. 2013;8(5):e60761.

128. Bat-Erdene U, Metcalfe A, McDonald S, Tough S. Validation of Canadian mothers' recall of events in labour and delivery with electronic health records. BMC Pregnancy and Childbirth. 2013;13(Suppl 1):S3.

129. Stanton C, Ronsmans C. Caesarean birth as a component of surgical services in low- and middle-income countries. Bull World Health Organ. 2008;86(12):A.

130. Howe L, Hargreaves J, Huttly S. Issues in the construction of wealth indices for the measurement of socio-economic position in low-income countries. Emerging Themes in Epidemiology. 2008;5(1):1-14.

131. Howe LD, Hargreaves JR, Gabrysch S, Huttly SRA. Is the wealth index a proxy for consumption expenditure? A systematic review. Journal of Epidemiology and Community Health. 2009;63(11):871-7.

132. Rutstein S. The DHS wealth index: approaches for rural and urban areas. Washington: Macro International, 2008.

133. Countdown to 2015. Countdown equity analyses by country – 2012 Geneva2013 [Accessed: 28 May 2013]. Available from: http://www.countdown2015mnch.org/documents/2012Report/2012Equity/full_equity_profiles_2012.pdf.

134. Bergström S. COMMENTARY: Who will do the caesareans when there is no doctor? Finding creative solutions to the human resource crisis. BJOG: An International Journal of Obstetrics & Gynaecology. 2005;112(9):1168-9.

135. Wilson A, Lissauer D, Thangaratinam S, Khan KS, MacArthur C, Coomarasamy A. A comparison of clinical officers with medical doctors on outcomes of caesarean section in the developing world: meta-analysis of controlled studies. BMJ. 2011;342.

136. Kruk ME, Wladis A, Mbembati N, Ndao-Brumblay SK, Hsia RY, Galukande M, et al. Human Resource and Funding Constraints for Essential Surgery in District Hospitals in Africa: A Retrospective Cross-Sectional Survey. PLoS Med. 2010;7(3):e1000242.

137. Hounton S, Newlands D, Meda N, De Brouwere V. A cost-effectiveness study of caesarean-section deliveries by clinical officers, general practitioners and obstetricians in Burkina Faso. Human Resources for Health. 2009;7(1):34.

138. Chilopora G, Pereira C, Kamwendo F, Chimbiri A, Malunga E, Bergstrom S. Postoperative outcome of caesarean sections and other major emergency obstetric surgery by clinical officers and medical officers in Malawi. Human Resources for Health. 2007;5(17).

139. Mullan F, Frehywot S. Non-physician clinicians in 47 sub-Saharan African countries. Lancet. 2007;370(9605):2158-63.

140. Stanton C, Tuncalp O, Castro A, Lattof S, Blanc A, Langer A. Opinion on a plausible range for emergency caesarean section in low income countries. 2013 [Unpublished].

141. Toh-adam R, Srisupundit K, Tongsong T. Short stature as an independent risk factor for cephalopelvic disproportion in a country of relatively small-sized mothers. Archives of Gynecology and Obstetrics. 2012;285(6):1513-6.

142. Cotzias CS, Paterson-Brown S, Fisk NM. Obstetricians say yes to maternal request for elective caesarean section: a survey of current opinion. Eur J Obstet Gynecol Reprod Biol. 2001;97(1):15-6.

143. Gonen R, Tamir A, Degani S. Obstetricians' opinions regarding patient choice in cesarean delivery. Obstet Gynecol. 2002;99(4):577-80.

144. Mc Gurgan P, Coulter-Smith S, PJ OD. A national confidential survey of obstetrician's personal preferences regarding mode of delivery. Eur J Obstet Gynecol Reprod Biol. 2001;97(1):17-9.

145. Al-Mufti R, McCarthy A, Fisk NM. Survey of obstetricians' personal preference and discretionary practice. Eur J Obstet Gynecol Reprod Biol. 1997;73(1):1-4.

146. DHS. The DHS Program - Country List [Accessed: 15th April 2014]. Available from: http://www.dhsprogram.com/Where-We-Work/Country-List.cfm.

147. WHO. Alphabetical List of WHO Member States [Accessed: 15th April 2014]. Available from: http://www.who.int/choice/demography/by_country/en/.

148. World Bank. Country and Lending Groups [Accessed: 15th April 2014]. Available from: http://data.worldbank.org/about/country-classifications/country-and-lending-groups.

149. Robson SJ, Tan WS, Adeyemi A, Dear KB. Estimating the rate of cesarean section by maternal request: anonymous survey of obstetricians in Australia. Birth. 2009;36(3):208-12.

