

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

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4 **Abstract**

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

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

15 Results. 380 of 387 (98%) hospital deliveries with recorded AMIs received surgery; an
16 additional eight with no AMI diagnosis died of AMI-related causes. Among the 50,148 deliveries
17 in the population, surgeries for AMIs increased from 0.6% among women with no education to
18 1.9% among women with post-secondary education ($p < 0.001$). However, there was no
19 association between AMI-related mortality and education ($p = 0.546$). Estimated AMI prevalence
20 was 0.84% (95% CI: 0.76%-0.92%), below the assumed 1% minimum threshold.

21 Discussion. Obstetric providers consider AMIs absolute indications for surgery. However, low
22 rates of surgeries for AMIs among less educated women were not associated with higher

23 mortality. The UON indicator should be used with caution in estimating the unmet need for life-
24 saving obstetric surgery; innovative approaches are needed to identify unmet need in the
25 context of rising caesarean rates.

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

27

28 **Introduction**

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

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

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

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

74 Although the assumptions underpinning the UON indicator have not been verified, it has been
75 widely used to measure the unmet need for obstetric surgery.^{11,12,16,17} Recent studies have
76 found 0.4-1.4% of deliveries receive surgery for AMIs in rural sub-Saharan Africa, deemed to
77 represent a substantial unmet need.^{13,14,18,19} A study in Bangladesh suggested that groups with

78 lower rates of surgery for AMIs did not suffer from higher AMI-related mortality, and the validity
79 of the indicator was called into question.²⁰

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

92 **Methods**

93 *Study setting*

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

100 *Data collection*

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

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

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

120 Pre-coded obstetric complications and indications for surgery were used to identify AMIs
121 among hospital deliveries, by adapting the standard definitions for the five AMI causes.⁹ For
122 each cause, a strict (high-specificity) definition was constructed; we also constructed a broad
123 definition (with high sensitivity and lower specificity) for sensitivity analyses (Table 1). For
124 example, strict malpresentation included transverse lie and brow presentation, while the broad
125 definition additionally included oblique lie, face and compound presentation, to account for
126 possible misclassification of strict malpresentations. Deliveries with multiple AMIs were

127 classified hierarchically in the following order: uterine rupture, incoercible postpartum
128 haemorrhage, severe antepartum haemorrhage, malpresentation, and major cephalopelvic
129 disproportion.

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

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

139 *Statistical analyses*

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

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

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

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

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

177 **Results**

178 In total, 50,289 deliveries occurred in the study area between 1st June 2005 and 9th October
179 2008 (Figure 1). There were 150 pregnancy-related deaths after the first trimester, leading to a
180 pregnancy-related mortality ratio after the first trimester of 298 per 100,000 deliveries. Overall,
181 59% of women delivered in a facility: 13,886 deliveries (28%) occurred in the district hospitals,
182 15,445 (31%) in lower-level facilities where surgery was not available, and 328 deliveries
183 (0.7%) in hospitals outside the study area. The sample of 13,886 district hospital deliveries was
184 used for objectives 1 and 2. The population-level analyses (objective 3) exclude 141 deliveries
185 with missing educational attainment, leaving 50,148 deliveries in the sample including 148
186 pregnancy-related deaths.

187 *AMIs among hospital deliveries (objectives 1 and 2)*

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

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

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

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

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

208 Among all deliveries in the population, 380 (0.75%) received surgery for an AMI in the district
209 hospitals; ranging from 0.56% among women with no education to 1.92% among women with
210 post-secondary education ($p < 0.001$, Table 3). The prevalence of surgeries for AMIs was below
211 the 2% threshold in all groups (although the 95% confidence interval included 2% for post-
212 secondary education [1.92%; 95% CI: 1.00-3.65]), and below the 1% threshold among women
213 with no, primary and secondary education (the 95% confidence interval included 1% in the
214 latter group [0.93%; 0.81-1.07]). The type of AMIs varied according to education (Figure 2): the
215 percentage of deliveries receiving surgery for major cephalopelvic disproportion increased from
216 0.24% among women with no education to 1.49% in the post-secondary education group
217 ($p < 0.001$).

218 Overall, among all deliveries in the population (regardless of delivery location), 40 of the 150
219 pregnancy-related deaths after 22 weeks were from AMI-related causes (including 5 women
220 who died after receiving surgery), corresponding to an AMI-related maternal mortality ratio of
221 80 per 100,000 deliveries. Mortality from AMIs decreased from 92 per 100,000 among women
222 with no education to 62 per 100,000 among women with secondary education (Figure 3, Table
223 3), although there was no statistical evidence of a difference by education ($p = 0.546$). The
224 sample size of one AMI-related death among women with post-secondary education was
225 insufficient to calculate a reliable mortality estimate.

226 The estimated prevalence of AMIs – including surgeries for AMIs and AMI-related deaths, as
227 well as the seven hospital AMIs without surgery – was 0.84% (0.76-0.92). It increased
228 consistently with educational level (Figure 3), from 0.66% among women with no education to
229 2.13% among women with post-secondary education ($p<0.001$).

230 Sensitivity analyses (Appendix S1) showed education was not associated with either
231 pregnancy-related mortality after 22 weeks ($p=0.839$) or all pregnancy-related mortality
232 ($p=0.846$). The broad AMI definition (Appendix S2) yielded a higher percentage of surgeries for
233 AMIs (2.01%), which also increased with education ($p<0.001$). However, when excluding major
234 cephalopelvic disproportion from the strict AMI definition, AMI prevalence ranged from 0.36% to
235 0.64% of deliveries, with no evidence of an educational difference ($p=0.322$).

