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Hospital variation in intrapartum-related perinatal mortality among women giving birth by caesarean section: secondary analysis of a cluster randomised trial in 21 hospitals in Burkina Faso

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1 **Hospital variation in intrapartum-related perinatal mortality among women giving birth by**
2 **caesarean section: secondary analysis of a cluster randomised trial in 21 hospitals in Burkina**
3 **Faso**
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Abstract

Objectives. To examine hospital variation in crude and risk-adjusted rates of intrapartum-related perinatal mortality among caesarean births

Design. Secondary analysis of data from the DECIDE cluster randomised trial post-intervention phase

Setting. 21 district and regional hospitals in Burkina Faso

Participants. All 5,134 women giving birth by caesarean section in a 6-month period in 2016

Primary outcome measure. Intrapartum-related perinatal mortality (fresh stillbirth or neonatal death within 24 hours of birth)

Results. Nine percent of 5,134 women giving birth by caesarean experienced an intrapartum-related perinatal death. Crude mortality rates varied substantially from 2-19% between hospitals. Variation was markedly reduced after adjusting for case mix differences, however higher and more variable adjusted mortality persisted among hospitals performing fewer caesareans per month. Additionally adjusting for caesarean care components did not further reduce variation.

Conclusions. There is a high burden of intrapartum-related perinatal deaths among caesarean births in Burkina Faso, and sub-Saharan Africa more widely. Variation in adjusted mortality rates indicates likely differences in quality of caesarean care between hospitals, particularly lower-volume hospitals. Improving access to and quality of emergency obstetric and newborn care is an important priority for improving survival of babies at birth.

Keywords: obstetrics, perinatology, neonatology

Strengths and limitations of this study

- This is the first study to examine hospital variation in intrapartum-related perinatal mortality among women giving birth by caesarean section in a sub-Saharan African country.
- Our study benefited from inclusion of all caesarean sections performed in a six-month period in 21 regional and district hospitals in Burkina Faso.
- We used high-quality clinical data from the DECIDE cluster-randomised trial, including standardised definitions for diagnoses and indications for caesarean, although some misclassification of obstetric complication severity was likely.
- More than 20% of data were missing for three risk factors (decision-to-incision interval, timing of antibiotics, and referral distance); we used multiple imputation to avoid a loss of power.
- Our hospital sample size and limited available information prevented us from examining hospital characteristics as risk factors for perinatal mortality.

Introduction

While facility births have increased over the past few decades in sub-Saharan Africa,¹ improvements in maternal and perinatal health have not been as extensive as hoped, raising questions about the quality of care in health facilities.¹⁻³ In particular, increases in population-based caesarean section rates have been small despite substantial increases in facility births, indicating limited improvements in access to emergency obstetric care in the region.^{4 5} Globally, the slowest rise was observed in West and Central Africa, from 3.0% caesarean births in 2000 to 4.1% in 2015.⁵ Due to a rise in total number of births, the absolute number of caesareans performed has nonetheless increased more rapidly – 3- to 5-fold in Senegal, Tanzania and Uganda over the past few decades.^{4 6 7}

Increases in caesarean births are concerning in the context of often under-resourced health systems with limited capacity to provide high-quality caesarean care. Caesarean sections account for one third of all surgeries in Africa, with higher post-operative morbidity and mortality than in other regions.⁸ A recent meta-analysis found over 1% mortality among women who deliver by caesarean in sub-Saharan Africa, 100 times higher than in the UK.⁹ Perinatal mortality is also very high in sub-Saharan Africa, with one in 10 mothers delivering by caesarean experiencing a stillbirth or early neonatal death.⁹ Severe complications before reaching health facilities and low capacity within facilities to provide high-quality care contribute to these adverse outcomes. Indeed, low capacity to provide caesarean section care has been reported in Burkina Faso^{10 11} and elsewhere in the region.⁶

12 13

In the context of rising caesareans, there is a need to better understand drivers of high perinatal mortality among women giving birth by caesarean in sub-Saharan Africa. Limited evidence is available on inter-hospital variation in outcomes among caesarean births. Although there is mixed evidence regarding whether hospital type (district, regional, or national) is independently associated with perinatal mortality,^{9 14} there are stark differences in material and human resources across hospital types in sub-Saharan Africa, restricting capacity to provide high-quality care in lower-level and rural facilities.^{4 6} Examining variation in crude and risk-adjusted rates of events between hospitals is a commonly used approach to determine whether differences between hospitals can be explained by heterogeneity in case mix, with any remaining variation in risk-adjusted rates suggesting differences in quality of patient care.¹⁵⁻¹⁷ In this study, we examined variation in crude and adjusted rates of intrapartum-related perinatal mortality among women giving birth by caesarean in 21 district and regional hospitals in Burkina Faso for a six month period in 2016. We used high-quality data from the DECIDE trial to assess the evidence that differences in intrapartum-related mortality between individual hospitals and hospital types were driven in part by variation in quality of care.

Methods

1 This study is a secondary analysis of the DECIDE cluster-randomised controlled trial, which
2 assessed the effectiveness of a multicomponent intervention including provider training, caesarean
3 audits, and SMS reminders to reduce non-medically indicated caesarean sections. The trial included
4 three phases (six-month pre-intervention, one-year intervention, and six-month post-intervention). It
5 was conducted in all 22 regional and district hospitals in Burkina Faso performing more than 200
6 caesareans per year in 2012; university hospitals in Ouagadougou and Bobo-Dioulasso were
7 excluded. Detailed trial methods are described elsewhere.¹⁸

13 *Health system context*

15 Similar to other West African countries, the caesarean rate in Burkina Faso is below 5% (3.7% in
16 2010-15),¹⁹ with large urban-rural, wealth and educational differentials.^{20 21} Although 85% of births
17 take place in health facilities, 70% occur in primary care facilities without surgical capacity.²² Women
18 who develop complications requiring a caesarean are referred to medical centres with surgical
19 capacity (*centres médicaux avec antenne chirurgicale*, referred to as district hospitals hereafter) or
20 regional hospitals. Women with severe complications may be referred onwards to tertiary university
21 hospitals in the capital (Ouagadougou) and second largest city (Bobo-Dioulasso). Most – but not all –
22 district and regional hospitals have at least one obstetrician or generalist doctor trained in emergency
23 obstetric care. Task-shifting of caesarean care has been supported in Burkina Faso through the
24 additional three-year training of nurses and midwives as non-physician providers with surgical skills
25 (*attachés en chirurgie*) and obstetrics skills (*attachés en gynéco-obstétrique*). Most anaesthesia care
26 is provided by nurses with additional training in anaesthesia.

35 *Participants*

37 We included all 5,134 women giving birth by caesarean section in the 21 study hospitals with
38 caesarean capacity in the post-intervention phase (2nd May-2nd November 2016; one study hospital's
39 operating theatre was no longer functional in the post-intervention phase). These 21 hospitals
40 accounted for 45% of all caesarean sections performed nationally in 2016.²³ Women delivering by
41 caesarean were included regardless of gestational age, whether they were referred to the study
42 hospital before the caesarean, or referred to another hospital after birth.

47 *Data source*

49 Patient medical records were used in the DECIDE trial, with prospective data collection in the post-
50 intervention phase using data extraction forms and standardised clinical definitions (including for
51 labour dystocia, acute fetal distress, and other indications for caesarean).¹⁸ We used post-
52 intervention data to provide the most recent description for a larger sample.

57 *Outcome*

1 Intrapartum-related perinatal mortality includes fresh stillbirths and very early neonatal deaths (within
2 24 hours of birth),^{24 25} and is recommended by the WHO as an indicator of the quality of emergency
3 obstetric and newborn care.²⁶
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6 *Risk factors and conceptual approach*

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8 We examined two groups of risk factors for intrapartum-related mortality: individual-level clinical risk
9 factors, and caesarean care components and hospital characteristics.
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12 We conceptualised case mix as the hospital prevalence of clinical risk factors for intrapartum-related
13 mortality (maternal age, parity, education, previous caesarean, multiple pregnancy, number of
14 antenatal visits, birthweight, congenital malformation, referral status and distance, labour phase,
15 diagnosis of acute fetal distress, transverse lie/brow presentation in active labour, other severe
16 obstetric complication or maternal death, and primary indication for caesarean). “Other severe
17 obstetric complications” included severe pre-eclampsia or eclampsia, retro-placental haematoma,
18 uterine (pre-)rupture, and placenta praevia in active labour. We conceptualised components of
19 caesarean care (provider cadre deciding and performing the caesarean, decision-to-incision interval,
20 anaesthesia type, skin/uterine incision type, and antibiotic prophylaxis administration) and hospital
21 characteristics (hospital type and monthly caesarean volume) as potential indicators of quality of
22 patient care.
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30 We used these risk factors to derive two sets of risk-adjusted mortality rates per hospital: adjusting
31 for case mix only, and additionally adjusting for components of care and hospital characteristics,
32 because some of these variables might capture remaining unmeasured differences in case mix (for
33 example, women receiving general anaesthesia are more likely to have complications requiring
34 urgent surgery), and to identify whether any care components (e.g. decision-to-incision interval) were
35 strongly associated with mortality. We included care components prior to delivery as risk factors even
36 when they were not hypothesised to causally affect perinatal mortality, since they may be proxies for
37 quality of care.
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44 *Multiple imputation of missing data among risk factors*

45 Data were complete for the outcome and nine risk factors (including multiple gestation, indication for
46 caesarean, and referral status) (Supplementary Table 1). 11 risk factors had <5% missing values; six
47 risk factors had >5% missing data, including decision-incision interval (24%) and timing of antibiotic
48 administration (23%). Overall, 68% of women had at least one risk factor missing, and 4% had at
49 least four risk factors missing (Supplementary Table 2). Missing information on previous caesarean
50 was assumed to indicate no previous caesarean (n=40), and missing deciding provider cadre was
51 imputed as the hospital mode for seven women (>90% of caesareans were decided by one cadre in
52 all relevant hospitals).
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Multiple imputation by chained equations was used for other variables to avoid a loss in efficiency, because missing values were likely to be missing at random given known risk factors (including referral status and severe obstetric complication).²⁷ Five imputed datasets were created using the *mi* package in Stata v14.2, including all risk factors and intrapartum-related mortality in the imputation model. The same model was used for all hospitals, with hospital type included as a risk factor. Missing values for continuous risk factors (age, parity, number of antenatal care visits, referral distance, birthweight, and decision-to-incision interval) were imputed from linear regression models, missing values for binary risk factors (acute fetal distress, antibiotic prophylaxis, incision type, anaesthesia type, congenital malformation, and neonatal resuscitation) were imputed from logistic regression models, and categorical risk factors (education, provider cadre performing the caesarean, and timing of antibiotic administration) were imputed from multinomial regression models. Gestational age at birth had >50% missing data; it was not considered as a risk factor in the analysis model, since it is highly correlated with low birthweight, which was more complete and likely to be more accurate in a setting without routine ultrasound in the first trimester. However, we included gestational age at birth in the imputation model to improve the prediction of birthweight. Distributions of imputed values were compared with observed values for variables with >5% missing data.

Hospital variation in intrapartum-related mortality rates

First, we calculated crude hospital intrapartum-related mortality rates with 95% confidence intervals, and described perinatal outcomes according to hospital type. Differences in hospital case mix were assessed by describing the prevalence of clinical risk factor for intrapartum-related mortality among women giving birth by caesarean, stratified by hospital and hospital type. We similarly described differences in components of care received. Chi-square tests accounted for clustering of women by hospital using the *svyset* package in Stata.

Next, we built two multivariable models for intrapartum-related death among caesarean births using multi-level logistic regression models of women, nested in hospitals to account for clustering. The first model (model 1) adjusted for case mix only, and included all individual-level clinical risk factors for intrapartum-related mortality with Wald test $p\text{-value} \leq 0.25$ in bivariate associations, using manual backward selection to retain only variables with $p\text{-values} < 0.1$. The second model (model 2) built upon model 1 by additionally including all care components and hospital characteristics with bivariate Wald test $p\text{-value} \leq 0.25$, and similarly using backward selection to retain only $p\text{-values} < 0.1$. Multicollinearity was examined by reviewing Spearman correlations and model standard errors. In building model 2, provider cadre deciding the caesarean met the criteria for inclusion, however its inclusion reduced the hospital-level estimate almost to zero, indicating that this variable acted as a proxy for broader differences between hospitals. Further inspection showed that deciding providing cadre was highly clustered within hospitals (one category accounted for >90% of women in 13 of 21 hospitals). We therefore removed it from risk factors considered for model 2.

1 We calculated the median odds ratio (OR) for model 1 and 2 as a measure of inter-hospital variation
2 in mortality that is not explained by the model covariates, expressed on the OR scale (formula in
3 Supplementary Figure 1).²⁸ For a multi-level model, the median OR is defined as the median of the
4 ORs that could be calculated by comparing two patients with identical individual-level characteristics
5 from two, randomly chosen, different hospitals.^{29 30}

6 Risk-adjusted mortality enables comparisons in hospital outcomes taking into account differences in
7 case mix.¹⁵⁻¹⁷ Risk-adjusted intrapartum-related mortality rates were calculated for each hospital by
8 multiplying the intrapartum-related mortality rate across the study sample by the ratio of the number
9 of observed deaths to predicted deaths based on model 1 and 2 in each hospital. Bootstrapping with
10 1,000 iterations was used to calculate 95% confidence intervals around both sets of risk-adjusted
11 hospital mortality rates and found to produce stable estimates. We used the Boot MI percentile
12 method to produce confidence intervals with nominal coverage.³¹

13 The DECIDE trial found a reduction in avoidable caesareans,³² suggesting changes in caesarean
14 decision-making which may affect intrapartum-related mortality. As a secondary analysis, we added
15 trial group as a risk factor to model 2 to determine whether it was associated with mortality after
16 adjusting for other covariates.

17 *Ethics*

18 The DECIDE trial received ethical approval from the National Ethics Committee in Burkina Faso
19 (#2014-02-016) and the Ethics Committee of the University of Montreal Hospital Research Centre
20 (CRCHUM) in Canada (#13.356).³² As a secondary analysis of de-identified data, this study did not
21 require ethical approval from the UCL Ethics Committee.

22 **Results**

23 Our analysis included 5,134 women giving birth by caesarean in the 21 study hospitals. Women with
24 multiple pregnancies, congenital malformation, transverse lie/brow presentation in active labour,
25 whose caesarean was decided by a non-physician provider with surgical skills, and delivering in a
26 rural district hospital were more likely to have missing data for four or more risk factors
27 (Supplementary Table 2).

28 *Hospital variation in intrapartum-related perinatal mortality among caesarean births*

29 Intrapartum-related perinatal mortality was high among caesarean births at 8.8% [95% CI: 8.1%-
30 9.6%], including 6.5% fresh stillbirths and 2.3% deaths within 24 hours of birth (Table 1). Crude
31 mortality rates varied substantially across hospitals, from 2.1% to 18.9%; intrapartum-related
32 mortality tended to be higher in hospitals performing fewer caesarean sections (List of figures
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Figure 1A). Intrapartum-related mortality was higher in regional and rural district hospitals than in urban district hospitals (12% vs 5%, $p=0.001$). Other perinatal outcomes showed similar patterns (Supplementary Table 3).

