Testing the assumptions of an indicator of unmet need for obstetric surgery in Ghana: a cross-sectional study of linked hospital and population-based delivery data

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Abstract

Background. The Unmet Obstetric Need (UON) indicator has been widely used to estimate unmet need for life-saving surgery at birth; however, its assumptions have not been verified. The objective of this study was to test two UON assumptions: (1) absolute maternal indications (AMIs) require surgery for survival and (2) 1-2% of deliveries develop AMIs, implying that rates of surgeries for AMIs below this threshold indicate excess mortality from these complications.

Methods. We used linked hospital and population-based data in central Ghana. Among hospital deliveries, we calculated the percentage of deliveries with AMIs who received surgery, and mortality among AMIs who did not. At the population level, we assessed whether the percentage of deliveries with surgeries for AMIs was inversely associated with mortality from these complications, stratified by education.

Results. 380 of 387 (98%) hospital deliveries with recorded AMIs received surgery; an additional eight with no AMI diagnosis died of AMI-related causes. Among the 50,148 deliveries in the population, surgeries for AMIs increased from 0.6% among women with no education to 1.9% among women with post-secondary education ($p<0.001$). However, there was no association between AMI-related mortality and education ($p=0.546$). Estimated AMI prevalence was 0.84% (95% CI: 0.76%-0.92%), below the assumed 1% minimum threshold.

Discussion. Obstetric providers consider AMIs absolute indications for surgery. However, low rates of surgeries for AMIs among less educated women were not associated with higher mortality. The UON indicator should be used with caution in estimating the unmet need for life-saving obstetric surgery; innovative approaches are needed to identify unmet need in the context of rising caesarean rates.

Keywords. Unmet obstetric need, absolute maternal indications, caesarean section, Ghana.

Introduction

Caesarean sections can be life-saving interventions, but they also entail risks. There is no consensus on the “optimal” caesarean section rate minimising morbidity and mortality,[1,2] usually referring to a range between the minimum rate, below which women suffer due to not receiving a necessary caesarean section, and the maximum rate, beyond which women suffer from the risks of unnecessary interventions. Because caesarean sections have been rising worldwide, maximum recommended rates have received considerable attention. Minimum rates, in contrast, have not been widely explored, despite their obvious relevance for settings where women still die due to poor access to life-saving surgery. Countries with caesarean rates below 1% rarely achieve a maternal mortality ratio below 300 per 100,000,[3-5] and such critically low caesarean rates are thought to indicate an unmet need for life-saving surgery.[6,7] However, unmet need likely persists among some groups when caesarean rates are above this threshold, and there is a need for a valid indicator to identify unmet need in higher caesarean rate settings to assess whether women with complications are receiving the care they need, in accordance with the framework for Quality Maternal and Newborn Care.[8]

In 2000, the Unmet Obstetric Need (UON) Network proposed an indicator of the unmet need for life-saving obstetric surgery, to estimate the burden of maternal deaths caused by not receiving surgery.[9] The indicator is based on two assumptions. First, it is possible to identify severe obstetric complications for which surgery is “absolutely” necessary for the woman’s survival. These conditions – called absolute maternal indications (AMIs) – are severe antepartum haemorrhage due to placenta praevia or abruptio placentae, incoercible postpartum haemorrhage, major cephalopelvic disproportion, transverse lie, and brow presentation. The “absoluteness” of the condition is essential for the indicator’s validity: either a woman with an AMI reaches a hospital, receives surgery and survives; or she does not receive surgery and does not survive.

Second, although the prevalence of AMIs may vary, at least 1-2% of deliveries in any population are assumed to develop AMIs. There is uncertainty around this minimum threshold, but its proponents argue it is a reasonable minimum estimate of the proportion of deliveries that require surgery to save the woman's life.[10] Many non-AMI complications such as severe pre-eclampsia may also be life-threatening, but surgery is not absolutely necessary in all such cases since many women can survive by inducing labour. Moreover, this indicator does not consider fetal indications for caesareans. By setting a threshold for surgery for AMIs only, the UON indicator represents a low-end estimate of the total unmet need.[10] Minimum thresholds between 1% and 2% have been used,[11-14] based on the prevalence of surgeries for AMIs observed in areas with access to surgery. In settings where this prevalence is unknown, 1.4% has been suggested as a "sensible low-end estimate" of the need for life-saving obstetric surgery,[15] calculated as the mean prevalence of surgeries for AMIs in urban areas in four West African countries.[12] This chosen threshold may not be valid if AMI diagnosis in these areas was biased, or some women with AMIs did not receive surgery.