236 **Discussion**

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

247 There are several possible explanations for why we did not find higher AMI-related maternal
248 mortality in groups with low rates of surgery for AMIs. First, the AMIs identified in this study may
249 not be absolute. However, 98% of recorded AMIs received surgery in hospitals, and obstetric
250 care providers globally report that most AMIs listed by the UON should receive a caesarean,

251 indicating widespread agreement among clinicians that they are considered absolute.² Uterine
252 rupture, complete placenta praevia (where the placenta attaches over the cervix, blocking the
253 birth canal) and retro-placental haematoma (where the placenta prematurely detaches from the
254 uterus) would cause the woman to bleed to death without intervention. True cephalopelvic
255 disproportion (where the foetus physically cannot fit through the birth canal) and transverse lie
256 (where the foetal angle prevents passage) render vaginal delivery impossible, leading the
257 woman to haemorrhage to death without surgery. One exception is brow presentation, where
258 vaginal delivery is difficult but possible; however, only two women in our dataset had brow
259 presentation (both received surgery). Clinically, therefore, the classification of these
260 complications as “absolute” indications is valid, and it is likely that the seven identified AMIs
261 which survived without surgery were misclassified (i.e. they were not true AMIs). Conversely,
262 although few hospital deliveries with AMIs did not have a recorded AMI-related complication or
263 indication for surgery (eight of 395), these accounted for the majority of AMI-related deaths in
264 hospitals (eight of 13), suggesting that missed AMI diagnoses may be an important contributor
265 to mortality in facilities.

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

274 Third, this study calls into question the assumption that at least 1-2% of deliveries develop
275 AMIs. AMI prevalence was below 1% in this population (0.84%, 95% CI: 0.76-0.92), indicating
276 that the minimum thresholds used to calculate the UON indicator may not be valid in all

277 populations. These thresholds were proposed on the basis of the population-based percentage
278 of surgeries for AMIs in urban areas of low-income countries thought to have good access to
279 surgical care, with the assumption that the need for surgeries for AMIs would be met in these
280 settings. Specifically, the 1.4% threshold was calculated as the average prevalence of
281 surgeries for AMIs in Benin, Burkina Faso, Mali, and Niger among women living within 5-15km
282 of a functioning surgical hospital.¹² This prevalence could have been overestimated if surgeries
283 among women living further from the hospital were included in the numerator and not the
284 denominator, or if less severe complications were misrecorded as AMIs. Moreover, the
285 assumption that AMI prevalence does not vary between populations may be unfounded. A
286 recent systematic review showed that the prevalence of postpartum haemorrhage and placenta
287 praevia varies globally.^{24,25} The prevalence of uterine rupture depends on clinical management
288 and rate of previous caesareans,²⁶ and the prevalence of malpresentation and major
289 cephalopelvic disproportion may also vary across populations based on the distribution of
290 malnutrition, age, BMI, and gestational diabetes among pregnant women.²⁷⁻²⁹ It is therefore
291 unlikely that a minimum AMI prevalence valid in all populations can be identified.

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

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

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

324 **Conclusions**

325 Our findings indicate that providers consider AMIs to be absolute indications for surgery in rural
326 Ghana, although most AMI-related deaths in hospitals occurred among women who did not
327 have a recorded AMI diagnosis. These results re-affirm the importance of training obstetric care

328 providers in accurately diagnosing these life-threatening complications and enabling rapid
329 access to surgery for women who develop them, in line with the framework for Quality Maternal
330 and Newborn Care.⁸ The population-based prevalence of AMIs was below 1%, calling into
331 question the minimum thresholds used to calculate the UON indicator. Population-based rates
332 of surgery for AMIs below the minimum threshold (whether 1%, 1.4% or 2%) therefore may not
333 be indicative of higher maternal mortality from these causes. Due to concerns with
334 misclassification of surgeries for AMIs and the validity of the minimum threshold, the UON
335 indicator should be used with caution in estimating the unmet need for maternal life-saving
336 obstetric surgery.

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

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

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

462 **Table 2. Number of AMIs receiving surgery and deaths among AMIs, among hospital deliveries –**
 463 **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

464 ^aSurgeries include caesarean section, hysterectomy, laparotomy, internal version, craniotomy/embryotomy and
 465 symphysiotomy.

466 ^bRecorded AMIs based on complications or indications for surgery

467 ^cMultiple AMIs could be recorded for one woman, therefore the total number of deaths does not equal to the sum of
 468 deaths for individual AMIs. One woman died following emergency caesarean and hysterectomy due to uterine
 469 rupture and incoercible postpartum haemorrhage.

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472 **Table 3. Percentage of facility deliveries, caesarean sections, surgeries for AMIs and deaths from**
 473 **AMIs among all deliveries in the population, stratified by woman's education (N=50,148), Ghana,**
 474 **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)
<i>Chi-square p-value</i>	-	<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)

475 ^aWomen with surgeries for AMIs, AMI-related deaths, as well as recorded hospital AMIs which did not receive
 476 surgery are included in the numerator for AMI prevalence

477 ^bThe number of AMI-related deaths among women with post-secondary education is too small to calculate a reliable
 478 mortality ratio (n=1)

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480 **List of figures**

481 **Figure 1. Description of study population and samples for objectives, Ghana, 2005-2008**

482 **Figure 2. Percentage of surgeries for each AMI among all deliveries in the population, stratified**
483 **by woman's education (N=50,148), Ghana, 2005-2008**

484 **Figure 3. Percentage of surgeries for AMIs and pregnancy-related deaths from AMIs among all**
485 **deliveries in the population, stratified by maternal education (N=50,148), Ghana, 2005-2008**

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