Table 1. Perinatal mortality among women giving birth by caesarean according to hospital type – Burkina Faso, 2016

		Fresh stillbirths (%)	Neonatal death within 24 hrs of births (live babies, %)	Intrapartum-related perinatal death (%) ^a	Intrapartum-related perinatal death – range across hospitals
Total	5,134	6.5	2.3	8.8	2.1-18.9
Hospital type					
Regional hospital	2,693	7.8	3.0	12.1	6.3-18.9
Urban district hospital	1,659	3.6	1.0	5.1	2.1-7.1
Rural district hospital	782	8.1	2.9	11.9	5.4-18.5
P-value	-	<0.001	0.016	0.001	-

^aFresh stillbirth or neonatal death within 24 hours of birth

Note: confidence intervals and additional outcomes are reported in Supplementary Table 3

Hospital variation in clinical risk factors among women giving birth by caesarean section

Case mix varied substantially across hospitals, with a range of 5%-37% for parity of four or more, 2%-29% for birthweight <2500g, and 1%-11% for transverse lie or brow presentation in active labour (Table 2). Regional hospitals and rural district hospitals had higher-risk populations of women giving birth by caesarean than urban district hospitals, with higher proportions of intrapartum caesareans, women with high parity, and referred to the study hospital immediately prior to the caesarean ($p<0.01$ for all).

Table 2. Characteristics of women giving birth by caesarean section, across hospitals and hospital types (N=5,134)

	Range across hospitals	Regional hospital ^a	Urban district hospital	Rural district hospital	Total
N facilities		9	5	7	21
Caesarean volume per month (median, range)	9-103	37	45	17	
N women giving birth by caesarean	54-619	2,693	1,659	782	5,134
Age (%)					
13-19	6-31	20.2	10.1	22	17.2
20-29	37-53	44.8	49.8	43.9	46.3
30-39	22-38	30.1	35.2	27.9	31.4
40-49	0-6	3.2	3.3	2.7	3.1
Missing	0-8	1.7	1.6	3.6	2.0
Educational level (%)					
None	33-88	73.6	41.8	74.0	63.4
Primary	1-38	7.7	24.1	15.0	14.1
Secondary or higher	3-45	17.9	31.2	10.2	21.0
Missing	0-9	0.7	3.0	0.8	1.4
Parity (%)					
0	30-43	34.4	35.2	35.0	34.7
1-3	31-64	42.9	53.8	39.5	45.9
4 or more	5-37	22.5	10.9	25.1	19.1
Missing	0- 2	0.2	0.1	0.4	0.2
Number of previous caesarean sections (%)					
0	60-89	76.3	66.9	78.3	73.5
1	6-31	17.9	22.4	14.8	18.9
2-4	2-13	4.9	9.8	5.8	6.6
Missing	0- 4	0.9	1.0	1.2	1.0
Number of antenatal visits (%)					
0	0-6	0.9	0.4	1.3	0.8
1-3	19-74	36.5	36.4	40.0	37.0
4 or more	21-71	53.5	58.1	52.0	54.8
Missing	1-24	9.1	5.1	6.6	7.4
Multiple pregnancy (%)					
Yes	2-10	5.8	6.1	5.8	5.9
Congenital malformation (%)					
No	30-100	91.3	92.7	89.1	91.4
Yes	0-4	1.2	0.4	0.6	0.9
Missing	0-69	7.5	6.9	10.2	7.7
Birthweight (%)					
Birthweight \geq 2,500g	65-95	77.8	80.6	81.8	79.3
Birthweight $<$ 2,500g	2-29	17.2	13.2	11.9	15.1
Missing	1-16	5.1	6.2	6.3	5.6
Referral for antepartum complications or during labour (%)					
Yes	26-89	74.7	50.7	73.7	66.8
Distance from referring facility (%)					
$<$ 20km	0-85	18.7	47.4	23.4	26.6
20-450km	0-86	48.7	11.8	69.6	43.1

Distance unknown	0-99	32.6	40.8	6.9	30.3
Caesarean during labour (%)					
No	2-49	15	34.1	8.1	20.1
Yes	51-98	85	65.9	91.9	79.9
Recorded indication for caesarean (%)					
Fetal distress	7-36	24.5	17.0	23.3	21.9
Prolonged labour	23-67	33.1	28.6	42.1	33.0
Previous caesarean	7-33	12.1	24.3	12.8	16.2
Pre-eclampsia	0- 8	4.2	4.1	1.7	3.8
Other	15-37	26.1	26	20.2	25.1
Diagnosis of acute fetal distress (%)	12-43	32.3	22.8	28.5	28.6
Transverse lie/brow presentation in active labour (%)	1-11	4.8	2.6	5.0	4.1
Other severe obstetric complication or maternal death (%)	6-38	22.6	14.3	19.6	19.5
<i>Severe pre-eclampsia/eclampsia</i>	2-13	6.4	6.1	3.2	5.8
<i>Retro-placental haematoma</i>	0- 5	2.8	1.5	1.4	2.2
<i>Placenta praevia in active labour</i>	0- 5	2	0.7	0.9	1.4
<i>Uterine (pre)-rupture</i>	2-24	12.3	6.4	15.0	10.8
<i>Maternal mortality (per 100,000)</i>	0-637	297	241	255	0.3

^aIn two largest cities (Ouagadougou and Bobo-Dioulasso)

Hospital variation in caesarean care received

Caesarean care differed between hospitals (Table 3). Differences in provider cadre were notable, with obstetricians deciding and performing 100% of caesareans in some hospitals, and non-physician providers deciding and performing over 90% of caesareans in others. Rural district hospitals relied primarily on generalist doctors and non-physician providers, while urban district hospitals relied primarily on obstetricians.

Hospitals reported up to 54% of caesareans performed more than one hour after decision. Almost 90% of all caesareans were performed under spinal anaesthesia, however in some hospitals 70% of caesareans were performed under general anaesthesia (with higher percentages of general anaesthesia in regional hospitals). Incision technique also showed important variation between hospitals (less so between hospital type). Antibiotic use was almost universal, recorded in 96% of women, but administered after skin incision in at least 41% of caesareans (62% estimated with imputed data, and up to 94% in individual hospitals).

Table 3. Caesarean care received by women, across BMJ hospitals and hospital types (N=5,134)

	Range across hospitals	Regional hospital	Urban district hospital	Rural district hospital	Total
N women	54-619	2,693	1,659	782	5,134
Cadre of provider deciding to perform caesarean					
Obstetrician	0-100	69.6	75.5	0.4	60.9
Generalist doctor with emergency surgical training	0-96	5.0	23.5	52.7	18.2
Generalist doctor	0-68	9.0	0.4	26.0	8.7

1	Midwife	0-100	16.1	0.4	7.5	9.7
2	Non-physician provider with surgical skills ^a	0-94	0.3	0.1	13.0	2.3
3	Missing	0-2	0.1	-	0.4	0.1
4	Cadre of provider who performed caesarean					
5	Obstetrician	0-100	28.3	68.9	0.1	37.1
6	Generalist doctor	0-88	13.0	11.8	44.6	17.4
7	Non-physician provider with obstetrics skills ^b	0-65	8.0	0.2	0.6	4.4
8	Non-physician provider with surgical skills ^a	0-94	48.3	18.9	54.2	39.7
9	Missing	0-8	2.4	0.2	0.4	1.4
10	Woman informed of decision to perform caesarean					
11	No	0-7	1.9	1.7	1.2	1.7
12	Yes	4-100	96.1	89.9	81.3	91.9
13	Missing	0-96	1.9	8.4	17.5	6.4
14	Decision-to-incision interval					
15	<60 minutes	3-84	64.1	61.2	31.6	60.3
16	≥60 minutes	1-54	18.7	11.4	17.0	16.1
17	Missing	3-97	13.2	27.4	51.4	23.6
18	Type of anaesthesia					
19	Spinal	30-100	83.8	91	94.5	87.7
20	General/other	0-70	16.0	7.7	4.2	11.5
21	Missing	0-4	0.3	1.3	1.3	0.8
22	Type of skin incision					
23	Joel-Cohen	9-100	79.6	83.1	77.5	80.4
24	Pfannenstiel	0-84	16.8	12.1	9.7	14.2
25	Midline/other	0-11	2.8	1.1	0.9	1.9
26	Missing	0-39	0.8	3.7	11.9	3.4
27	Type of uterine incision					
28	Lower segment	45-100	94.7	98.3	94.8	95.9
29	Other	0-55	5.2	0.6	1.3	3.1
30	Missing	0-12	0.1	1.1	4.0	1.0
31	Antibiotic administration					
32	Antibiotics before incision	0-87	32.5	26.6	15.0	27.9
33	Antibiotics after incision	0-94	49.1	39.0	45.7	45.3
34	Antibiotics, timing unclear	2-95	12.6	32.9	35.2	22.6
35	No recorded antibiotics	0-10	2.0	0.5	0.4	1.3
36	Missing	0-22	3.9	0.9	3.8	2.9

^aNurses or midwives with additional 3-year training in surgery; ^bMidwives with additional 3-year training in obstetrics and gynaecology, including performing caesareans

Risk factors for intrapartum-related mortality and risk-adjusted hospital mortality rates

The median OR for crude intrapartum-related mortality was 1.9 [95% CI: 1.5-2.5], indicating that if a woman moved to another, randomly selected, hospital with higher mortality, the median increase in her odds of intrapartum-related mortality would be almost two-fold.

In model 1, congenital malformation, diagnosis of acute fetal distress, transverse lie or brow presentation in active labour, and other severe obstetric complication or maternal death were strongly associated with intrapartum-related mortality (Supplementary Table 4). Other risk factors retained in the model were parity, education, number of antenatal visits, primary caesarean indication, referral immediately prior to caesarean, and birthweight. The median OR was 1.3 [1.2-1.7], indicating that a

1 woman moving to a different hospital with higher mortality would experience a 1.3-fold increase in
2 odds of intrapartum-related mortality on average, a modest effect compared with individual-level
3 clinical risk factors. Inter-hospital variation in mortality rates was reduced, but not eliminated, after
4 adjusting for individual-level risk factors, with larger variation among hospitals performing fewer
5 caesareans per month (below 50 caesareans per month; List of figures
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12 Figure 1B).

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14 In model 2, all clinical risk factors except for number of antenatal visits were retained in the model
15 with similar effect sizes, and two care component risk factors were identified – general anaesthesia,
16 and not receiving antibiotic prophylaxis (Figure 2, Supplementary Table 4). Decision-to-incision
17 interval was not associated with intrapartum-related mortality. There was no meaningful change in
18 inter-hospital variation after adding care components, compared with model 1 (median OR=1.4 [1.2-
19 1.8], List of figures
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27 Figure 1C).

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29 There was no evidence that adding trial arm improved the fit of model 2 ($p=0.78$).
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35 Discussion

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37 Our study fills an important gap in the evidence by examining hospital variation in intrapartum-related
38 perinatal mortality among caesarean births in sub-Saharan Africa, a region with a high burden of
39 perinatal deaths. Almost one in ten women giving birth by caesarean in regional and district hospitals
40 in Burkina Faso experienced an intrapartum-related perinatal death. The substantial hospital variation
41 in crude mortality rates (range: 2-19%) was markedly reduced after adjusting for individual-level
42 differences in case mix between hospitals. However, important variation remained, with lower-volume
43 hospitals tending to have higher and more variable adjusted mortality than hospitals performing more
44 caesareans per month. Additionally adjusting for caesarean care components did not further reduce
45 variation. Remaining variation in adjusted rates indicate likely differences in quality of caesarean care
46 between hospitals, particularly those with low or moderate monthly caesarean volumes.
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54 Indeed, while some of the remaining differences in risk-adjusted mortality rates between hospitals
55 may be due to unmeasured confounding by case mix (since the accuracy of obstetric complication
56 measurement using hospital records was likely limited), this is unlikely to explain all the variation in
57 adjusted mortality between lower-volume hospitals. Caesarean volume and hospital type were not
58 independently associated with intrapartum-related mortality in our study, although the number of
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1 hospitals in our analysis (n=21) was too small to detect such effects. Hospitals performing more
2 caesareans likely differ from lower-volume hospitals in multiple ways affecting quality of perinatal
3 care, including presence of obstetricians or paediatricians, resources available for care of small and
4 sick newborns, as well as differences in access to care for the population they serve.
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8 We identified two care components associated with intrapartum-related mortality: general
9 anaesthesia and not receiving antibiotic prophylaxis, both associated with a doubling of mortality
10 (compared with spinal anaesthesia and receiving antibiotics before incision). These odds ratios may
11 reflect unmeasured confounding by complication severity in the association with intrapartum-related
12 mortality, or differences in quality of care: although general anaesthesia is independently associated
13 with perinatal mortality,³³ women undergoing general anaesthesia are also likely to be in poorer
14 clinical condition at the time of the caesarean, with independently higher risk of perinatal death.
15 Antibiotics may indicate very urgent caesareans without sufficient time to administer antibiotics, or
16 poor organisation of care, with up to 10% of women not receiving antibiotics in some hospitals. It is
17 not possible to disentangle the relative contributions of unmeasured confounding and quality of care
18 for these two care components with our data, and therefore spinal anaesthesia and antibiotic
19 prophylaxis should not be recommended for the reduction of perinatal mortality on the basis of our
20 study.
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29 High rates of fresh stillbirths among caesarean births – 6.5% in our study, 6% total stillbirths in a
30 previous systematic review⁹ – indicate that many caesareans are performed too late in Burkina Faso.
31 Limited access to caesarean section contributes to these poor outcomes: a higher proportion of
32 women in sub-Saharan Africa arrive at the surgical hospital with severe complications and more
33 caesareans are performed in the second stage of labour, with higher associated complications.⁹
34 Some babies may die before arrival at the hospital, but nonetheless are delivered by caesarean; our
35 data indicate poor identification of stillbirths using the Pinard stethoscope in this setting (one third of
36 babies with no audible fetal heart rate were born alive, while one quarter of macerated stillbirths had
37 a recorded audible fetal heart rate). Other babies die *in utero* after arrival at the hospital, due to
38 delayed diagnosis of fetal distress or long waiting times between decision and caesarean – we
39 estimated a median decision-to-incision interval of 81 minutes for caesareans for fetal distress, based
40 on imputed data.
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49 To our knowledge, this is the first study to examine hospital variation in crude and risk-adjusted
50 perinatal mortality in sub-Saharan Africa. A major strength of our study was the use of a novel
51 dataset with high-quality, detailed clinical information on all women delivering by caesarean section in
52 a 6-month period in all Burkinabe regional and district hospitals with >200 caesareans per year. Our
53 21 study hospitals accounted for 45% of all caesareans performed in Burkina Faso in 2016
54 (university hospitals and lower-volume district hospitals accounted for 26% each, with only 3% in the
55 private sector).²³ However, some data limitations are worth noting. Missing data were common for
56 several risk factors. We used multiple imputation to preserve statistical power, and the distribution of
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1 imputed variables was similar to non-missing data. Moreover, like other studies using hospital
2 records, some misclassification in obstetric complication severity was likely, leading to remaining
3 unmeasured confounding in case mix between hospitals. Indeed, limited granularity was available for
4 severity (within pre-eclampsia, for example), and previous studies indicate obstetric complications
5 may be incompletely recorded or overestimated in caesarean indications.³⁴⁻³⁶ As a result, reported
6 odds ratios for risk factors should be interpreted as measures of association within our study
7 population, rather than causal effect estimates. The number of hospitals in our sample was too small
8 to enable us to examine hospital characteristics as risk factors, and we were unable to examine
9 hospital variation in maternal outcomes since post-caesarean morbidity was not collected.
10 Nonetheless, these prospectively collected trial data likely represent the best available clinical data
11 for caesarean sections in sub-Saharan Africa, and it would have been difficult to further reduce
12 complication misclassification.
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21 Several recommendations for improving the quality of caesarean care stem from our findings. Two-
22 thirds of women were referred immediately prior to the caesarean, and those referred from further
23 away had higher rates of perinatal mortality: there is a need to strengthen emergency referral
24 systems by minimising delays in women reaching surgical facilities (through shared ambulances and
25 maternity waiting homes, for example), and reducing the delay in receiving treatment after arrival,
26 including through pre-referral notification and patient referral notes.³⁷ Improved antenatal care would
27 help identify women needing an elective caesarean before labour. Monitoring of labour should be
28 improved for all women, including those with risk factors for intrapartum-related mortality, to enable
29 early intervention and prevent perinatal deaths among vaginal and caesarean births. Provider training
30 in fetal monitoring, supportive supervision, and making low-cost Doppler ultrasounds widely available
31 in hospitals would help improve identification of fetal distress and stillbirths.³⁸ Many stillbirths can be
32 delivered vaginally at lower risk of maternal complications;⁹ however, suspected stillbirths should be
33 confirmed with ultrasound scans, where available, to avoid misdiagnosis. Although the decision-to-
34 incision interval was not associated with intrapartum-related mortality in our study (likely because of
35 successful prioritisation of higher-risk women and delayed decision to perform some caesareans),
36 the estimated median 81 minute interval for caesareans for fetal distress should be reduced closer to
37 the 30 minutes recommended in the UK and USA,^{39 40} wherever possible. Lastly, improving care for
38 small and sick newborns – including newborn resuscitation and care throughout the continuum
39 through the Helping babies breathe⁴¹ programme and Every Newborn Action Plan⁴² – is essential to
40 increase survival among babies born alive.
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53 Our data also suggest sub-optimal surgical technique which may affect maternal outcomes: although
54 the Joel-Cohen incision has advantages over the Pfannenstiel technique,⁴³ the latter was used in at
55 least 14% of caesareans. An estimated 62% of women received antibiotics after incision based on
56 imputed data, contrary to WHO recommendations.⁴⁴ Universal administration of antibiotic prophylaxis
57 before incision could help reduce the incidence of surgical site infection and sepsis, which accounts
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1 for 10% of maternal deaths in sub-Saharan Africa.⁴⁵ The Lancet Global Surgery commission
2 recommendations for improving access to and the safety of essential surgical services in low-
3 resource settings should be followed,⁴⁶ first and foremost the creation of a national surgical plan
4 including provisions for healthcare delivery, human resources, financing, and information
5 management.
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10 *Conclusions*