One advantage of the UON indicator is that it only requires data from surgical facilities: the percentage of surgeries for AMIs in a population is calculated as total surgeries for AMIs performed in these facilities, divided by total births in the population. The "unmet obstetric need" at the population level can be calculated as the difference between the minimum threshold of AMI prevalence and the observed percentage of surgeries for AMIs. Percentages below the minimum threshold are thought to indicate that women have died as a result of not receiving surgery.

Although the assumptions underpinning the UON indicator have not been verified, it has been widely used to measure the unmet need for obstetric surgery.[11,12,16,17] Recent studies have found 0.4-1.4% of deliveries receive surgery for AMIs in rural sub-Saharan Africa, deemed to represent a substantial unmet need.[13,14,18,19] A study in Bangladesh suggested that groups with lower rates of surgery for AMIs did not suffer from higher AMI-related mortality, and the validity of the indicator was called into question.[20]

The aim of this study was to test the assumptions underpinning the UON indicator for maternal life-saving obstetric surgery using linked hospital and population-based data from rural Ghana. Among hospital deliveries in the population, the first objective was to determine whether all women with AMIs receive surgery (that is, whether providers consider them absolute indications). The second objective was to examine whether all hospital deliveries with AMIs result in maternal death if they do not receive surgery. Among all deliveries in the population, the third objective was to determine whether AMI-related maternal mortality is inversely associated with the percentage of deliveries receiving surgery for AMIs. To asses this, we compared women's educational groups because we hypothesised this socio-economic variable would produce the largest differences in rates of AMI-related surgery and mortality. Based on the UON indicator assumptions, we hypothesised that AMI-related mortality would be higher in educational groups with a lower percentage of surgery for AMIs.

Methods

Study setting

This study used data from the ObaapaVitA trial, which took place between 2000 and 2008 in four districts in the Brong-Ahafo region of Ghana. ObaapaVitA was a cluster-randomised, double-blind, placebo-controlled trial aiming to assess the effect of weekly low-dose vitamin A supplementation on mortality among women of reproductive age (15-45). The ObaapaVitA trial and data collection methods are described in detail elsewhere.[21] There was no effect of vitamin A supplementation on maternal mortality.

Data collection

Population-based surveillance of all women was conducted every four weeks, to distribute study capsules and collect data on pregnancies, births and deaths. Socio-demographic information was systematically collected at women's first report of a pregnancy from May 2005. Verbal post-mortem interviews, based on WHO standard questionnaires, were undertaken with relatives or close friends for all deaths of women aged 15-45, around 6 weeks after the death. The forms were independently reviewed by two doctors who determined whether the woman was pregnant or had recently delivered, and assigned a single cause of death. If the assigned cause differed, the form was reviewed by a third physician and their cause of death coding accepted if identical to either of the first two physicians. If all three physicians disagreed, they either agreed on a consensus cause, or cause of death "uncertain".

The four district hospitals were the only facilities with surgical capacity within the study area. Clinical information was collected on all admissions to the maternity and delivery wards for pregnant and postpartum women, and linked to the population-based data. Data on hospital diagnoses, management, indications for obstetric surgery, and pregnancy outcomes were extracted from hospital records by field supervisors using a pre-coded form. Physician research managers from the ObaapaVitA team reviewed the data extracted for women with obstetric complications on a weekly basis. A single cause of death was ascertained by doctors at the hospital for women who died before discharge.