150. Bettes BA, Coleman VH, Zinberg S, Spong CY, Portnoy B, DeVoto E, et al. Cesarean delivery on maternal request: obstetrician-gynecologists' knowledge, perception, and practice patterns. Obstet Gynecol. 2007;109(1):57-66.

151. Habiba M, Kaminski M, Da Fre M, Marsal K, Bleker O, Librero J, et al. Caesarean section on request: a comparison of obstetricians' attitudes in eight European countries. Bjog. 2006;113(6):647-56.

152. Bergholt T, Ostberg B, Legarth J, Weber T. Danish obstetricians' personal preference and general attitude to elective cesarean section on maternal request: a nation-wide postal survey. Acta Obstet Gynecol Scand. 2004;83(3):262-6.

153. Cook J, Dickinson H, Eccles M. Response rates in postal surveys of healthcare professionals between 1996 and 2005: An observational study. BMC Health Services Research. 2009;9(1):160.

154. Thaddeus S, Maine D. Too far to walk: maternal mortality in context. Soc Sci Med. 1994;38(8):1091-110.

155. Gabrysch S, Campbell OM. Still too far to walk: literature review of the determinants of delivery service use. BMC Pregnancy Childbirth. 2009;9:34.

156. Padmadas SS, Kumar S S, Nair SB, Kumari K.R A. Caesarean section delivery in Kerala, India: evidence from a National Family Health Survey. Social Science & Medicine. 2000;51(4):511-21.

157. Abdul-Rahim HF, Abu-Rmeileh NME, Wick L. Cesarean section deliveries in the occupied Palestinian territory (oPt): An analysis of the 2006 Palestinian Family Health Survey. Health Policy. 2009;93(2–3):151-6.

158. Briand V, Dumont A, Abrahamowicz M, Traore M, Watier L, Fournier P. Individual and institutional determinants of caesarean section in referral hospitals in Senegal and Mali: a cross-sectional epidemiological survey. BMC Pregnancy and Childbirth. 2012;12(1):114.

159. Ganatra BR, Coyaji KJ, Rao VN. Too far, too little, too late: a community-based case-control study of maternal mortality in rural west Maharashtra, India. Bull World Health Organ. 1998;76(6):591-8.

160. Ramos S, Karolinski A, Romero M, Mercer R, Maternal Mortality in Argentina Study G. A comprehensive assessment of maternal deaths in Argentina: translating multicentre collaborative research into action. Bulletin of the World Health Organization. 2007;85(8):615-22.

161. Taguchi N, Kawabata M, Maekawa M, Maruo T, Aditiawarman, Dewata L. Influence of socio-economic background and antenatal care programmes on maternal mortality in Surabaya, Indonesia. Tropical Medicine & International Health. 2003;8(9):847-52.

162. Yego F, D'Este C, Byles J, Williams J, Nyongesa P. Risk factors for maternal mortality in a Tertiary Hospital in Kenya: a case control study. BMC Pregnancy and Childbirth. 2014;14(1):38.

163. Olsen BE, Hinderaker SG, Bergsjo P, Lie RT, Olsen OHE, Gasheka P, et al. Causes and characteristics of maternal deaths in rural northern Tanzania. Acta Obstetricia Et Gynecologica Scandinavica. 2002;81(12):1101-9.

164. Ghana Statistical Service (GSS), Ghana Health Service (GHS), Macro I. Ghana Demographic and Health Survey 2008. Accra, Ghana: GSS, GHS and ICF Macro, 2009.

165. World Bank. Ghana Country Statistics [Accessed: 6th May 2014]. Available from: http://data.worldbank.org/country/ghana.

166. WHO, UNICEF, UNFPA, World Bank, United Nations Population Division. Trends in maternal mortality: 1990 to 2013 - Estimates by WHO, UNICEF, UNFPA, The World Bank and the United Nations Population Division. Geneva: World Health Organisation, 2014.

167. Witter S, Arhinful DK, Kusi A, Zakariah-Akoto S. The Experience of Ghana in Implementing a User Fee Exemption Policy to Provide Free Delivery Care. Reproductive Health Matters. 2007;15(30):61-71.

168. Dzakpasu S, Soremekun S, Manu A, ten Asbroek G, Tawiah C, Hurt L, et al. Impact of Free Delivery Care on Health Facility Delivery and Insurance Coverage in Ghana's Brong Ahafo Region. PLoS ONE. 2012;7(11):e49430.

169. Ghana Statistical Service. 2010 Population & Housing Census - Summary report of final results. Accra, Ghana: Ghana Statistical Service, 2012.