11 Women giving birth by caesarean section in sub-Saharan Africa face a high risk of perinatal death.
12 Our study found variation in intrapartum-related perinatal mortality between hospitals remained after
13 adjustment for case mix, indicating that differences in quality of care contribute to variation in
14 perinatal mortality in Burkina Faso. Improving access to caesareans and the quality of caesarean
15 care in the region is a considerable challenge for Ministries of Health and reproductive health
16 partners; improving training and resources for fetal distress monitoring, reducing decision-to-incision
17 intervals, and improving resuscitation and care of newborns seem important priorities to enable more
18 babies to survive at birth.
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29 **Footnotes**

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31 **Author contributions:** FC conceptualised the study, with help from CR. CK and AD designed the
32 DECIDE trial and oversaw data collection. FC designed the analyses and analysed the data, with
33 support from RP, RB and AD. All authors contributed to the interpretation of results and writing of the
34 final manuscript.
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46

47 **Competing interests:** none declared.
48

49 **Data sharing statement:** No data are available. Reasonable requests may be directed to Dr Charles
50 Kaboré (kaborewendyam@yahoo.fr).
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Figure 2. Odds ratios and 95% confidence intervals for risk factors for intrapartum-related mortality among women giving birth by caesarean section in 21 hospitals (model 2) – Burkina Faso, 2016

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References

1. Montagu D, Sudhinaraset M, Diamond-Smith N, et al. Where women go to deliver: understanding the changing landscape of childbirth in Africa and Asia. *Health Policy and Planning* 2017;32(8):1146-52. doi: 10.1093/heapol/czx060
2. Gabrysch S, Nesbitt RC, Schoeps A, et al. Does facility birth reduce maternal and perinatal mortality in Brong Ahafo, Ghana? A secondary analysis using data on 119 244 pregnancies from two cluster-randomised controlled trials. *The Lancet Global Health* 2019;7(8):e1074-e87. doi: [https://doi.org/10.1016/S2214-109X\(19\)30165-2](https://doi.org/10.1016/S2214-109X(19)30165-2)
3. Kunkel M, Marete I, Cheng ER, et al. Place of delivery and perinatal mortality in Kenya. *Seminars in Perinatology* 2019;43(5):252-59. doi: <https://doi.org/10.1053/j.semperi.2019.03.014>
4. Cavallaro FL, Benova L, Dioukhane EH, et al. What the percentage of births in facilities does not measure: readiness for emergency obstetric care and referral in Senegal. *BMJ Global Health* 2020;5(3):e001915. doi: 10.1136/bmjgh-2019-001915
5. Boerma T, Ronsmans C, Melesse DY, et al. Global epidemiology of use of and disparities in caesarean sections. *The Lancet* 2018;392(10155):1341-48. doi: 10.1016/S0140-6736(18)31928-7
6. Cavallaro FL, Pembe AB, Campbell O, et al. Caesarean section provision and readiness in Tanzania: analysis of cross-sectional surveys of women and health facilities over time. *BMJ Open* 2018;8(9):e024216. doi: 10.1136/bmjopen-2018-024216
7. Benova L, Dennis ML, Lange IL, et al. Two decades of antenatal and delivery care in Uganda: a cross-sectional study using Demographic and Health Surveys. *BMC Health Services Research* 2018;18(1):758. doi: 10.1186/s12913-018-3546-3
8. Biccard BM, Madiba TE, Kluyts HL, et al. Perioperative patient outcomes in the African Surgical Outcomes Study: a 7-day prospective observational cohort study. *Lancet* 2018 doi: 10.1016/s0140-6736(18)30001-1
9. Sobhy S, Arroyo-Manzano D, Murugesu N, et al. Maternal and perinatal mortality and complications associated with caesarean section in low-income and middle-income countries: a systematic review and meta-analysis. *The Lancet* 2019;393(10184):1973-82. doi: [https://doi.org/10.1016/S0140-6736\(18\)32386-9](https://doi.org/10.1016/S0140-6736(18)32386-9)
10. Compaoré GD, Sombié I, Ganaba R, et al. Readiness of district and regional hospitals in Burkina Faso to provide caesarean section and blood transfusion services: a cross-sectional study. *BMC Pregnancy and Childbirth* 2014;14(1):158. doi: 10.1186/1471-2393-14-158
11. Richard F, Ouédraogo C, De Brouwere V. Quality cesarean delivery in Ouagadougou, Burkina Faso: A comprehensive approach. *Int J Gynecol Obstet* 2008;103(3):283-90. doi: <http://dx.doi.org/10.1016/j.ijgo.2008.08.008>
12. Nyamtema A, Mwakatundu N, Dominico S, et al. Increasing the availability and quality of caesarean section in Tanzania. *Bjog* 2016;123(10):1676-82. doi: 10.1111/1471-0528.14223
13. Kasongo S, Mukuku O, Kinenkinda X, et al. Kakoma JB. Quality of Caesarean Delivery and its Determinants in Lubumbashi, Democratic Republic of Congo. *Ann Obstet Gynecol* 2020;1:1014.
14. Bishop D, Dyer RA, Maswime S, et al. Maternal and neonatal outcomes after caesarean delivery in the African Surgical Outcomes Study: a 7-day prospective observational cohort study. *The Lancet Global Health* 2019;7(4):e513-e22. doi: 10.1016/S2214-109X(19)30036-1
15. Bragg F, Cromwell DA, Edozien LC, et al. Variation in rates of caesarean section among English NHS trusts after accounting for maternal and clinical risk: cross sectional study. *BMJ* 2010;341:c5065. doi: 10.1136/bmj.c5065
16. Schemann K, Patterson JA, Nippita TA, et al. Variation in hospital caesarean section rates for women with at least one previous caesarean section: a population based cohort study. *BMC Pregnancy and Childbirth* 2015;15(1):179. doi: 10.1186/s12884-015-0609-x
17. Bailit JL, Love TE, Dawson NV. Quality of obstetric care and risk-adjusted primary cesarean delivery rates. *Am J Obstet Gynecol* 2006;194(2):402-7. doi: 10.1016/j.ajog.2005.07.045
18. Kabore C, Ridde V, Kouanda S, et al. DECIDE: a cluster randomized controlled trial to reduce non-medically indicated caesareans in Burkina Faso. *BMC Pregnancy Childbirth* 2016;16(1):322. doi: 10.1186/s12884-016-1112-8
19. Global Health Observatory. Births by caesarean section - Data by country. 2018 [Available: <http://apps.who.int/gho/data/view.main.BIRTHSBYCAESAREANv> accessed December 2019]
20. Institut National de la Statistique et de la Démographie (INSD) and ICF International. Enquête Démographique et de Santé et à Indicateurs Multiples du Burkina Faso 2010. Calverton, Maryland, USA: ISND and ICF International; 2012 [Available: <https://dhsprogram.com/pubs/pdf/FR256/FR256.pdf> accessed December 2019]
21. Boatin AA, Schlottheuber A, Betran AP, et al. Within country inequalities in caesarean section rates: observational study of 72 low and middle income countries. *BMJ* 2018;360:k55. doi: 10.1136/bmj.k55
22. INSD. Enquête multisectorielle continue (EMC) 2014 - Santé générale et santé de la reproduction. Institut national de la statistique et de la démographie [Burkina Faso]; 2015 [Available:

- 1 http://www.insd.bf/n/contenu/enquetes_recensements/Enq EMC/Sante_generale_et_Sante_de_la_r%e9production.pdf accessed October 2019]
- 2
- 3 23. Ministère de la Santé du Burkina Faso. Annuaire Statistique 2016, 2017.
- 4 24. Goldenberg RL, McClure EM, Kamath BD. Intrapartum perinatal mortality. *Indian pediatrics* 2012;49(3):187-88. doi: 10.1007/s13312-012-0050-4
- 5
- 6 25. MEASURE Evaluation. Intrapartum and very early neonatal death rate. [Available: https://www.measureevaluation.org/prh/rh_indicators/womens-health/nb/intrapartum-and-very-early-neonatal-death-rate accessed March 2020]
- 7
- 8 26. WHO, UNFPA, UNICEF, et al. Monitoring emergency obstetric care: a handbook. Geneva, Switzerland: World Health Organisation. 2009 [Available: <https://www.who.int/reproductivehealth/publications/monitoring/9789241547734/en/> accessed November 2019]
- 9
- 10 27. Sterne JAC, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ* 2009;338:b2393. doi: 10.1136/bmj.b2393
- 11
- 12 28. Sanagou M, Wolfe R, Forbes A, et al. Hospital-level associations with 30-day patient mortality after cardiac surgery: a tutorial on the application and interpretation of marginal and multilevel logistic regression. *BMC Medical Research Methodology* 2012;12(1):28. doi: 10.1186/1471-2288-12-28
- 13
- 14 29. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health: integrating random and fixed effects in multilevel logistic regression. *Am J Epidemiol* 2005;161(1):81-8. doi: 10.1093/aje/kwi017
- 15
- 16 30. Larsen K, Petersen JH, Budtz-Jørgensen E, et al. Interpreting parameters in the logistic regression model with random effects. *Biometrics* 2000;56(3):909-14. doi: 10.1111/j.0006-341x.2000.00909.x
- 17
- 18 31. Bartlett JW, Hughes RA. Bootstrap inference for multiple imputation under uncongeniality and misspecification. *Statistical Methods in Medical Research* 2020;29(12):3533-46. doi: 10.1177/0962280220932189
- 19
- 20 32. Kaboré C, Ridde V, Chaillet N, et al. DECIDE: a cluster-randomized controlled trial to reduce unnecessary caesarean deliveries in Burkina Faso. *BMC Medicine* 2019;17(1):87. doi: 10.1186/s12916-019-1320-y
- 21
- 22 33. Fenton PM, Whitty CJM, Reynolds F. Caesarean section in Malawi: prospective study of early maternal and perinatal mortality. *BMJ* 2003;327(7415):587. doi: 10.1136/bmj.327.7415.587
- 23
- 24 34. Kabore C, Ridde V, Kouanda S, et al. Determinants of non-medically indicated cesarean deliveries in Burkina Faso. *Int J Gynaecol Obstet* 2016;135 Suppl 1:S58-s63. doi: 10.1016/j.ijgo.2016.08.019
- 25
- 26 35. Landry E, Pett C, Fiorentino R, et al. 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.
- 27
- 28 36. Cavallaro FL, Hurt LS, Cresswell JA, et al. 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. *Birth* 2019;46(4):638-47. doi: <https://doi.org/10.1111/birt.12452>
- 29
- 30 37. Pittalis C, Brugha R, Gajewski J. Surgical referral systems in low- and middle-income countries: A review of the evidence. *PLOS ONE* 2019;14(9):e0223328. doi: 10.1371/journal.pone.0223328
- 31
- 32 38. Byaruhanga R, Bassani DG, Jagau A, et al. Use of wind-up fetal Doppler versus Pinard for fetal heart rate intermittent monitoring in labour: a randomised clinical trial. *BMJ Open* 2015;5(1):e006867. doi: 10.1136/bmjopen-2014-006867
- 33
- 34 39. RCOG. Classification of urgency of caesarean section - a continuum of risk. Royal College of Obstetricians and Gynaecologists, Royal College of Anaesthetists; 2010 [Available: <https://www.rcog.org.uk/globalassets/documents/guidelines/goodpractice11classificationofurgency.pdf> accessed November 2019]
- 35
- 36 40. ACOG. Standards for Obstetric Services. Sixth ed. In: The College, ed. Washington, DC, 1988.
- 37
- 38 41. Versantvoort JMD, Kleinhout MY, Ockhuijsen HDL, et al. Helping Babies Breathe and its effects on intrapartum-related stillbirths and neonatal mortality in low-resource settings: a systematic review. *Archives of Disease in Childhood* 2020;105(2):127-33. doi: 10.1136/archdischild-2018-316319
- 39
- 40 42. WHO, UNICEF. Every Newborn: an action plan to end preventable deaths. Geneva: World Health Organization; 2014 [Available: https://www.healthynewbornnetwork.org/hnn-content/uploads/Every_Newborn_Action_Plan-ENGLISH_updated_July2014.pdf accessed May 2021]
- 41
- 42 43. Mathai M, Hofmeyr GJ, Mathai NE. Abdominal surgical incisions for caesarean section. *Cochrane Database Syst Rev* 2013(5):Cd004453. doi: 10.1002/14651858.CD004453.pub3
- 43
- 44 44. WHO. WHO recommendations for prevention and treatment of maternal peripartum infections. Geneva: World Health Organization; 2015 [Available: https://apps.who.int/iris/bitstream/handle/10665/186171/9789241549363_eng.pdf?sequence=1 accessed June 2019]
- 45
- 46 45. Seale AC, Mwaniki M, Newton CRJC, et al. Maternal and early onset neonatal bacterial sepsis: burden and strategies for prevention in sub-Saharan Africa. *The Lancet Infectious Diseases* 2009;9(7):428-38. doi: [https://doi.org/10.1016/S1473-3099\(09\)70172-0](https://doi.org/10.1016/S1473-3099(09)70172-0)
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47
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49
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51
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46. Meara JG, Leather AJM, Hagander L, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *The Lancet* 2015;386(9993):569-624. doi: 10.1016/S0140-6736(15)60160-X