Definitions of Absolute Maternal Indications, obstetric surgeries, and AMI-related deaths

Pre-coded obstetric complications and indications for surgery were used to identify AMIs among hospital deliveries, by adapting the standard definitions for the five AMI causes.[9] For each cause, a strict (high-specificity) definition was constructed; we also constructed a broad definition (with high sensitivity and lower specificity) for sensitivity analyses (Table 1). For example, strict malpresentation included transverse lie and brow presentation, while the broad definition additionally included oblique lie, face and compound presentation, to account for possible misclassification of strict malpresentations. Deliveries with multiple AMIs were classified hierarchically in the following order: uterine rupture, incoercible postpartum haemorrhage, severe antepartum haemorrhage, malpresentation, and major cephalopelvic disproportion.

Obstetric surgeries were identified among district hospital deliveries based on recorded mode of delivery (caesarean sections) and major operations (hysterectomy, laparotomy, internal version, craniotomy/embryotomy and symphysiotomy), as specified by the UON definition.[9] Information on obstetric complications and surgery was not collected for deliveries that occurred in hospitals outside the study area.

Deaths from obstructed labour, uterine rupture, antepartum and postpartum haemorrhage were considered AMI-related deaths, regardless of where the delivery occurred. Deaths were classified based on hospital cause of death, or verbal post-mortem where deaths occurred outside the hospitals.

Statistical analyses

The sample used in this study consisted of all deliveries (live births and stillbirths after 22 weeks gestation, and undelivered pregnancy-related deaths in the second or third trimester) in the study population between 1st June 2005 and 9th October 2008. This period was selected based on availability of hospital data. We did two distinct analyses: one among deliveries occurring in the four district hospitals in the study area; and one among all deliveries in the population (Figure 1).

Among hospital deliveries, we first described the prevalence of AMIs. We then calculated the percentage of women with AMIs who received surgery to assess whether providers consider them absolute indications for surgery (objective 1). Mortality among women delivering in hospitals with AMIs who had not received surgery was examined to determine whether surgery is necessary for survival (objective 2).

At the population level, we first examined facility and caesarean deliveries according to educational attainment (highest educational level reached, grouped into four categories: none, primary, secondary, and post-secondary education). Woman's education was selected as the stratifying variable for this analysis because it best represented socio-economic status in this population, and because it showed the largest variation in caesarean rates, and was therefore expected to maximise variation in surgeries for AMIs. Variation was necessary to assess whether AMI-related surgeries and mortality were inversely associated (objective 3). We calculated the percentage of surgeries for AMIs and AMI-related deaths with 95% confidence intervals among all deliveries in the population stratified by educational attainment, and report; chi-square tests-for-trends where the change across categories was unidirectional, and Pearson's chi-square tests otherwise. We compared the percentage of surgeries for AMIs and AMI-related deaths across educational groups to assess whether these were inversely associated where surgeries for AMIs fell below the minimum threshold, using the largest minimum threshold of 2% to capture a broader range of prevalence. Women who received surgery for an AMI and subsequently died were included among AMI-related deaths. Lastly, we estimated the prevalence of AMIs and 95% confidence intervals by education, classifying surgeries for AMIs and AMI-related deaths as AMIs. Hospital deliveries with recorded AMIs who did not receive surgery were also included in the numerator.

The population-level analyses were repeated using two other mortality definitions (all pregnancy-related deaths, and all pregnancy-related deaths after 22 weeks), and two other AMI definitions (using the broad AMI definition, and excluding cephalopelvic disproportion due to the lack of diagnostic gold standard and propensity for misclassification[22,23]), to assess any potential effect of misclassification of AMIs or cause of death.

Ethical approval for the ObaapaVitA trial was obtained from the Ghana Health Service and the London School of Hygiene and Tropical Medicine; ethical approval for this secondary analysis was provided by the London School of Hygiene & Tropical Medicine (ref 6429).

Results

In total, 50,289 deliveries occurred in the study area between 1st June 2005 and 9th October 2008 (Figure 1). There were 150 pregnancy-related deaths after the first trimester, leading to a pregnancy-related mortality ratio after the first trimester of 298 per 100,000 deliveries. Overall, 59% of women delivered in a facility: 13,886 deliveries (28%) occurred in the district hospitals, 15,445 (31%) in lower-level facilities where surgery was not available, and 328 deliveries (0.7%) in hospitals outside the study area. The sample of 13,886 district hospital deliveries was used for objectives 1 and 2. The population-level analyses (objective 3) exclude 141 deliveries with missing educational attainment, leaving 50,148 deliveries in the sample including 148 pregnancy-related deaths.