170. Ghana Statistical Service. 2010 Population & Housing Census - Regional analytical Report, Brong Ahafo region. Ghana Statistical Service, 2013.

171. Edmond KM, Quigley MA, Zandoh C, Danso S, Hurt C, Agyei SO, et al. Aetiology of stillbirths and neonatal deaths in rural Ghana: implications for health programming in developing countries. Paediatric and Perinatal Epidemiology. 2008;22(5):430-7.

172. 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. The Lancet. 2011;377(9774):1319-30.

173. Ghana AIDS Commission. 2012 HIV Sentinel Survey and National HIV Prevalence and Estimates Report (Brief) [Accessed: 20th June 2014]. Available from: http://ghanaids.gov.gh/gac1/aids_info.php.

174. Nesbitt RC, Lohela TJ, Manu A, Vesel L, Okyere E, Edmond K, et al. Quality along the Continuum: A Health Facility Assessment of Intrapartum and Postnatal Care in Ghana. PLoS ONE. 2013;8(11):e81089.

175. Kirkwood BR, Hurt L, Amenga-Etego S, Tawiah C, Zandoh C, Danso S, et al. Effect of vitamin A supplementation in women of reproductive age on maternal survival in Ghana (ObaapaVitA): a cluster-randomised, placebo-controlled trial. The Lancet. 2010;375(9726):1640-9.

176. Calvert C, Ronsmans C. Pregnancy and Infection. New England Journal of Medicine. 2014;371(11):1075-7.

177. Calvert C, Ronsmans C. Pregnancy and HIV disease progression: a systematic review and meta-analysis. Tropical Medicine & International Health. 2014;20(2):122-45.

178. WHO. The WHO application of ICD-10 to deaths during pregnancy, childbirth and puerperium: ICD MM. Geneva: World Health Organisation, 2012.

179. Gwatkin D, Rutstein S, Johnson K, Suliman E, Wagstaff A, Amouzou A. Socio-Economic Differences in Health, Nutrition, and Population GHANA. World Bank, 2007.

180. Ghana Statistical Services, Ghana Health Service, Macro International. Ghana Maternal Health Survey 2007. 2009.

181. Asamoah B, Moussa K, Stafstrom M, Musinguzi G. Distribution of causes of maternal mortality among different socio-demographic groups in Ghana; a descriptive study. BMC Public Health. 2011;11(1):159.

182. Hounton S, Chapman G, Menten J, De Brouwere V, Ensor T, Sombie I, et al. Accessibility and utilisation of delivery care within a Skilled Care Initiative in rural Burkina Faso. Tropical medicine & international health : TM & IH. 2008;13 Suppl 1:44-52.

183. Gabrysch S, Cousens S, Cox J, Campbell O. The influence of distance and level of care on delivery place in rural Zambia: A study of linked national data in a geographic information system. PLoS Med / Public Libr Sc. 2011;8(1):e1000394.

184. Hanson C. The Epidemiology of Maternal Mortality in Southern Tanzania [PhD thesis]: London School of Hygiene & Tropical Medicine; 2013.

185. Mpembeni R, Killewo J, Leshabari M, Massawe S, Jahn A, Mushi D, et al. Use pattern of maternal health services and determinants of skilled care during delivery in Southern Tanzania: Implications for achievement of MDG-5 targets. BMC Pregnancy Childbirth. 2007;7:29.

186. Chowdhury ME, Ronsmans C, Killewo J, Anwar I, Gausia K, Das-Gupta S, et al. Equity in use of home-based or facility-based skilled obstetric care in rural Bangladesh: an observational study. Lancet. 2006;367(9507):327-32.

187. Høj L, Da Silva D, Hedegaard K, Sandström A, Aaby P. Factors associated with maternal mortality in rural Guinea-Bissau. A longitudinal population-based study. BJOG: An International Journal of Obstetrics & Gynaecology. 2002;109(7):792-9.

188. Aggarwal A, Pandey A, Bhattacharya BN. Risk factors for maternal mortality in Delhi slums: a community-based case-control study. Indian J Med Sci. 2007;61(9):517-26.

189. Fikree FF, Midhet F, Sadruddin S, Berendes HW. Maternal mortality in different Pakistani sites: ratios, clinical causes and determinants. Acta Obstet Gynecol Scand. 1997;76(7):637-45.

190. Bell JS, Ouedraogo M, Ganaba R, Sombie I, Byass P, Baggaley RF, et al. The epidemiology of pregnancy outcomes in rural Burkina Faso. Tropical Medicine & International Health. 2008;13 Suppl 1:31-43.