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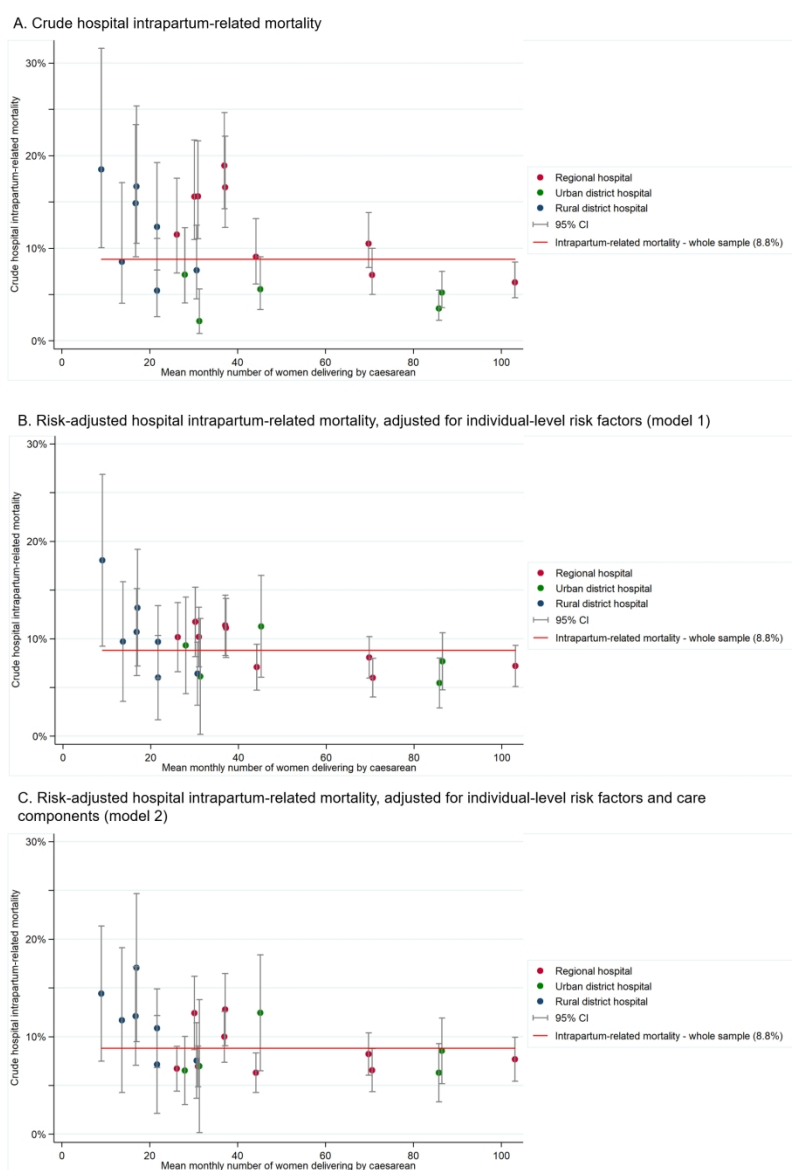


Figure 1. Crude and risk-adjusted hospital intrapartum-related mortality rates among women giving birth by caesarean section in 21 hospitals, according to mean monthly number of caesareans – Burkina Faso, 2016

Note: no hospital characteristics were independently associated with intrapartum-related perinatal mortality

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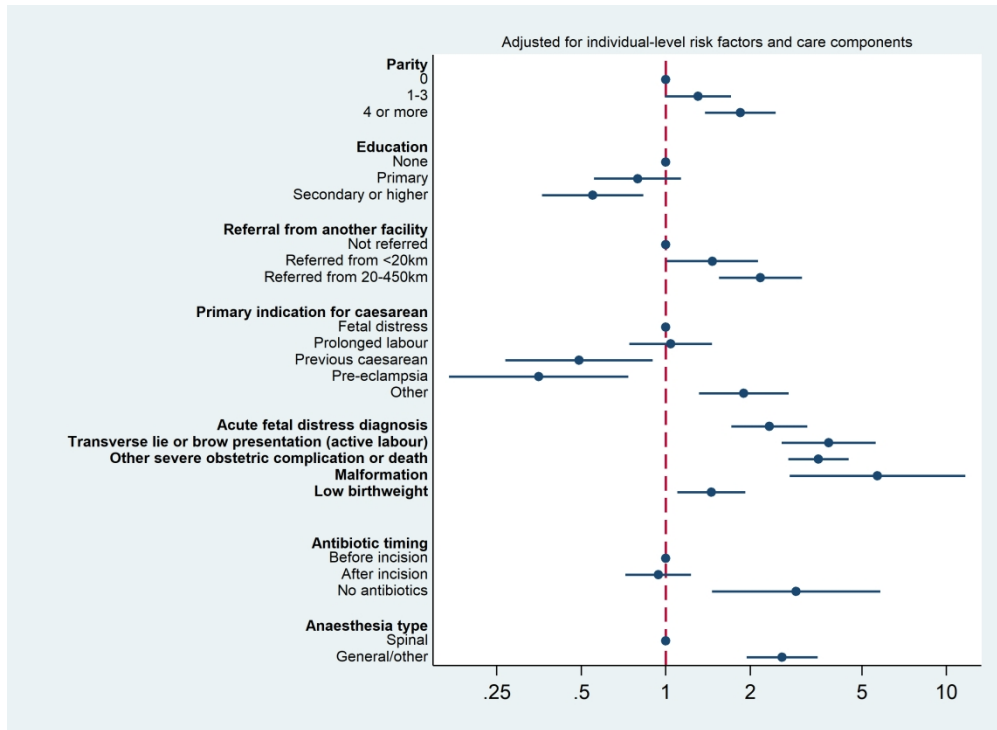


Figure 2. Odds ratios and 95% confidence intervals for risk factors for intrapartum-related mortality among women giving birth by caesarean section in 21 hospitals (model 2) – Burkina Faso, 2016

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Supplementary materials

Supplementary Figure 1. Odds ratios and 95% confidence intervals for individual-level predictors of intrapartum-related mortality (model 1)

$$\text{median OR} = \exp[\sqrt{2 \times \tau^2 \times 0.6745}]$$

where τ^2 is the hospital-level variance.

Supplementary Table 1. Missing data for risk factors for intrapartum-related perinatal mortality among 5,134 women in sample

Variable	N total expected	N missing	% missing (whole sample)	% missing (sub-sample)
Risk factors for which all women are expected to have data				
Maternal age	5,134	102	2.0	-
Parity	5,134	10	0.2	-
Education	5,134	74	1.4	-
Previous caesarean	5,134	0	0	-
Number of antenatal visits	5,134	382	7.4	-
Multiple pregnancy	5,134	0	0	-
Malformation	5,134	396	7.7	-
Birthweight	5,134	253	4.9	-
Acute fetal distress diagnosis	5,134	496	9.7	-
Transverse lie or brow presentation	5,134	0	0	-
Other severe obstetric complication or maternal death	5,134	0	0	-
Neonatal resuscitation	5,134	242	4.7	-
Labour phase	5,134	0	0	-
Referral status	5,134	0	0	-
Primary indication for caesarean	5,134	0	0	-
Provider deciding to perform caesarean	5,134	7	0.1	-
Provider performing caesarean	5,134	71	1.4	-
Decision-incision interval	5,134	1212	23.6	-
Anaesthesia type	5,134	39	0.8	-
Skin incision type	5,134	176	3.4	-
Antibiotic prophylaxis administration	5,134	149	2.9	-
Hospital type	5,134	0	0	-
Monthly caesarean volume	5,134	0	0	-
Risk factors for which a subset of women are expected to have data				
Birthweight for second baby among multiple pregnancies	301	91	1.8	30.2
Referral distance among referred women	3,429	1039	20.2	30.3
Timing of antibiotic administration among women receiving antibiotic prophylaxis	4,918	1159	22.6	23.6
Variable used in the imputation model but not in the risk factor analysis				
Gestational age at birth	5,134	2808	54.7	-

Supplementary Table 2. Characteristics of women with missing data on predictors among 5,134 women in sample

Predictor	N	Missing data for 0 predictors (row %)	Missing data for 1-3 predictors (row %)	Missing data for 4 or more predictors (row %)
Maternal age				
13-19	883	31	65	4
20-29	2,376	33	63	4
30-39	1,612	33	63	4
40-49	161	26	70	4
Missing	102	0	90	10
Parity				
0	1,784	33	64	4
1-3	2,358	32	64	4
4 or more	982	29	67	4
Missing	10	0	70	30
Education				
None	3,256	31	65	4
Primary	724	29	66	4
Secondary or higher	1,080	38	60	2
Missing	74	0	88	12
Previous caesarean				
No	3,776	31	65	4
Yes	1,308	33	64	3
Missing	50	24	54	22
Number of antenatal care visits				
0	42	19	76	5
1-3	1,899	32	65	3
4 or more	2,811	36	61	3
Missing	382	0	87	13
Multiple pregnancy				
No	4,833	32	64	4
Yes	301	20	71	9
Congenital malformation				
No	4,694	35	64	2
Yes	44	14	77	9
Missing	396	0	73	27
Gestational age at birth				
Preterm	286	26	69	6
Term	2,040	36	61	3
Missing	2,715	30	66	4
Birthweight				
Birthweight \geq 2,500g	4,071	35	63	2
Birthweight $<$ 2,500g	775	28	68	3
Missing	288	0	72	28
Acute fetal distress				
No	3,168	34	64	2
Yes	1,470	37	61	2
Missing	496	0	81	19
Transverse lie or brow presentation in active labour				
No	4,922	32	65	4

1	Yes	212	29	63	8
2	Other severe obstetric complication or maternal				
3	death				
4	No	4,125	32	64	3
5	Yes	1,009	29	66	5
6	Neonatal resuscitation				
7	No	4,273	34	63	2
8	Yes	619	27	70	3
9	Missing	242	0	70	30
10	Labour phase				
11	Pre-labour	1,031	29	67	4
12	Latent phase	1,577	36	61	3
13	Active phase	2,526	30	66	4
14	Referral status				
15	Not referred before caesarean	1,705	39	58	3
16	Referred before caesarean	3,429	28	68	4
17	Referral distance				
18	<20km	911	43	55	3
19	20-450km	1,479	39	58	4
20	Distance unknown	1,039	0	94	6
21	Primary indication for caesarean				
22	Fetal distress	1,125	36	61	3
23	Prolonged labour	1,695	31	66	4
24	Previous caesarean	830	30	66	3
25	Pre-eclampsia	193	28	67	5
26	Other	1,291	31	64	5
27	Provider cadre deciding to perform caesarean				
28	Obstetrician	3,129	37	60	3
29	Generalist doctor with emergency surgical				
30	training	936	27	68	4
31	Generalist doctor	446	21	74	5
32	Midwife	500	24	73	3
33	Non-physician provider with surgical skills	116	7	86	7
34	Missing	7	0	71	29
35	Provider cadre performing caesarean				
36	Obstetrician	1,905	32	63	5
37	Generalist doctor	895	28	67	5
38	Non-physician provider with obstetrics skills	224	18	81	0
39	Non-physician provider with surgical skills	2,039	36	62	3
40	Missing	71	0	92	8
41	Decision-to-incision interval				
42	<60min	878	36	61	2
43	≥60min	3,044	43	56	1
44	Missing	1,212	0	89	11
45	Anaesthesia type				
46	Spinal	4,505	32	64	3
47	General/other	590	29	66	5
48	Missing	39	0	46	54
49	Skin incision type				
50	Joel-Cohen	4,128	34	63	3
51	Pfannenstiel	730	27	70	4
52	Midline/other	100	25	72	3
53	Missing	176	0	78	22
54	Uterine incision type				
55					
56					
57					
58					
59					
60					

Lower segment	4,921	33	64	3
Other	161	11	86	2
Missing	52	0	60	40
Antibiotic prophylaxis administration				
Antibiotics before incision	1,434	43	56	1
Antibiotics after incision	2,325	43	56	1
Antibiotics, timing unclear	1,159	0	90	10
No recorded antibiotics	67	24	75	1
Missing	149	0	74	26
Hospital type				
Regional hospital	2,693	39	58	2
Urban district hospital	1,659	26	70	4
Rural district hospital	782	18	75	7
Mean monthly caesarean volume				
<30	923	25	70	4
30-60	1,717	20	74	5
60-105	2,494	42	56	2

Supplementary Table 3. Maternal and perinatal outcomes among women giving birth by caesarean section in 21 hospitals – Burkina Faso, 2016

	N women	Perinatal outcomes						
		Macerated stillbirths (%)	Fresh stillbirths (%)	Apgar score <3, live birth (%)	Neonatal death within 24 hrs of birth (%)	Neonatal death after 24 hrs, before discharge (%)	Intrapartum-related perinatal death (%)	Total perinatal death before discharge (%)
Total	5,134	0.7 [0.5-0.9]	6.5 [5.8-7.2]	2.4 [2.0-2.9]	2.3 [2.0-2.8]	0.3 [0.2-0.5]	8.8 [8.1-9.6]	9.8 [9.0-10.7]
Range across hospitals	5,134	0-2.25	1.6-13.5	0-9.0	0-9.0	0-3.2	2.1-18.6	3.2-24.3
Facility type								
Regional hospital	2,693	0.9 [0.6-1.4]	7.8 [6.8-8.9]	3.2 [2.6-3.9]	3.0 [2.4-3.7]	0.4 [0.2-0.7]	10.8 [9.7-12.0]	12.1 [10.9-13.4]
Urban district hospital	1,659	0.3 [0.1-0.7]	3.6 [2.8-4.6]	0.9 [0.5-1.5]	1.0 [0.6-1.6]	0.2 [0.1-0.6]	4.6 [3.7-5.7]	5.1 [4.2-6.3]
Rural district hospital	782	0.5 [0.2-1.4]	8.1 [6.3-10.2]	3.1 [2.1-4.5]	2.9 [2.0-4.4]	0.4 [0.1-1.2]	11.0 [9.0-13.4]	11.9 [9.8-14.4]
P-value	-	0.08	<0.001	0.029	0.016	0.793	0.001	0.001

Supplementary table 4. Predictors of intrapartum-related deaths among 5,134 women giving birth by caesarean section in 21 hospitals – Burkina Faso, 2016

Predictor	Unadjusted OR (95% CI)	Model 1 ^a (95% CI)	Model 2 ^b (95% CI)
Individual-level predictors			
Maternal age			
13-19	1 [ref]	-	-
20-29	1.31 (0.98-1.76)	-	-
30-39	1.56 (1.15-2.10)	-	-
40-54	2.09 (1.21-3.58)	-	-
Parity			
0	1 [ref]	1 [ref]	1 [ref]
1-3	1.15 (0.90-1.47)	0.80 (0.56-1.13)	1.30 (0.99-1.71)
4 or more	2.46 (1.91-3.18)	0.52 (0.34-0.78)	1.84 (1.38-2.46)
Education			
None	1 [ref]	1 [ref]	1 [ref]
Primary	0.64 (0.46-0.89)	0.89 (0.61-1.31)	0.79 (0.56-1.13)
Secondary or higher	0.31 (0.21-0.46)	0.53 (0.34-0.85)	0.55 (0.36-0.83)
Number of previous caesareans			
0	1 [ref]	-	-
1 or more	0.39 (0.29-0.52)	-	-
Number of ANC visits			
0	1 [ref]	1 [ref]	-
1-3	0.58 (0.24-1.36)	0.54 (0.19-1.48)	-
4 or more	0.35 (0.15-0.81)	0.43 (0.16-1.18)	-
Multiple pregnancy			
No	1 [ref]	-	-
Yes	1.43 (0.99-2.07)	-	-
Malformation			
No	1 [ref]	1 [ref]	1 [ref]
Yes	7.15 (3.75-13.64)	6.01 (2.95-12.23)	5.67 (2.79-11.55)
Birthweight			
Birthweight ≥2,500g	1 [ref]	1 [ref]	1 [ref]
Birthweight <2,500g	1.77 (1.39-2.25)	1.50 (1.14-1.97)	1.45 (1.10-1.92)
Diagnosis of acute fetal distress			
No	1 [ref]	1 [ref]	1 [ref]
Yes	2.26 (1.79-2.86)	2.42 (1.80-3.26)	2.34 (1.72-3.17)
Transverse lie or brow presentation in active labour			
No	1 [ref]	1 [ref]	1 [ref]
Yes	3.69 (2.65-5.13)	3.56 (2.43-5.22)	3.81 (2.59-5.59)
Other severe obstetric complication or maternal death			
No	1 [ref]	1 [ref]	1 [ref]
Yes	3.49 (2.84-4.29)	3.88 (3.04-4.95)	3.50 (2.73-4.49)
Labour phase			
Pre-labour	1 [ref]	-	-
Latent phase	1.20 (0.84-1.71)	-	-
Active phase	2.12 (1.53-2.92)	-	-