AMIs among hospital deliveries (objectives 1 and 2)

There were 387 (2.8%) recorded AMIs among hospital deliveries (Table 2). Major cephalopelvic disproportion was the most common AMI (56% of AMIs), and incoercible postpartum haemorrhage the least common (9%). Over 98% of hospital deliveries with recorded AMIs underwent surgery, ranging from 94% for malpresentation to 100% for incoercible postpartum haemorrhage (Table 2).

Of the 387 hospital deliveries with recorded AMIs, only seven did not receive surgery. These included all AMI causes except for incoercible postpartum haemorrhage, which by definition includes only women receiving surgery (three malpresentations, two major cephalopelvic disproportions, one uterine rupture, and one severe antepartum haemorrhage). All seven women survived.

However, an additional eight women died of an AMI-related cause – postpartum haemorrhage – despite having no recorded AMI-related complication or indication for surgery, bringing the total number of AMIs among hospital deliveries to 395 (2.8%). Three of these eight women died following surgery and five without having received surgery.

Variation in AMI-related mortality according to prevalence of surgeries for AMIs (objective 3)

At the population level, facility deliveries and caesarean sections increased substantially with maternal education (Table 3): 42% of deliveries occurred in facilities among women without formal education, compared to 93% among those with post-secondary education. The caesarean rate was 3% among women with no education, and 14% among women with post-secondary education.

Among all deliveries in the population, 380 (0.75%) received surgery for an AMI in the district hospitals; ranging from 0.56% among women with no education to 1.92% among women with post-secondary education ($p<0.001$, Table 3). The prevalence of surgeries for AMIs was below the 2% threshold in all groups (although the 95% confidence interval included 2% for post-secondary education [1.92%; 95% CI: 1.00-3.65]), and below the 1% threshold among women with no, primary and secondary education (the 95% confidence interval included 1% in the latter group [0.93%; 0.81-1.07]). The type of AMIs varied according to education (Figure 2): 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 education group ($p<0.001$).

Overall, among all deliveries in the population (regardless of delivery location), 40 of the 150 pregnancy-related deaths after 22 weeks were from AMI-related causes (including 5 women who died after receiving surgery), corresponding to an AMI-related maternal mortality ratio of 80 per 100,000 deliveries. Mortality from AMIs decreased from 92 per 100,000 among women with no education to 62 per 100,000 among women with secondary education (Figure 3,Table 3), although there was no statistical evidence of a difference by education ($p=0.546$). The sample size of one AMI-related death among women with post-secondary education was insufficient to calculate a reliable mortality estimate.

The estimated prevalence of AMIs – including surgeries for AMIs and AMI-related deaths, as well as the seven hospital AMIs without surgery – was 0.84% (0.76-0.92). It increased consistently with educational level (Figure 3), from 0.66% among women with no education to 2.13% among women with post-secondary education ($p<0.001$).

Sensitivity analyses (Appendix S1) showed education was not associated with either pregnancy-related mortality after 22 weeks ($p=0.839$) or all pregnancy-related mortality ($p=0.846$). The broad AMI definition (Appendix S2) yielded a higher percentage of surgeries for AMIs (2.01%), which also increased with education ($p<0.001$). However, when excluding major cephalopelvic disproportion from the strict AMI definition, AMI prevalence ranged from 0.36% to 0.64% of deliveries, with no evidence of an educational difference ($p=0.322$).

Discussion

This is the first peer-reviewed study testing the assumptions of the Unmet Obstetric Need indicator in sub-Saharan Africa. Our findings show that, first, almost all women diagnosed with AMIs in hospital received surgery, indicating that obstetric providers consider them absolute indications for surgery. Second, only seven hospital deliveries with recorded AMIs did not receive surgery, and all women survived. However, an additional eight women died of AMI-related causes despite not having a recorded AMI diagnosis, including five who did not receive surgery. Third, surgeries for AMIs increased substantially with education, but the low percentage of surgeries for AMIs among women with no or primary education – which were below the lowest threshold of 1% – was not offset by higher AMI-related maternal mortality in these groups.