191. Carlson VM, Omer MI, Ibrahim SA, Ahmed SE, O'Byrne KJ, Kenny LC, et al. Fifty years of Sudanese hospital-based obstetric outcomes and an international partnership. BJOG: An International Journal of Obstetrics & Gynaecology. 2011;118(13):1608-16.

192. de Bernis L, Dumont A, Bouillin D, Gueye A, Dompnier J, Bouvier-Colle M. Maternal morbidity and mortality in two different populations of Senegal: a prospective study (MOMA survey). British Journal of Obstetrics and Gynecology. 2000;107(1):68 - 74.

193. Bergstrom S. Pre-eclampsia and eclmpsia. In: Lawson JB, Harrison KA, Bergstrom S, editors. Maternity care in developing countries. London: Royal College of Obstetricians and Gynaecologists; 2003. p. 146.

194. Bauni E, Ndila C, Mochamah G, Nyutu G, Matata L, Ondieki C, et al. Validating physician-certified verbal autopsy and probabilistic modeling (InterVA) approaches to verbal

autopsy interpretation using hospital causes of adult deaths. Population Health Metrics. 2011;9(1):49.

195. Ronsmans C, Graham WJ. Maternal mortality: who, when, where, and why. Lancet. 2006;368(9542):1189-200.

196. Quigley MA, Chandramohan D, Rodrigues LC. Diagnostic accuracy of physician review, expert algorithms and data-derived algorithms in adult verbal autopsies. Int J Epidemiol. 1999;28(6):1081-7.

197. Setel PW, Whiting DR, Hemed Y, Chandramohan D, Wolfson LJ, Alberti KGMM, et al. Validity of verbal autopsy procedures for determining cause of death in Tanzania. Tropical Medicine & International Health. 2006;11(5):681-96.

198. Davies HT, Crombie IK, Tavakoli M. When can odds ratios mislead? Bmj. 1998;316(7136):989-91.

199. Dudley DJ. Chapter 22 - Complications of Labor. In: Scott JR, Gibbs RS, Karlan BY, Haney AF, editors. Danforth's Obstetrics and Gynecology, 9th Ed: Lippincott Williams & Wilkins Publishers; 2003.

200. Unmet Obstetric Need Network. Final Report - Part I. Synthesis. Antwerp, Belgium: Institute of Tropical Medicine (ITM).

201. Dubourg D, Derveeuw M, Litt V, De Brouwere V, Van Lerberghe W, The UON Network. Tackling unmet need for major obstetric interventions.

202. Maaløe N, Bygbjerg IC, Onesmo R, Secher NJ, Sorensen BL. Disclosing doubtful indications for emergency cesarean sections in rural hospitals in Tanzania: a retrospective criterion-based audit. Acta Obstetricia et Gynecologica Scandinavica. 2012;91(9):1069-76.

203. Kwee A, Bots ML, Visser GHA, Bruinse HW. Emergency peripartum hysterectomy: A prospective study in The Netherlands. European Journal of Obstetrics & Gynecology and Reproductive Biology. 2006;124(2):187-92.

204. Schorn MN. Measurement of Blood Loss: Review of the Literature. The Journal of Midwifery & Women's Health. 2010;55(1):20-7.

205. Althabe F, Belizán JM, Villar J, Alexander S, Bergel E, Ramos S, et al. Mandatory second opinion to reduce rates of unnecessary caesarean sections in Latin America: a cluster randomised controlled trial. The Lancet. 2004;363(9425):1934-40.

206. Andersen HM. “Villagers”: Differential treatment in a Ghanaian hospital. Social Science & Medicine. 2004;59(10):2003-12.

207. Blencowe H, Cousens S, Oestergaard MZ, Chou D, Moller AB, Narwal R, et al. National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: a systematic analysis and implications. Lancet. 2012;379(9832):2162-72.

208. 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.

209. Dzakpasu S, Powell-Jackson T, Campbell OMR. Impact of user fees on maternal health service utilization and related health outcomes: a systematic review. Health Policy and Planning. 2013.

210. Penfold S, Harrison E, Bell J, Fitzmaurice A. Evaluation of the delivery fee exemption policy in Ghana: Population estimates of changes in delivery service utilization in two regions. Ghana Med Jour. 2007;41(3):100 - 9.

211. Stanton C, Ronsmans C. Caesarean birth as a component of surgical services in low- and middle-income countries. Bulletin of the World Health Organization. 2008;86(12):A.

212. United Nations. Open Working Group proposal for Sustainable Development Goals. [Accessed: 15th Nov 2014]. Available from: http://sustainabledevelopment.un.org/content/documents/1579SDGs%20Proposal.pdf.