1	Referral status			
2				
3	Not referred	1 [ref]	1 [ref]	1 [ref]
4	Referred from <20km	2.17 (1.51-3.11)	1.52 (1.04-2.21)	1.46 (1.01-2.13)
5	Referred from 20-450km	4.24 (3.10-5.80)	2.17 (1.55-3.04)	2.18 (1.55-3.06)
6				
7	Decision-to-delivery interval			
8	<60 minutes	1 [ref]	-	-
9	≥60 minutes	0.85 (0.65-1.11)	-	-
10				
11	Primary indication for caesarean			
12	Fetal distress	1 [ref]	1 [ref]	1 [ref]
13	Prolonged labour	1.10 (0.85-1.43)	1.14 (0.81-1.59)	1.04 (0.74-1.46)
14	Previous caesarean	0.23 (0.13-0.39)	0.51 (0.28-0.92)	0.49 (0.27-0.90)
15	Pre-eclampsia	0.59 (0.31-1.13)	0.38 (0.19-0.80)	0.35 (0.17-0.74)
16	Other	1.37 (1.04-1.80)	2.08 (1.44-3.00)	1.90 (1.31-2.74)
17				
18	Provider cadre deciding the caesarean			
19	Obstetrician	1 [ref]		-
20	Generalist doctor with emergency surgical training	1.20 (0.84-1.73)		-
21	Generalist doctor	1.20 (0.73-1.96)		-
22	Midwife	1.78 (1.07-2.96)		-
23	Non-physician provider with surgical skills ^c	1.87 (0.82-4.28)		-
24				
25	Provider cadre performing the caesarean			
26	Obstetrician	1 [ref]		-
27	Generalist doctor	0.94 (0.62-1.44)		-
28	Non-physician provider with obstetrics skills ^d	1.47 (0.81-2.68)		-
29	Non-physician provider with surgical skills ^c	1.01 (0.68-1.49)		-
30				
31	Type of anaesthesia			
32	Spinal	1 [ref]		1 [ref]
33	General/other	4.46 (3.41-5.84)		2.60 (1.94-3.47)
34				
35	Type of skin incision			
36	Joel-Cohen	1 [ref]		-
37	Other	0.89 (0.62-1.28)		-
38				
39	Type of uterine incision			
40	Lower segment	1 [ref]		-
41	Other	1.23 (0.69-2.19)		-
42				
43	Antibiotics administration			
44	Antibiotics before incision	1 [ref]		1 [ref]
45	Antibiotics after incision	0.99 (0.74-1.31)		0.94 (0.72-1.23)
46	No recorded antibiotics	2.31 (1.25-4.25)		2.91 (1.46-5.81)
47				
48	Neonatal resuscitation			
49	No	1 [ref]		-
50	Yes	1.71 (1.31-2.24)		-
51				
52	Facility type			
53	Regional hospital	1 [ref]		-
54	Urban district hospital	0.36 (0.23-0.58)		-
55	Rural district hospital	0.96 (0.62-1.47)		-
56				
57	Facility caesarean volume (per month)			
58	<30	1 [ref]		-

30-60	0.93 (0.55-1.57)	-
60-105	0.53 (0.30-0.94)	-

^aModel 1 was built by manual backward elimination of individual-level predictors with $p > 0.1$ in a model including all variables with $p < 0.25$ in the unadjusted model, with the exception of maternal age which had $p < 0.25$ in the unadjusted model but was removed due to collinearity with parity

^bModel 2 was built by adding all care components and hospital characteristics with $p < 0.25$ to model 1, followed by manual backward selection until all remaining variables had $p < 0.1$

^cNurses or midwives with additional 3-year training in surgery

^dMidwives with additional 3-year training in obstetrics and gynaecology, including performing caesareans

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Reporting checklist for cross sectional study.

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			Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	#3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	#4	Present key elements of study design early in the paper	4
Setting	#5	Describe the setting, locations, and relevant dates, including periods of	4

		recruitment, exposure, follow-up, and data collection	
1			
2			
3	Eligibility criteria	#6a Give the eligibility criteria, and the sources and methods of selection of participants.	4
4			
5			
6		#7 Clearly define all outcomes, exposures, predictors, potential	5
7		confounders, and effect modifiers. Give diagnostic criteria, if applicable	
8			
9			
10	Data sources /	#8 For each variable of interest give sources of data and details of methods	4-5
11	measurement	of assessment (measurement). Describe comparability of assessment	
12		methods if there is more than one group. Give information separately	
13		for for exposed and unexposed groups if applicable.	
14			
15			
16			
17	Bias	#9 Describe any efforts to address potential sources of bias	5-6
18			
19	Study size	#10 Explain how the study size was arrived at	4
20			
21	Quantitative	#11 Explain how quantitative variables were handled in the analyses. If	5-7
22	variables	applicable, describe which groupings were chosen, and why	
23			
24			
25	Statistical	#12a Describe all statistical methods, including those used to control for	5-7
26	methods	confounding	
27			
28			
29	Statistical	#12b Describe any methods used to examine subgroups and interactions	N/A
30	methods		
31			
32			
33	Statistical	#12c Explain how missing data were addressed	5-6
34	methods		
35			
36			
37	Statistical	#12d If applicable, describe analytical methods taking account of sampling	6-7
38	methods	strategy	
39			
40			
41	Statistical	#12e Describe any sensitivity analyses	N/A
42	methods		
43			
44	Results		
45			
46			
47	Participants	#13a Report numbers of individuals at each stage of study—eg numbers	7
48		potentially eligible, examined for eligibility, confirmed eligible,	
49		included in the study, completing follow-up, and analysed. Give	
50		information separately for for exposed and unexposed groups if	
51		applicable.	
52			
53			
54			
55	Participants	#13b Give reasons for non-participation at each stage	N/A
56			
57	Participants	#13c Consider use of a flow diagram	N/A
58			
59			
60			

1	Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	9-10
2				
3				
4				
5				
6	Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	7, 9-10
7				
8				
9				
10	Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	7-8
11				
12				
13				
14	Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7, 11-12
15				
16				
17				
18				
19	Main results	#16b	Report category boundaries when continuous variables were categorized	7-12
20				
21	Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
22				
23				
24				
25	Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	12
26				
27				
28				
29	Discussion			
30				
31	Key results	#18	Summarise key results with reference to study objectives	12
32				
33				
34	Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	13-14
35				
36				
37				
38				
39	Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	12-13
40				
41				
42				
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44	Generalisability	#21	Discuss the generalisability (external validity) of the study results	14-15
45				
46				
47	Other			
48	Information			
49				
50				
51	Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15
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Does hospital variation in intrapartum-related perinatal mortality among caesarean births reflect differences in quality of care? Cross-sectional study in 21 hospitals in Burkina Faso

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Primary Subject Heading:	Obstetrics and gynaecology
Secondary Subject Heading:	Epidemiology
Keywords:	OBSTETRICS, PERINATOLOGY, NEONATOLOGY

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1 **Does hospital variation in intrapartum-related perinatal mortality among caesarean births**
2 **reflect differences in quality of care? Cross-sectional study in 21 hospitals in Burkina Faso**

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42 21 Word count: 4,342

Abstract

Objectives. To examine hospital variation in crude and risk-adjusted rates of intrapartum-related perinatal mortality among caesarean births

Design. Secondary analysis of data from the DECIDE cluster randomised trial post-intervention phase

Setting. 21 district and regional hospitals in Burkina Faso

Participants. All 5,134 women giving birth by caesarean section in a 6-month period in 2016

Primary outcome measure. Intrapartum-related perinatal mortality (fresh stillbirth or neonatal death within 24 hours of birth)

Results. Almost one in ten of 5,134 women giving birth by caesarean experienced an intrapartum-related perinatal death. Crude mortality rates varied substantially from 21-189 per 1,000 between hospitals. Variation was markedly reduced after adjusting for case mix differences (the median odds ratio, representing the median increase in odds of intrapartum-related mortality if a woman moved to another hospital with higher mortality, decreased from 1.9 [95% CI: 1.5-2.5] to 1.3 [1.2-1.7]). However, higher and more variable adjusted mortality persisted among hospitals performing fewer caesareans per month. Additionally adjusting for caesarean care components did not further reduce variation (median odds ratio = 1.4 [1.2-1.8]).

Conclusions. There is a high burden of intrapartum-related perinatal deaths among caesarean births in Burkina Faso, and sub-Saharan Africa more widely. Variation in adjusted mortality rates indicates likely differences in quality of caesarean care between hospitals, particularly lower-volume hospitals. Improving access to and quality of emergency obstetric and newborn care is an important priority for improving survival of babies at birth.

Keywords: caesarean section, stillbirth, perinatal mortality, hospital variation, Burkina Faso

Strengths and limitations of this study

- This is the first study to examine hospital variation in intrapartum-related perinatal mortality among women giving birth by caesarean section in a sub-Saharan African country.
- Our study benefited from inclusion of all caesarean sections performed in a six-month period in 21 regional and district hospitals in Burkina Faso.
- We used high-quality clinical data from the DECIDE cluster-randomised trial, including standardised definitions for diagnoses and indications for caesarean, although some misclassification of obstetric complication severity was likely.

- More than 20% of data were missing for three risk factors (decision-to-incision interval, timing of antibiotics, and referral distance); we used multiple imputation to avoid a loss of power.
- Our hospital sample size and limited available information prevented us from examining hospital characteristics as risk factors for perinatal mortality.

Introduction

While facility births have increased over the past few decades in sub-Saharan Africa,¹ improvements in maternal and perinatal health have been limited, raising questions about the quality of care in health facilities.¹⁻³ In particular, although facility births have increased substantially, increases in population-based caesarean section rates have been small. Persisting low caesarean rates indicate that improvements in access to emergency obstetric care have been limited.^{4 5} Globally, the slowest rise was observed in West and Central Africa, from 3.0% caesarean births in 2000 to 4.1% in 2015.⁵ The absolute number of caesareans performed has increased more rapidly due to a rise in total number of births – 3- to 5-fold in Senegal, Tanzania and Uganda over the past few decades.^{4 6 7}

Increases in caesarean births raise concerns in health systems with limited resources and capacity to provide high-quality caesarean care. Caesarean sections account for one third of all surgeries in Africa, where post-operative morbidity and mortality is higher than in other regions.⁸ A recent meta-analysis found over 1% mortality among women who deliver by caesarean in sub-Saharan Africa, 100 times higher than in the UK.⁹ Perinatal mortality is also very high in sub-Saharan Africa, with one in 10 mothers delivering by caesarean experiencing a stillbirth or early neonatal death.⁹ This high mortality is driven both by severe complications before reaching health facilities and low capacity within facilities to provide high-quality care. Indeed, low capacity to provide caesarean section care has been reported in Burkina Faso^{10 11} and elsewhere in the region.^{6 12 13}

In the context of rising caesareans, there is a need to better understand why perinatal mortality is so high among women giving birth by caesarean in sub-Saharan Africa. Limited evidence is available on inter-hospital variation in outcomes among caesarean births. Hospital type (district, regional, or national) is independently associated with perinatal mortality in some studies but not others,^{9 14} however severe restrictions in material and human resources restrict capacity to provide high-quality care in lower-level and rural facilities.^{4 6} Comparing variation in crude and risk-adjusted outcome rates between hospitals is a commonly used approach to determine whether differences between hospitals are entirely explained by heterogeneity in case mix. Any remaining variation in risk-adjusted rates suggest differences in quality of patient care.¹⁵⁻¹⁷ In this study, we examined variation in crude and adjusted rates of intrapartum-related perinatal mortality among women giving birth by caesarean in 21 district and regional hospitals in Burkina Faso for a six month period in 2016. We used high-quality data from the DECIDE trial to assess the evidence that differences in intrapartum-related mortality between individual hospitals and hospital types were driven in part by variation in quality of care.

Methods

This study is a secondary analysis of the DECIDE cluster-randomised controlled trial, which assessed the effectiveness of a multicomponent intervention including provider training, caesarean audits, and SMS reminders to reduce non-medically indicated caesarean sections. The trial included three phases: six-month pre-intervention, one-year intervention, and six-month post-intervention. It was conducted in all 22 regional and district hospitals in Burkina Faso performing more than 200 caesareans per year in 2012; university hospitals in Ouagadougou and Bobo-Dioulasso were excluded. Detailed trial methods are described elsewhere.¹⁸

Health system context

Similar to other West African countries, the caesarean rate in Burkina Faso is below 5% (3.7% in 2010-15),¹⁹ with large urban-rural, wealth and educational differentials.^{20 21} Although 85% of births take place in health facilities, 70% occur in primary care facilities without surgical capacity.²² Women who develop complications requiring a caesarean are referred to medical centres with surgical capacity (*centres médicaux avec antenne chirurgicale*, referred to as district hospitals hereafter) or regional hospitals. Women with severe complications may be referred onwards to tertiary university hospitals in the capital Ouagadougou and second largest city Bobo-Dioulasso. Most – but not all – district and regional hospitals have at least one obstetrician or generalist doctor trained in emergency obstetric care. Task-shifting of caesarean care has been supported in Burkina Faso through additional three-year training of nurses and midwives as non-physician providers with surgical skills (*attachés en chirurgie*) and obstetrics skills (*attachés en gynéco-obstétrique*). Most anaesthesia care is provided by nurses with additional training in anaesthesia. More than three quarters of study hospitals did not have Doppler ultrasounds, CTG monitors or ultrasound capacity, relying on Pinard stethoscopes for assessment of fetal wellbeing. Fetal scalp pH was only available in one hospital.¹⁸

Emergency obstetric care has been subsidised to improve access since 2006, initially with an 80% subsidy of the cost of caesareans, which were made free to women from 2016 onwards. Hospitals get reimbursed according to the number of caesareans and vaginal births; this policy absorbed around 3.5% of total health expenditure in 2011.²³ However, some costs (formal or informal) not included in the “free” package continue to be borne by households, and remain unaffordable for some.^{24 25} Women express fears around caesarean birth related primarily to poor quality of care and economic burden.²⁶

Participants

We included all 5,134 women giving birth by caesarean section in the 21 study hospitals with caesarean capacity in the post-intervention phase (2nd May-2nd November 2016). One study hospital's operating theatre was no longer functional in the post-intervention phase. These 21 hospitals accounted for 45% of all caesarean sections performed nationally in 2016.²⁷ Women

1 126 delivering by caesarean were included regardless of gestational age, whether they were referred to
2 127 the study hospital before the caesarean, or referred to another hospital after birth.