There are several possible explanations for why we did not find higher AMI-related maternal mortality in groups with low rates of surgery for AMIs. First, the AMIs identified in this study may not be absolute. However, 98% of recorded AMIs received surgery in hospitals, and obstetric care providers globally report that most AMIs listed by the UON should receive a caesarean, indicating widespread agreement among clinicians that they are considered absolute.[2] Uterine rupture, complete placenta praevia (where the placenta attaches over the cervix, blocking the birth canal) and retro-placental haematoma (where the placenta prematurely detaches from the uterus) would cause the woman to bleed to death without intervention. True cephalopelvic disproportion (where the foetus physically cannot fit through the birth canal) and transverse lie (where the foetal angle prevents passage) render vaginal delivery impossible, leading the woman to haemorrhage to death without surgery. One exception is brow presentation, where vaginal delivery is difficult but possible; however, only two women in our dataset had brow presentation (both received surgery). Clinically, therefore, the classification of these complications as “absolute” indications is valid, and it is likely that the seven identified AMIs which survived without surgery were misclassified (i.e. they were not true AMIs). Conversely, although few hospital deliveries with AMIs did not have a recorded AMI-related complication or indication for surgery (eight of 395), these accounted for the majority of AMI-related deaths in hospitals (eight of 13), suggesting that missed AMI diagnoses may be an important contributor to mortality in facilities.

Second, AMI-related deaths outside of facilities may have been underestimated, particularly among less educated women who were more likely to deliver at home. Data were collected prospectively during four-weekly household visits, however, and death ascertainment is likely to have been good. Some AMI-related deaths outside hospitals may have been misclassified as non-AMI deaths if the verbal post-mortem cause of death was incorrect, but a true AMI-related maternal mortality of 432 per 100,000 would have been needed – or almost 80% of AMI-related deaths to be misclassified – to achieve a minimum threshold of 1% among women with no education. It is unlikely that deaths were underestimated to this extent.

Third, this study calls into question the assumption that at least 1-2% of deliveries develop AMIs. AMI prevalence was below 1% in this population (0.84%, 95% CI: 0.76-0.92), indicating that the minimum thresholds used to calculate the UON indicator may not be valid in all populations. These thresholds were proposed on the basis of the population-based percentage of surgeries for AMIs in urban areas of low-income countries thought to have good access to surgical care, with the assumption that the need for surgeries for AMIs would be met in these settings. Specifically, the 1.4% threshold was calculated as the average prevalence of surgeries for AMIs in Benin, Burkina Faso, Mali, and Niger among women living within 5-15km of a functioning surgical hospital.[12] This prevalence could have been overestimated if surgeries among women living further from the hospital were included in the numerator and not the denominator, or if less severe complications were misrecorded as AMIs. Moreover, the assumption that AMI prevalence does not vary between populations may be unfounded. A recent systematic review showed that the prevalence of postpartum haemorrhage and placenta praevia varies globally.[24,25] The prevalence of uterine rupture depends on clinical management and rate of previous caesareans,[26] and the prevalence of malpresentation and major cephalopelvic disproportion may also vary across populations based on the distribution of malnutrition, age, BMI, and gestational diabetes among pregnant women.[27-29] It is therefore unlikely that a minimum AMI prevalence valid in all populations can be identified.

Fourth, AMIs may have been overdiagnosed among women who underwent a caesarean section, perhaps more so among the more educated. The educational gradient in surgeries for AMIs in our study is similar to that reported in Bangladesh.[20] Most of the increase in AMIs among more educated women was due to major cephalopelvic disproportion. While more educated women may be at increased risk of macrosomia and cephalopelvic disproportion due to higher BMI and diabetes,[27,28] less educated women may be more malnourished/stunted and give birth at a younger age, leading to a small or deformed pelvis with cephalopelvic disproportion as a result.[29] Nonetheless, variation in the true prevalence of major cephalopelvic disproportion with education is unlikely to explain the six-fold higher rate of surgeries for cephalopelvic disproportion among post-secondary educated women, and it is likely this condition was substantially overdiagnosed in this group.