3 128 *Data source*

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7 129 Patient medical records were used in the DECIDE trial, with prospective data collection in the post-
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9 130 intervention phase using data extraction forms and standardised clinical definitions (including for
10
11 131 labour dystocia, acute fetal distress, and indications for caesarean).¹⁸ We used post-intervention data
12 132 to provide the most recent description for a larger sample.
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14 133 *Outcome*

15 134 We defined intrapartum-related perinatal mortality as the rate of fresh stillbirths and very early
16
17 135 neonatal deaths (within 24 hours of birth) per 1,000 caesareans.^{28 29} Intrapartum-related mortality is
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19
20 136 recommended by the WHO as an indicator of the quality of emergency obstetric and newborn care.³⁰
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22 137 *Risk factors and conceptual approach*

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24 138 We examined two groups of risk factors for intrapartum-related mortality: individual-level clinical risk
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26 139 factors, and caesarean care components and hospital characteristics.

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28 140 We conceptualised case mix as the hospital prevalence of clinical risk factors for intrapartum-related
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30 141 mortality (maternal age, parity, highest educational level achieved, previous caesarean, multiple
31 142 pregnancy, number of antenatal visits, birthweight, congenital malformation, referral status and
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33 143 distance, labour phase, diagnosis of acute fetal distress, transverse lie/brow presentation in active
34 144 labour, other severe obstetric complication or maternal death, and primary indication for caesarean).
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36 145 “Other severe obstetric complications” included severe pre-eclampsia or eclampsia, retro-placental
37 146 haematoma, uterine (pre-)rupture, and placenta praevia in active labour. Uterine pre-rupture was
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39 147 defined as women with severe dystocia and signs of pre-rupture, such as Bandl’s ring. Acute fetal
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41 148 distress was defined as fetal heart rate <120 or >160 bpm, either persistent after oxygen
42 149 administration and lateral decubitus position, or with IUGR, placental abruption, prolonged labour,
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44 150 maternal fever, or tinted amniotic fluid. Some women diagnosed with acute fetal distress had a
45 151 primary indication for caesarean other than “fetal distress” (e.g. pre-eclampsia), while some women
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47 152 had a caesarean with “fetal distress” recorded as the primary indication despite not having met the
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49 153 diagnostic criteria for acute fetal distress.

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51 154 We conceptualised components of caesarean care (provider cadre deciding and performing the
52 155 caesarean, decision-to-incision interval, anaesthesia type, skin/uterine incision type, and antibiotic
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54 156 prophylaxis administration) and hospital characteristics (hospital type and monthly caesarean
55
56 157 volume) as potential indicators of quality of patient care. Monthly caesarean volume was calculated
57 158 as the mean number of caesareans performed per month in the study period, per hospital.
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59 159 We used these risk factors to derive two sets of risk-adjusted mortality rates per hospital: adjusting
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160 for case mix only, and additionally adjusting for components of care and hospital characteristics,

1 161 because some of these variables might capture unmeasured differences in case mix. For example,
2 162 women receiving general anaesthesia are more likely to have complications requiring urgent surgery.
3 163 Including these additional variables also allowed us to identify whether any care components (e.g.
4 164 decision-to-incision interval) were strongly associated with mortality. We included care components
5 165 prior to delivery as risk factors even when they were not hypothesised to causally affect perinatal
6 166 mortality, since they may be proxies for quality of care.

11 12 167 *Multiple imputation of missing data among risk factors*

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14 168 Data were complete for the outcome and nine risk factors, including multiple gestation, indication for
15 169 caesarean, and referral status (Supplementary Table 1). 11 risk factors had <5% missing values; six
16 170 risk factors had >5% missing data, including decision-to-incision interval (24%) and timing of antibiotic
17 171 administration (23%). Overall, 68% of women had at least one risk factor missing, and 4% had at
18 172 least four risk factors missing (Supplementary Table 2). Missing information on previous caesarean
19 173 was assumed to indicate no previous caesarean (n=40), and missing deciding provider cadre was
20 174 imputed as the hospital mode for seven women.

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22 175 Multiple imputation by chained equations was used for other variables to avoid a loss in efficiency,
23 176 because missing values were likely to be missing at random given known risk factors, including
24 177 referral status and severe obstetric complication.³¹ Five imputed datasets were created using the mi
25 178 package in Stata v14.2, including all risk factors and intrapartum-related mortality in the imputation
26 179 model. The same model was used for all hospitals, with hospital type included as a risk factor.
27 180 Missing values for continuous risk factors (age, parity, number of antenatal care visits, referral
28 181 distance, birthweight, and decision-to-incision interval) were imputed from linear regression models,
29 182 missing values for binary risk factors (acute fetal distress, antibiotic prophylaxis, incision type,
30 183 anaesthesia type, congenital malformation, and neonatal resuscitation) were imputed from logistic
31 184 regression models, and categorical risk factors (education, provider cadre performing the caesarean,
32 185 and timing of antibiotic administration) were imputed from multinomial regression models. Gestational
33 186 age at birth had >50% missing data; it was not considered as a risk factor in the analysis model,
34 187 since it is highly correlated with low birthweight, which was more complete and likely to be more
35 188 accurate in a setting without routine ultrasound in the first trimester. However, we included
36 189 gestational age at birth in the imputation model to improve the prediction of birthweight. Distributions
37 190 of imputed values were compared with observed values for variables with >5% missing data.

38 39 191 *Hospital variation in intrapartum-related mortality rates*

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41 192 First, we calculated crude hospital intrapartum-related mortality rates with 95% confidence intervals,
42 193 and described perinatal outcomes according to hospital type. Differences in hospital case mix were
43 194 assessed by describing the prevalence of clinical risk factor for intrapartum-related mortality among
44 195 women giving birth by caesarean, stratified by hospital and hospital type. We similarly described
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1 196 differences in components of care received. Chi-square tests accounted for clustering of women by
2 197 hospital using the svyset package in Stata.

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5 198 Next, we built two multivariable models for intrapartum-related death among caesarean births using
6 multi-level logistic regression models of women, nested in hospitals to account for clustering. The first
7 199 model (model 1) adjusted for case mix only, and included all individual-level clinical risk factors for
8 200 intrapartum-related mortality with Wald test $p\text{-value} \leq 0.25$ in bivariate associations, using manual
9 201 backward selection to retain only variables with $p\text{-values} < 0.1$. The second model (model 2) built upon
10 202 model 1 by additionally including all care components and hospital characteristics with bivariate Wald
11 203 test $p\text{-value} \leq 0.25$, and similarly using backward selection to retain only $p\text{-values} < 0.1$. Multicollinearity
12 204 was examined by reviewing Spearman correlations and model standard errors. In building model 2,
13 205 provider cadre deciding the caesarean met the criteria for inclusion, however its inclusion reduced
14 206 the hospital-level estimate almost to zero, indicating that this variable acted as a proxy for broader
15 207 differences between hospitals. Further inspection showed that deciding providing cadre was highly
16 208 clustered within hospitals, with one category accounting for $>90\%$ of women in 13 of 21 hospitals. We
17 209 therefore removed it from risk factors considered for model 2.

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19 211 We calculated the median odds ratio (OR) for model 1 and 2 as a measure of inter-hospital variation
20 212 in mortality that is not explained by the model covariates, expressed on the OR scale (see formula in
21 213 Supplementary Figure 1).³² For a multi-level model, the median OR is defined as the median of the
22 214 ORs that could be calculated by comparing two patients with identical individual-level characteristics
23 215 from two, randomly chosen, different hospitals.^{33 34}

24 216 Risk-adjusted mortality enables comparisons in hospital outcomes taking into account differences in
25 217 case mix.¹⁵⁻¹⁷ Risk-adjusted intrapartum-related mortality rates were calculated for each hospital by
26 218 multiplying the intrapartum-related mortality rate across the study sample by the ratio of the number
27 219 of observed deaths to predicted deaths based on model 1 and 2 in each hospital. Bootstrapping with
28 220 1,000 iterations was used to calculate 95% confidence intervals around both sets of risk-adjusted
29 221 hospital mortality rates and found to produce stable estimates. We used the Boot MI percentile
30 222 method to produce confidence intervals with nominal coverage.³⁵

31 223 The DECIDE trial found a reduction in avoidable caesareans,³⁶ suggesting changes in caesarean
32 224 decision-making which may affect intrapartum-related mortality. As a secondary analysis, we added
33 225 trial group as a risk factor to model 2 to determine whether it was associated with mortality after
34 226 adjusting for other covariates.

35 227 *Ethics*

36 228 The DECIDE trial received ethical approval from the National Ethics Committee in Burkina Faso
37 229 (#2014-02-016) and the Ethics Committee of the University of Montreal Hospital Research Centre in
38 230 Canada (#13.356).³⁶ As a secondary analysis of de-identified data, this study did not require ethical
39 231 approval from the UCL Ethics Committee.

1 232 *Patient and public involvement*

2 233 No patients were involved in the design, conducting, reporting or dissemination of this study.

3 234 **Results**

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9 235 Our analysis included 5,134 women giving birth by caesarean in the 21 study hospitals. Women with
10 multiple pregnancies, congenital malformation, transverse lie/brow presentation in active labour,
11 236 whose caesarean was decided by a non-physician provider with surgical skills, and delivering in a
12 237 rural district hospital were more likely to have missing data for four or more risk factors
13 238 (Supplementary Table 2).

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18 240 *Hospital variation in intrapartum-related perinatal mortality among caesarean births*

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20 241 Intrapartum-related perinatal mortality was high among caesarean births at 88 per 1,000 [95% CI: 81-
21 242 96], including 65 per 1,000 fresh stillbirths and 23 per 1,000 deaths within 24 hours of birth (Table 1).
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23 243 Crude mortality rates varied substantially across hospitals, from 21 to 189 per 1,000. Intrapartum-
24 244 related mortality tended to be higher in hospitals performing fewer caesarean sections (Figure 1A).
25
26 245 Intrapartum-related mortality was higher in regional and rural district hospitals than in urban district
27 246 hospitals (110 vs 46 per 1,000, $p=0.001$). Other perinatal outcomes showed similar patterns
28 247 (Supplementary Table 3).

review only

Table 1. Perinatal mortality among women giving birth by caesarean according to hospital type – Burkina Faso, 2016

		Fresh stillbirths (per 1,000)	Neonatal death within 24 hrs of births (live babies, per 1,000)	Intrapartum-related perinatal death (per 1,000) ^a	Intrapartum-related perinatal death – range across hospitals
Total	5,134	65	23	88	21-189
Hospital type					
Regional hospital	2,693	78	30	108	63-189
Urban district hospital	1,659	36	10	46	21-71
Rural district hospital	782	81	29	110	54-185
P-value	-	<0.001	0.016	<0.001	-

^aFresh stillbirth or neonatal death within 24 hours of birth

Note: confidence intervals and additional outcomes are reported in Supplementary Table 3

Hospital variation in clinical risk factors among women giving birth by caesarean section

Case mix varied substantially across hospitals, with a range of 5%-37% for parity of four or more, 2%-29% for birthweight <2500g, and 1%-11% for transverse lie or brow presentation in active labour (Table 2). Regional hospitals and rural district hospitals had higher-risk populations of women giving birth by caesarean than urban district hospitals, with higher proportions of intrapartum caesareans, women with high parity, and referred to the study hospital immediately prior to the caesarean ($p < 0.01$ for all).

1 263 **Table 2. Characteristics of women giving birth by caesarean section, across hospitals and hospital**
 2 264 **types (N=5,134)**
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	Range across hospitals	Regional hospital	Urban district hospital ^a	Rural district hospital	Total
N facilities		9	5	7	21
Monthly caesarean volume (median)	9-103	37	45	17	31
N women giving birth by caesarean	54-619	2,693	1,659	782	5,134
Age (%)					
13-19	6-31	20.2	10.1	22	17.2
20-29	37-53	44.8	49.8	43.9	46.3
30-39	22-38	30.1	35.2	27.9	31.4
40-49	0-6	3.2	3.3	2.7	3.1
Missing	0-8	1.7	1.6	3.6	2.0
Educational level (%)					
None	33-88	73.6	41.8	74.0	63.4
Primary	1-38	7.7	24.1	15.0	14.1
Secondary or higher	3-45	17.9	31.2	10.2	21.0
Missing	0-9	0.7	3.0	0.8	1.4
Parity (%)					
0	30-43	34.4	35.2	35.0	34.7
1-3	31-64	42.9	53.8	39.5	45.9
4 or more	5-37	22.5	10.9	25.1	19.1
Missing	0- 2	0.2	0.1	0.4	0.2
Number of previous caesarean sections (%)					
0	60-89	76.3	66.9	78.3	73.5
1	6-31	17.9	22.4	14.8	18.9
2-4	2-13	4.9	9.8	5.8	6.6
Missing	0- 4	0.9	1.0	1.2	1.0
Number of antenatal visits (%)					
0	0-6	0.9	0.4	1.3	0.8
1-3	19-74	36.5	36.4	40.0	37.0
4 or more	21-71	53.5	58.1	52.0	54.8
Missing	1-24	9.1	5.1	6.6	7.4
Multiple pregnancy (%)					
Yes	2-10	5.8	6.1	5.8	5.9
Congenital malformation (%)					
No	30-100	91.3	92.7	89.1	91.4
Yes	0-4	1.2	0.4	0.6	0.9
Missing	0-69	7.5	6.9	10.2	7.7
Birthweight (%)					
Birthweight \geq 2,500g	65-95	77.8	80.6	81.8	79.3
Birthweight $<$ 2,500g	2-29	17.2	13.2	11.9	15.1
Missing	1-16	5.1	6.2	6.3	5.6
Referral for antepartum complications or during labour (%)					
Yes	26-89	74.7	50.7	73.7	66.8
Distance from referring facility (%)					
$<$ 20km	0-85	18.7	47.4	23.4	26.6
20-450km	0-86	48.7	11.8	69.6	43.1
Distance unknown	0-99	32.6	40.8	6.9	30.3
Caesarean during labour (%)					

No	2-49	15	34.1	8.1	20.1
Yes	51-98	85	65.9	91.9	79.9
Primary indication for caesarean (%)					
Fetal distress	7-36	24.5	17.0	23.3	21.9
Prolonged labour	23-67	33.1	28.6	42.1	33.0
Previous caesarean	7-33	12.1	24.3	12.8	16.2
Pre-eclampsia	0- 8	4.2	4.1	1.7	3.8
Other	15-37	26.1	26	20.2	25.1
Diagnosis of acute fetal distress (%)					
Transverse lie/brow presentation in active labour (%)	1-11	4.8	2.6	5.0	4.1
Other severe obstetric complication or maternal death (%)					
<i>Severe pre-eclampsia/eclampsia</i>	2-13	6.4	6.1	3.2	5.8
<i>Retro-placental haematoma</i>	0- 5	2.8	1.5	1.4	2.2
<i>Placenta praevia in active labour</i>	0- 5	2	0.7	0.9	1.4
<i>Uterine (pre)-rupture</i>	2-24	12.3	6.4	15.0	10.8
<i>Maternal mortality (per 100,000)</i>	0-637	297	241	256	273

^aIn two largest cities (Ouagadougou and Bobo-Dioulasso)

Hospital variation in caesarean care received

Caesarean care differed between hospitals (Table 3). We found large differences in the type of provider (cadre) deciding for or conducting the caesarean between hospitals, with obstetricians deciding and performing 100% of caesareans in some hospitals, and non-physician providers deciding and performing over 90% of caesareans in others. Rural district hospitals relied primarily on generalist doctors and non-physician providers, while urban district hospitals relied primarily on obstetricians.

Hospitals reported up to 54% of caesareans performed more than one hour after decision. Almost 90% of all caesareans were performed under spinal anaesthesia, however in some hospitals 70% of caesareans were performed under general anaesthesia. General anaesthesia was more common in regional hospitals. Incision technique also showed important variation between hospitals, less so between hospital type. Antibiotic use was almost universal, recorded in 96% of women, but administered after skin incision in at least 41% of caesareans (62% estimated with imputed data, and up to 94% in individual hospitals).

1 282 **Table 3. Caesarean care received by women, across hospitals and hospital types (N=5,134)**

	Range across hospitals	Regional hospital	Urban district hospital	Rural district hospital	Total
N women	54-619	2,693	1,659	782	5,134
Cadre of provider deciding to perform caesarean					
Obstetrician	0-100	69.6	75.5	0.4	60.9
Generalist doctor with emergency surgical training	0-96	5.0	23.5	52.7	18.2
Generalist doctor	0-68	9.0	0.4	26.0	8.7
Midwife	0-100	16.1	0.4	7.5	9.7
Non-physician provider with surgical skills ^a	0-94	0.3	0.1	13.0	2.3
Missing	0-2	0.1	-	0.4	0.1
Cadre of provider who performed caesarean					
Obstetrician	0-100	28.3	68.9	0.1	37.1
Generalist doctor	0-88	13.0	11.8	44.6	17.4
Non-physician provider with obstetrics skills ^b	0-65	8.0	0.2	0.6	4.4
Non-physician provider with surgical skills ^a	0-94	48.3	18.9	54.2	39.7
Missing	0-8	2.4	0.2	0.4	1.4
Decision-to-incision interval					
<60 minutes	3-84	64.1	61.2	31.6	60.3
≥60 minutes	1-54	18.7	11.4	17.0	16.1
Missing	3-97	13.2	27.4	51.4	23.6
Type of anaesthesia					
Spinal	30-100	83.8	91	94.5	87.7
General/other	0-70	16.0	7.7	4.2	11.5
Missing	0-4	0.3	1.3	1.3	0.8
Type of skin incision					
Joel-Cohen	9-100	79.6	83.1	77.5	80.4
Pfannenstiel	0-84	16.8	12.1	9.7	14.2
Midline/other	0-11	2.8	1.1	0.9	1.9
Missing	0-39	0.8	3.7	11.9	3.4
Type of uterine incision					
Lower segment	45-100	94.7	98.3	94.8	95.9
Other	0-55	5.2	0.6	1.3	3.1
Missing	0-12	0.1	1.1	4.0	1.0
Antibiotic administration					
Antibiotics before incision	0-87	32.5	26.6	15.0	27.9
Antibiotics after incision	0-94	49.1	39.0	45.7	45.3
Antibiotics, timing unclear	2-95	12.6	32.9	35.2	22.6
No recorded antibiotics	0-10	2.0	0.5	0.4	1.3
Missing	0-22	3.9	0.9	3.8	2.9

47 283 ^aNurses or midwives with additional 3-year training in surgery; ^bMidwives with additional 3-year training in
 48 284 obstetrics and gynaecology, including performing caesareans

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53 286 *Risk factors for intrapartum-related mortality and risk-adjusted hospital mortality rates*

55 287 The median OR for crude intrapartum-related mortality was 1.9 [95% CI: 1.5-2.5], indicating that if a
 56 288 woman moved to another, randomly selected, hospital with higher mortality, the median increase in
 58 289 her odds of intrapartum-related mortality would be almost two-fold.

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2 290 In model 1, congenital malformation, diagnosis of acute fetal distress, transverse lie or brow
3 291 presentation in active labour, and other severe obstetric complication or maternal death were strongly
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5 292 associated with intrapartum-related mortality (Supplementary Table 4). Other risk factors retained in
6 293 the model were parity, education, number of antenatal visits, primary caesarean indication, referral
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8 294 immediately prior to caesarean, and birthweight. The median OR was 1.3 [1.2-1.7], indicating that a
9 295 woman moving to a different hospital with higher mortality would experience a 1.3-fold increase in
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11 296 odds of intrapartum-related mortality on average, a modest effect compared with individual-level
12
13 297 clinical risk factors. Inter-hospital variation in mortality rates was reduced, but not eliminated, after
14 298 adjusting for individual-level risk factors, with larger variation among hospitals performing less than
15
16 299 50 caesareans per month (Figure 1B).

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18 300 In model 2, all clinical risk factors except for number of antenatal visits were retained in the model
19
20 301 with similar effect sizes, and two care component risk factors were identified – general anaesthesia,
21 302 and not receiving antibiotic prophylaxis (Figure 2, Supplementary Table 4). Decision-to-incision
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23 303 interval, hospital type and monthly caesarean volume were not independently associated with
24 304 intrapartum-related mortality. There was no meaningful change in inter-hospital variation after adding
25
26 305 care components, compared with model 1 (median OR=1.4 [1.2-1.8], Figure 1C).

27
28 306 There was no evidence that adding trial arm improved the fit of model 2 ($p=0.78$).

30 31 32 33 34 308 **Discussion**

35
36 309 Our study fills an important gap in the evidence by examining hospital variation in intrapartum-related
37
38 310 perinatal mortality among caesarean births in sub-Saharan Africa, a region with a high burden of
39
40 311 perinatal deaths. Almost one in ten women giving birth by caesarean in regional and district hospitals
41 312 in Burkina Faso experienced an intrapartum-related perinatal death. The substantial hospital variation
42
43 313 in crude mortality rates, ranging between 21-189 per 1,000, was markedly reduced after adjusting for
44 314 individual-level differences in case mix between hospitals. However, important variation remained,
45
46 315 with lower-volume hospitals tending to have higher and more variable adjusted mortality than
47 316 hospitals performing more caesareans per month. Additionally adjusting for caesarean care
48
49 317 components did not further reduce variation. Remaining variation in adjusted rates indicate likely
50 318 differences in quality of caesarean care between hospitals, particularly those with low or moderate
51
52 319 monthly caesarean volumes.

53
54 320 Some of the remaining differences in risk-adjusted mortality rates between hospitals may be due to
55
56 321 unmeasured confounding by case mix, since the accuracy of obstetric complication measurement
57
58 322 using hospital records was likely limited. However, this is unlikely to explain all the variation in
59 323 adjusted mortality between lower-volume hospitals. Caesarean volume and hospital type were not
60
324 independently associated with intrapartum-related mortality in our study, although the number of

1 325 hospitals in our analysis (n=21) was too small to detect such effects. Hospitals performing more
2 326 caesareans likely differ from lower-volume hospitals in multiple ways affecting quality of perinatal
3 327 care, including presence of obstetricians or paediatricians, resources available for care of small and
4 328 sick newborns, as well as differences in access to care for the population they serve.
5 329

6 329 We identified two care components associated with intrapartum-related mortality: general
7 330 anaesthesia and not receiving antibiotic prophylaxis, each associated with a doubling of mortality,
8 331 compared with spinal anaesthesia and receiving antibiotics before incision. These odds ratios may
9 332 reflect unmeasured confounding by complication severity in the association with intrapartum-related
10 333 mortality, or differences in quality of care. Indeed, although general anaesthesia is independently
11 334 associated with perinatal mortality,³⁷ women undergoing general anaesthesia are also likely to be in
12 335 poorer clinical condition at the time of the caesarean, with independently higher risk of perinatal
13 336 death. Antibiotics may indicate very urgent caesareans without sufficient time to administer
14 337 antibiotics, or poor organisation of care, with up to 10% of women not receiving antibiotics in some
15 338 hospitals. Maternal antibiotic prophylaxis is unlikely to affect intrapartum-related survival.^{38 39} It is not
16 339 possible to disentangle the relative contributions of unmeasured confounding and quality of care for
17 340 these two care components with our data.
18 341

19 341 High rates of fresh stillbirths among caesarean births – 65 per 1,000 in our study, 60 per 1,000 total
20 342 stillbirths in a previous systematic review⁹ – indicate that many caesareans are performed too late in
21 343 Burkina Faso. Limited access to caesarean section contributes to these poor outcomes: a higher
22 344 proportion of women in sub-Saharan Africa arrive at the surgical hospital with severe complications
23 345 and more caesareans are performed in the second stage of labour, with higher associated
24 346 complications.⁹ Some babies may die before arrival at the hospital, but nonetheless are delivered by
25 347 caesarean. Indeed, our data indicate poor identification of stillbirths using the Pinard stethoscope in
26 348 this setting: one third of babies with no audible fetal heart rate were born alive, while one quarter of
27 349 macerated stillbirths had a recorded audible fetal heart rate. Other babies die *in utero* after arrival at
28 350 the hospital, due to delayed diagnosis of fetal distress or long waiting times between decision and
29 351 caesarean. We estimated a median decision-to-incision interval of 81 minutes for caesareans for fetal
30 352 distress, based on imputed data.
31 353

32 353 To our knowledge, this is the first study to examine hospital variation in crude and risk-adjusted
33 354 perinatal mortality in sub-Saharan Africa. A major strength of our study was the use of a novel
34 355 dataset with high-quality, detailed clinical information on all women delivering by caesarean section in
35 356 a six-month period in all Burkinabe regional and district hospitals with >200 caesareans per year. Our
36 357 21 study hospitals accounted for 45% of all caesareans performed in Burkina Faso in 2016.
37 358 University hospitals and lower-volume district hospitals accounted for 26% each, with only 3% in the
38 359 private sector.²⁷ While our results cannot be generalised to tertiary or private hospitals in Burkina
39 360 Faso, higher and more variable perinatal mortality is also likely to occur in lower-caesarean volume
40 361 hospitals in other West African countries.

1 362 Some data limitations are worth noting. Missing data were common for several risk factors. We used
2 363 multiple imputation to preserve statistical power, and the distribution of imputed variables was similar
3 364 to non-missing data. Moreover, like other studies using hospital records, some misclassification in
4 365 obstetric complication severity was likely, leading to residual unmeasured confounding in case mix
5 366 between hospitals. Indeed, limited granularity was available for severity (within pre-eclampsia, for
6 367 example), and previous studies indicate obstetric complications may be incompletely recorded or
7 368 overestimated in caesarean indications.⁴⁰⁻⁴² As a result, reported odds ratios for risk factors should be
8 369 interpreted as measures of association within our study population, rather than causal effects. The
9 370 number of hospitals in our sample was too small to enable us to examine hospital characteristics as
10 371 risk factors. We were also unable to examine hospital variation in maternal outcomes since post-
11 372 caesarean morbidity was not collected. Nonetheless, these prospectively collected trial data likely
12 373 represent the best available clinical data for caesarean sections in sub-Saharan Africa, and it would
13 374 have been difficult to further reduce complication misclassification.

14 375 Several recommendations for improving the quality of caesarean care stem from our findings. Two-
15 376 thirds of women were referred immediately prior to the caesarean, and those referred from further
16 377 away had higher rates of perinatal mortality. There is an urgent need to strengthen emergency
17 378 referral systems by minimising delays in women reaching surgical facilities, through shared
18 379 ambulances and maternity waiting homes, for example.⁴³ Delays in receiving treatment after arrival
19 380 should also be reduced, including through pre-referral notification and patient referral notes.⁴³
20 381 Improved antenatal care would help identify women needing an elective caesarean before labour.
21 382 Monitoring of labour should be improved for all women, including those with risk factors for
22 383 intrapartum-related mortality, to enable early intervention and prevent perinatal deaths among vaginal
23 384 and caesarean births. Provider training in fetal monitoring, supportive supervision, and making low-
24 385 cost Doppler ultrasounds widely available in hospitals would help improve identification of fetal
25 386 distress and stillbirths.⁴⁴ Many stillbirths can be delivered vaginally at lower risk of maternal
26 387 complications;⁹ however, suspected stillbirths should be confirmed with ultrasound scans, where
27 388 available, to avoid misdiagnosis. The decision-to-incision interval was not associated with
28 389 intrapartum-related mortality in our study, likely because of successful prioritisation of higher-risk
29 390 women and delayed decision to perform some caesareans. This mirrors the mixed results reported in
30 391 the literature, which is based on limited observational data only.⁴⁵ Nonetheless, the estimated median
31 392 81 minute interval for caesareans for fetal distress should be reduced closer to the 30 minutes
32 393 recommended in the UK and USA,^{46 47} wherever possible. Lastly, improving care for small and sick
33 394 newborns – including neonatal resuscitation and intensive care through the Helping babies breathe⁴⁸
34 395 programme and Every Newborn Action Plan⁴⁹ – is essential to increase survival after birth. Provider
35 396 training in newborn care has been shown to be cost-effective in other African countries.^{50 51}
36 397
37 398 Our data also suggest sub-optimal surgical technique which may affect maternal outcomes: although
38 399 the Joel-Cohen incision has advantages over the Pfannenstiel technique,⁵² the latter was used in at

1 399 least 14% of caesareans. An estimated 62% of women received antibiotics only after incision based
2 400 on imputed data, contrary to WHO recommendations.⁵³ Universal administration of antibiotic
3 401 prophylaxis before incision could help reduce the incidence of surgical site infection and sepsis,
4 402 which accounts for 10% of maternal deaths in sub-Saharan Africa.⁵⁴ The Lancet Global Surgery
5 403 commission recommendations for improving access to and the safety of essential surgical services in
6 404 low-resource settings should be followed,⁵⁵ first and foremost the creation of a national surgical plan
7 405 including provisions for healthcare delivery, human resources, financing, and information
8 406 management.

14 407 *Conclusions*

15 408 Women giving birth by caesarean section in Burkina Faso face a high risk of perinatal death. Our
16 409 study found variation in intrapartum-related perinatal mortality between hospitals remained after
17 410 adjustment for case mix, indicating that differences in quality of care contribute to variation in
18 411 perinatal mortality. Improving access to caesareans and the quality of caesarean care in the region is
19 412 a considerable challenge for Ministries of Health and reproductive health partners in West Africa;
20 413 improving training and resources for fetal distress monitoring, reducing decision-to-incision intervals,
21 414 and improving resuscitation and care of newborns seem important priorities to enable more babies to
22 415 survive at birth.

29 416 **Footnotes**

30 417 **Author contributions:** FC conceptualised the study, with help from CR. CK and AD designed the
31 418 DECIDE trial and oversaw data collection. FC designed the analyses and analysed the data, with
32 419 support from RP, RB and AD. All authors, including SS and APB, contributed to the interpretation of
33 420 results and writing of the final manuscript.

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39 426 **Competing interests:** none declared.

40 427 **Data sharing statement:** No data are available. Reasonable requests may be directed to Dr Charles
41 428 Kaboré (kaborewendyam@yahoo.fr).