Indeed, major cephalopelvic disproportion is notoriously difficult to diagnose:[30] there is no gold standard diagnosis[6,23] and misclassification is common, even in high-income countries.[22,31] Doctors are known to overestimate the severity of caesarean indications in various settings, including in countries with low population-based caesarean rates.[32-34] Standardised clinical data in the ObaapaVitA trial were extracted prospectively, and it would have been difficult to further minimise errors in diagnoses. Excluding major cephalopelvic disproportion from the AMI definition would not eliminate misclassification, since other conditions (apart from uterine rupture) also lack definite clinical criteria – in particular, identifying life-threatening antepartum haemorrhage is likely to be subjective.

The availability of high-quality and comprehensive hospital data linked to population-based socio-economic and mortality data was a major strength of this study. These data were collected between 2005-2008; however the implications of our findings are unchanged, since the assumptions of the UON indicator should be valid in any time period. Clinical information was missing for the 0.7% of deliveries occurring in hospitals outside of the study area. Two of these 328 women died from AMI-related causes and were included in the estimate of AMI prevalence, but some of the remaining 326 women may have received surgery for AMIs and would not be accounted for in our analysis. However, the proportion of hospital deliveries without information was 0.37% among women with no education, among whom AMI prevalence was estimated at 0.66%: it is very unlikely that most of these women developed AMIs and received surgery, and therefore that having information from these deliveries would raise AMI prevalence to 1% in this group.

Conclusions

Our findings indicate that providers consider AMIs to be absolute indications for surgery in rural Ghana, although most AMI-related deaths in hospitals occurred among women who did not have a recorded AMI diagnosis. These results re-affirm the importance of training obstetric care providers in accurately diagnosing these life-threatening complications and enabling rapid access to surgery for women who develop them, in line with the framework for Quality Maternal and Newborn Care.[8] The population-based prevalence of AMIs was below 1%, calling into question the minimum thresholds used to calculate the UON indicator. Population-based rates of surgery for AMIs below the minimum threshold (whether 1%, 1.4% or 2%) therefore may not be indicative of higher maternal mortality from these causes. Due to concerns with misclassification of surgeries for AMIs and the validity of the minimum threshold, the UON indicator should be used with caution in estimating the unmet need for maternal life-saving obstetric surgery.

The Robson classification[35,36] has been used to identify groups with potentially unnecessary caesareans in facilities, however its interpretation in relation to the unmet need for caesareans is unclear. The minimum need for caesareans at the population level is thought to be 1-2% of deliveries,[6,7] but innovative methodological approaches are needed to measure and minimise the unmet need for caesareans in the vast majority of settings with higher caesarean rates. There are no internationally standardised clinical protocols to define which women need a caesarean, although these would be unlikely to help identify all such women accurately in clinical databases. It is likely that the unmet need for caesareans cannot be precisely quantified with a single indicator, but rather will be estimated qualitatively from a range of information including the proportion of deliveries in facilities equipped to provide emergency obstetric care, use of partographs and other tools to identify women in need of a caesarean, and facility- and community-based audits of adverse maternal and perinatal outcomes.

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Tables

Table 1. Strict and broad definitions for absolute maternal indications, using recorded obstetric complications and indications for surgery, Ghana, 2005-2008

	Included in strict definition	Additionally included in broad definition
Uterine rupture		
Obstetric complications	• Uterine rupture • Pre-uterine rupture, Bandl's ring	None
Indications for obstetric surgery	• Uterine rupture • Pre-uterine rupture, Bandl's ring	None
Incoercible postpartum haemorrhage		
Obstetric complications	• Any hysterectomy	None
Indications for obstetric surgery	• Any hysterectomy	None
Severe antepartum haemorrhage		
Obstetric complications	• Partial placenta praevia, placenta praevia type III • Complete placenta praevia, placenta praevia type IV	• Low lying placenta, placenta praevia types I or II • Unspecified placenta praevia • Placental abruption • Unspecified antepartum haemorrhage
Indications for obstetric surgery	• Antepartum haemorrhage due to placenta praevia	• Antepartum haemorrhage due to placental abruption • Antepartum haemorrhage, cause unspecified
Malpresentation		
Obstetric complications	• Transverse lie • Brow presentation	• Oblique lie • Face presentation • Compound presentation
Indications for obstetric surgery	• Transverse lie • Brow presentation	• Oblique lie • Face presentation
Major cephalopelvic disproportion		
Obstetric complications	• Obstructed labour • Any craniotomy, embryotopmy, or symphysiotomy	• Cephalopelvic disproportion
Indications for obstetric surgery	• Any craniotomy, embryotopmy, or symphysiotomy	• Cephalopelvic disproportion • Macrosomia

Table 2. Number of AMIs receiving surgery and deaths among AMIs, among hospital deliveries – strict definition of AMIs (N= 13,886), Ghana, 2005-2008

Absolute Maternal Indication (AMI)	N	Hospital deliveries with AMI [%]	Deliveries with AMIs receiving surgery[a]		Deliveries with AMIs not receiving surgery	
			N (%)	Deaths (all causes) [N]	N (%)	Deaths (all causes) [N]
Severe antepartum haemorrhage	54	0.39	53 (98.1)	0	1 (1.9)	0
Incoercible postpartum haemorrhage	33	0.24	33 (100.0)	3	0	0
Uterine rupture	61	0.44	60 (98.4)	1	1 (1.6)	0
Malpresentation	52	0.37	49 (94.2)	1	3 (5.8)	0
Major cephalopelvic disproportion	218	1.58	216 (99.1)	1	2 (0.9)	0
Any recorded strict AMIs[b]	**387**	**2.79**	**380 (98.2)**	**5[c]**	**7 (1.8)**	**0**
AMI-related deaths with no recorded AMI diagnosis	8	0.06	3 (37.5)	3	5 (62.5)	5
Total strict AMIs	**395**	**2.84**	**383 (96.7)**	**8**	**12 (3.0)**	**5**

[a]Surgeries include caesarean section, hysterectomy, laparotomy, internal version, craniotomy/embryotomy and symphysiotomy.

[b]Recorded AMIs based on complications or indications for surgery

[c]Multiple AMIs could be recorded for one woman, therefore the total number of deaths does not equal to the sum of deaths for individual AMIs. One woman died following emergency caesarean and hysterectomy due to uterine rupture and incoercible postpartum haemorrhage.

Table 3. Percentage of facility deliveries, caesarean sections, surgeries for AMIs and deaths from AMIs among all deliveries in the population, stratified by woman's education (N=50,148), Ghana, 2005-2008

Woman's educational attainment	N	Facility deliveries [%]	Caesarean sections [%]	Surgeries for AMIs [% (95% CI)]	AMI-related deaths [N]	Pregnancy-related mortality from AMIs [ratio per 100,000 deliveries (95% CI)]	AMI prevalence[a] [% (95% CI)]
None	18,465	41.9	2.9	0.56 (0.46-0.68)	17	92 (57-148)	0.66 (0.55-0.78)
Primary	10,101	57.6	4.6	0.68 (0.54-0.86)	8	79 (40-158)	0.77 (0.62-0.96)
Secondary	21,113	73.9	7.2	0.93 (0.81-1.07)	13	62 (36-106)	0.99 (0.87-1.14)
Post-secondary	469	93.0	14.3	1.92 (1.00-3.65)	1	-[b]	2.13 (1.15-3.92)
Chi-square p-value	-	*<0.001*	*<0.001*	*<0.001*	-	*0.546*	*<0.001*
Total	**50,148**	**59.0**	**5.2**	**0.75 (0.68-0.83)**	**39**	**78 (57-106)**	**0.84 (0.76-0.92)**

[a]Women with surgeries for AMIs, AMI-related deaths, as well as recorded hospital AMIs which did not receive surgery are included in the numerator for AMI prevalence

[b]The number of AMI-related deaths among women with post-secondary education is too small to calculate a reliable mortality ratio (n=1)

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