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9 **Faso, 2016**

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11
12 **Figure 2. Odds ratios and 95% confidence intervals for risk factors for intrapartum-related mortality**
13 **among women giving birth by caesarean section in 21 hospitals (model 2) – Burkina Faso, 2016**

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References

1. Montagu D, Sudhinaraset M, Diamond-Smith N, et al. Where women go to deliver: understanding the changing landscape of childbirth in Africa and Asia. *Health Policy and Planning* 2017;32(8):1146-52. doi: 10.1093/heapol/czx060
2. Gabrysch S, Nesbitt RC, Schoeps A, et al. Does facility birth reduce maternal and perinatal mortality in Brong Ahafo, Ghana? A secondary analysis using data on 119 244 pregnancies from two cluster-randomised controlled trials. *The Lancet Global Health* 2019;7(8):e1074-e87. doi: [https://doi.org/10.1016/S2214-109X\(19\)30165-2](https://doi.org/10.1016/S2214-109X(19)30165-2)
3. Kunkel M, Marete I, Cheng ER, et al. Place of delivery and perinatal mortality in Kenya. *Seminars in Perinatology* 2019;43(5):252-59. doi: <https://doi.org/10.1053/j.semperi.2019.03.014>
4. Cavallaro FL, Benova L, Dioukhane EH, et al. What the percentage of births in facilities does not measure: readiness for emergency obstetric care and referral in Senegal. *BMJ Global Health* 2020;5(3):e001915. doi: 10.1136/bmjgh-2019-001915
5. Boerma T, Ronsmans C, Melesse DY, et al. Global epidemiology of use of and disparities in caesarean sections. *The Lancet* 2018;392(10155):1341-48. doi: 10.1016/S0140-6736(18)31928-7
6. Cavallaro FL, Pembe AB, Campbell O, et al. Caesarean section provision and readiness in Tanzania: analysis of cross-sectional surveys of women and health facilities over time. *BMJ Open* 2018;8(9):e024216. doi: 10.1136/bmjopen-2018-024216
7. Benova L, Dennis ML, Lange IL, et al. Two decades of antenatal and delivery care in Uganda: a cross-sectional study using Demographic and Health Surveys. *BMC Health Services Research* 2018;18(1):758. doi: 10.1186/s12913-018-3546-3
8. Biccard BM, Madiba TE, Kluyts HL, et al. Perioperative patient outcomes in the African Surgical Outcomes Study: a 7-day prospective observational cohort study. *Lancet* 2018 doi: 10.1016/s0140-6736(18)30001-1
9. Sobhy S, Arroyo-Manzano D, Murugesu N, et al. Maternal and perinatal mortality and complications associated with caesarean section in low-income and middle-income countries: a systematic review and meta-analysis. *The Lancet* 2019;393(10184):1973-82. doi: [https://doi.org/10.1016/S0140-6736\(18\)32386-9](https://doi.org/10.1016/S0140-6736(18)32386-9)
10. Compaoré GD, Sombié I, Ganaba R, et al. Readiness of district and regional hospitals in Burkina Faso to provide caesarean section and blood transfusion services: a cross-sectional study. *BMC Pregnancy and Childbirth* 2014;14(1):158. doi: 10.1186/1471-2393-14-158
11. Richard F, Ouédraogo C, De Brouwere V. Quality cesarean delivery in Ouagadougou, Burkina Faso: A comprehensive approach. *Int J Gynecol Obstet* 2008;103(3):283-90. doi: <http://dx.doi.org/10.1016/j.ijgo.2008.08.008>
12. Nyamtema A, Mwakatundu N, Dominico S, et al. Increasing the availability and quality of caesarean section in Tanzania. *Bjog* 2016;123(10):1676-82. doi: 10.1111/1471-0528.14223
13. Kasongo S, Mukuku O, Kinenkinda X, et al. Kakoma JB. Quality of Caesarean Delivery and its Determinants in Lubumbashi, Democratic Republic of Congo. *Ann Obstet Gynecol* 2020;1:1014.
14. Bishop D, Dyer RA, Maswime S, et al. Maternal and neonatal outcomes after caesarean delivery in the African Surgical Outcomes Study: a 7-day prospective observational cohort study. *The Lancet Global Health* 2019;7(4):e513-e22. doi: 10.1016/S2214-109X(19)30036-1
15. Bragg F, Cromwell DA, Edozien LC, et al. Variation in rates of caesarean section among English NHS trusts after accounting for maternal and clinical risk: cross sectional study. *BMJ* 2010;341:c5065. doi: 10.1136/bmj.c5065
16. Schemann K, Patterson JA, Nippita TA, et al. Variation in hospital caesarean section rates for women with at least one previous caesarean section: a population based cohort study. *BMC Pregnancy and Childbirth* 2015;15(1):179. doi: 10.1186/s12884-015-0609-x
17. Bailit JL, Love TE, Dawson NV. Quality of obstetric care and risk-adjusted primary cesarean delivery rates. *Am J Obstet Gynecol* 2006;194(2):402-7. doi: 10.1016/j.ajog.2005.07.045
18. Kabore C, Ridde V, Kouanda S, et al. DECIDE: a cluster randomized controlled trial to reduce non-medically indicated caesareans in Burkina Faso. *BMC Pregnancy Childbirth* 2016;16(1):322. doi: 10.1186/s12884-016-1112-8
19. Global Health Observatory. Births by caesarean section - Data by country. 2018 [Available: <http://apps.who.int/gho/data/view.main.BIRTHSBYCAESAREANv> accessed December 2019]
20. Institut National de la Statistique et de la Démographie (INSD) and ICF International. Enquête Démographique et de Santé et à Indicateurs Multiples du Burkina Faso 2010. Calverton, Maryland, USA: ISND and ICF International; 2012 [Available: <https://dhsprogram.com/pubs/pdf/FR256/FR256.pdf> accessed December 2019]
21. Boatin AA, Schlottheuber A, Betran AP, et al. Within country inequalities in caesarean section rates: observational study of 72 low and middle income countries. *BMJ* 2018;360:k55. doi: 10.1136/bmj.k55
22. INSD. Enquête multisectorielle continue (EMC) 2014 - Santé générale et santé de la reproduction. Institut national de la statistique et de la démographie [Burkina Faso]; 2015 [Available:

- 1 http://www.insd.bf/n/contenu/enquetes_recensements/Enq_EMC/Sante_generale_et_Sante_de_la_r%e9production.pdf accessed October 2019]
- 2 505
- 3 506 23. Witter S, Boukhalifa C, Cresswell JA, et al. Cost and impact of policies to remove and reduce fees for
- 4 507 obstetric care in Benin, Burkina Faso, Mali and Morocco. *International Journal for Equity in Health*
- 5 508 2016;15(1):123. doi: 10.1186/s12939-016-0412-y
- 6 509 24. Ganaba R, Ilboudo PGC, Cresswell JA, et al. The obstetric care subsidy policy in Burkina Faso: what are
- 7 510 the effects after five years of implementation? Findings of a complex evaluation. *BMC Pregnancy and*
- 8 511 *Childbirth* 2016;16(1):84. doi: 10.1186/s12884-016-0875-2
- 9 512 25. Ridde V, Richard F, Bicaba A, et al. The national subsidy for deliveries and emergency obstetric care in
- 10 513 Burkina Faso. *Health Policy Plan* 2011;26 Suppl 2:ii30-40. doi: 10.1093/heapol/czr060
- 11 514 26. Richard F, Zongo S, Ouattara F. Fear, guilt, and debt: an exploration of women's experience and
- 12 515 perception of cesarean birth in Burkina Faso, West Africa. *Int J Womens Health* 2014;6:469-78. doi:
- 13 516 10.2147/ijwh.S54742
- 14 517 27. Ministère de la Santé du Burkina Faso. Annuaire Statistique 2016, 2017.
- 15 518 28. Goldenberg RL, McClure EM, Kamath BD. Intrapartum perinatal mortality. *Indian pediatrics* 2012;49(3):187-
- 16 519 88. doi: 10.1007/s13312-012-0050-4
- 17 520 29. MEASURE Evaluation. Intrapartum and very early neonatal death rate. [Available:
- 18 521 [https://www.measureevaluation.org/prh/rh_indicators/womens-health/nb/intrapartum-and-very-early-](https://www.measureevaluation.org/prh/rh_indicators/womens-health/nb/intrapartum-and-very-early-neonatal-death-rate)
- 19 522 [neonatal-death-rate](https://www.measureevaluation.org/prh/rh_indicators/womens-health/nb/intrapartum-and-very-early-neonatal-death-rate) accessed March 2020]
- 20 523 30. WHO, UNFPA, UNICEF, et al. Monitoring emergency obstetric care: a handbook. Geneva, Switzerland:
- 21 524 World Health Organisation. 2009 [Available:
- 22 525 <https://www.who.int/reproductivehealth/publications/monitoring/9789241547734/en/> accessed
- 23 526 November 2019]
- 24 527 31. Sterne JAC, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical
- 25 528 research: potential and pitfalls. *BMJ* 2009;338:b2393. doi: 10.1136/bmj.b2393
- 26 529 32. Sanagou M, Wolfe R, Forbes A, et al. Hospital-level associations with 30-day patient mortality after cardiac
- 27 530 surgery: a tutorial on the application and interpretation of marginal and multilevel logistic regression.
- 28 531 *BMC Medical Research Methodology* 2012;12(1):28. doi: 10.1186/1471-2288-12-28
- 29 532 33. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health: integrating random
- 30 533 and fixed effects in multilevel logistic regression. *Am J Epidemiol* 2005;161(1):81-8. doi:
- 31 534 10.1093/aje/kwi017
- 32 535 34. Larsen K, Petersen JH, Budtz-Jørgensen E, et al. Interpreting parameters in the logistic regression model
- 33 536 with random effects. *Biometrics* 2000;56(3):909-14. doi: 10.1111/j.0006-341x.2000.00909.x
- 34 537 35. Bartlett JW, Hughes RA. Bootstrap inference for multiple imputation under uncongeniality and
- 35 538 misspecification. *Statistical Methods in Medical Research* 2020;29(12):3533-46. doi:
- 36 539 10.1177/0962280220932189
- 37 540 36. Kaboré C, Ridde V, Chaillet N, et al. DECIDE: a cluster-randomized controlled trial to reduce unnecessary
- 38 541 caesarean deliveries in Burkina Faso. *BMC Medicine* 2019;17(1):87. doi: 10.1186/s12916-019-1320-y
- 39 542 37. Fenton PM, Whitty CJM, Reynolds F. Caesarean section in Malawi: prospective study of early maternal and
- 40 543 perinatal mortality. *BMJ* 2003;327(7415):587. doi: 10.1136/bmj.327.7415.587
- 41 544 38. Smaill FM, Grivell RM. Antibiotic prophylaxis versus no prophylaxis for preventing infection after cesarean
- 42 545 section. *Cochrane Database Syst Rev* 2014;2014(10):Cd007482. doi:
- 43 546 10.1002/14651858.CD007482.pub3
- 44 547 39. Bollig C, Nothacker M, Lehane C, et al. Prophylactic antibiotics before cord clamping in cesarean delivery: a
- 45 548 systematic review. *Acta Obstet Gyn Scan* 2018;97(5):521-35. doi: <https://doi.org/10.1111/aogs.13276>
- 46 549 40. Kabore C, Ridde V, Kouanda S, et al. Determinants of non-medically indicated cesarean deliveries in
- 47 550 Burkina Faso. *Int J Gynaecol Obstet* 2016;135 Suppl 1:S58-s63. doi: 10.1016/j.ijgo.2016.08.019
- 48 551 41. Landry E, Pett C, Fiorentino R, et al. Assessing the quality of record keeping for cesarean deliveries: results
- 49 552 from a multicenter retrospective record review in five low-income countries. *BMC Pregnancy and*
- 50 553 *Childbirth* 2014;14(1):139.
- 51 554 42. Cavallaro FL, Hurt LS, Cresswell JA, et al. Testing the assumptions of an indicator of unmet need for
- 52 555 obstetric surgery in Ghana: A cross-sectional study of linked hospital and population-based delivery
- 53 556 data. *Birth* 2019;46(4):638-47. doi: <https://doi.org/10.1111/birt.12452>
- 54 557 43. Pittalis C, Brugha R, Gajewski J. Surgical referral systems in low- and middle-income countries: A review of
- 55 558 the evidence. *PLOS ONE* 2019;14(9):e0223328. doi: 10.1371/journal.pone.0223328
- 56 559 44. Byaruhanga R, Bassani DG, Jagau A, et al. Use of wind-up fetal Doppler versus Pinard for fetal heart rate
- 57 560 intermittent monitoring in labour: a randomised clinical trial. *BMJ Open* 2015;5(1):e006867. doi:
- 58 561 10.1136/bmjopen-2014-006867
- 59 562 45. Cavallaro FL, Marchant TJ. Responsiveness of emergency obstetric care systems in low- and middle-
- 60 563 income countries: a critical review of the "third delay". *Acta Obstet Gyn Scan* 2013;92(5):496-507. doi:
- 61 564 10.1111/aogs.12071
- 62 565 46. RCOG. Classification of urgency of caesarean section - a continuum of risk. Royal College of Obstetricians
- 63 566 and Gynaecologists, Royal College of Anaesthetists; 2010 [Available:

- 1 567 <https://www.rcog.org.uk/globalassets/documents/guidelines/goodpractice11classificationofurgency.pdf>
2 568 accessed November 2019]
- 3 569 47. ACOG. Standards for Obstetric Services. Sixth ed. In: The College, ed. Washington, DC, 1988.
- 4 570 48. Versantvoort JMD, Kleinhout MY, Ockhuijsen HDL, et al. Helping Babies Breathe and its effects on
5 571 intrapartum-related stillbirths and neonatal mortality in low-resource settings: a systematic review.
6 572 *Archives of Disease in Childhood* 2020;105(2):127-33. doi: 10.1136/archdischild-2018-316319
- 7 573 49. WHO, UNICEF. Every Newborn: an action plan to end preventable deaths. Geneva: World Health
8 574 Organization; 2014 [Available: [https://www.healthynewbornnetwork.org/hnn-](https://www.healthynewbornnetwork.org/hnn-content/uploads/Every_Newborn_Action_Plan-ENGLISH_updated_July2014.pdf)
9 575 [content/uploads/Every_Newborn_Action_Plan-ENGLISH_updated_July2014.pdf](https://www.healthynewbornnetwork.org/hnn-content/uploads/Every_Newborn_Action_Plan-ENGLISH_updated_July2014.pdf) accessed May 2021]
- 10 576 50. Bogdewic S, Ramaswamy R, Goodman DM, et al. The cost-effectiveness of a program to reduce
11 577 intrapartum and neonatal mortality in a referral hospital in Ghana. *PLOS ONE* 2020;15(11):e0242170.
12 578 doi: 10.1371/journal.pone.0242170
- 13 579 51. Manasyan A, Chomba E, McClure EM, et al. Cost-effectiveness of essential newborn care training in urban
14 580 first-level facilities. *Pediatrics* 2011;127(5):e1176-e81. doi: 10.1542/peds.2010-2158
- 15 581 52. Mathai M, Hofmeyr GJ, Mathai NE. Abdominal surgical incisions for caesarean section. *Cochrane Database*
16 582 *Syst Rev* 2013(5):Cd004453. doi: 10.1002/14651858.CD004453.pub3
- 17 583 53. WHO. WHO recommendations for prevention and treatment of maternal peripartum infections. Geneva:
18 584 World Health Organization; 2015 [Available:
19 585 https://apps.who.int/iris/bitstream/handle/10665/186171/9789241549363_eng.pdf?sequence=1
20 586 accessed June 2019]
- 21 587 54. Seale AC, Mwaniki M, Newton CRJC, et al. Maternal and early onset neonatal bacterial sepsis: burden and
22 588 strategies for prevention in sub-Saharan Africa. *The Lancet Infectious Diseases* 2009;9(7):428-38. doi:
23 589 [https://doi.org/10.1016/S1473-3099\(09\)70172-0](https://doi.org/10.1016/S1473-3099(09)70172-0)
- 24 590 55. Meara JG, Leather AJM, Hagander L, et al. Global Surgery 2030: evidence and solutions for achieving
25 591 health, welfare, and economic development. *The Lancet* 2015;386(9993):569-624. doi: 10.1016/S0140-
26 592 6736(15)60160-X

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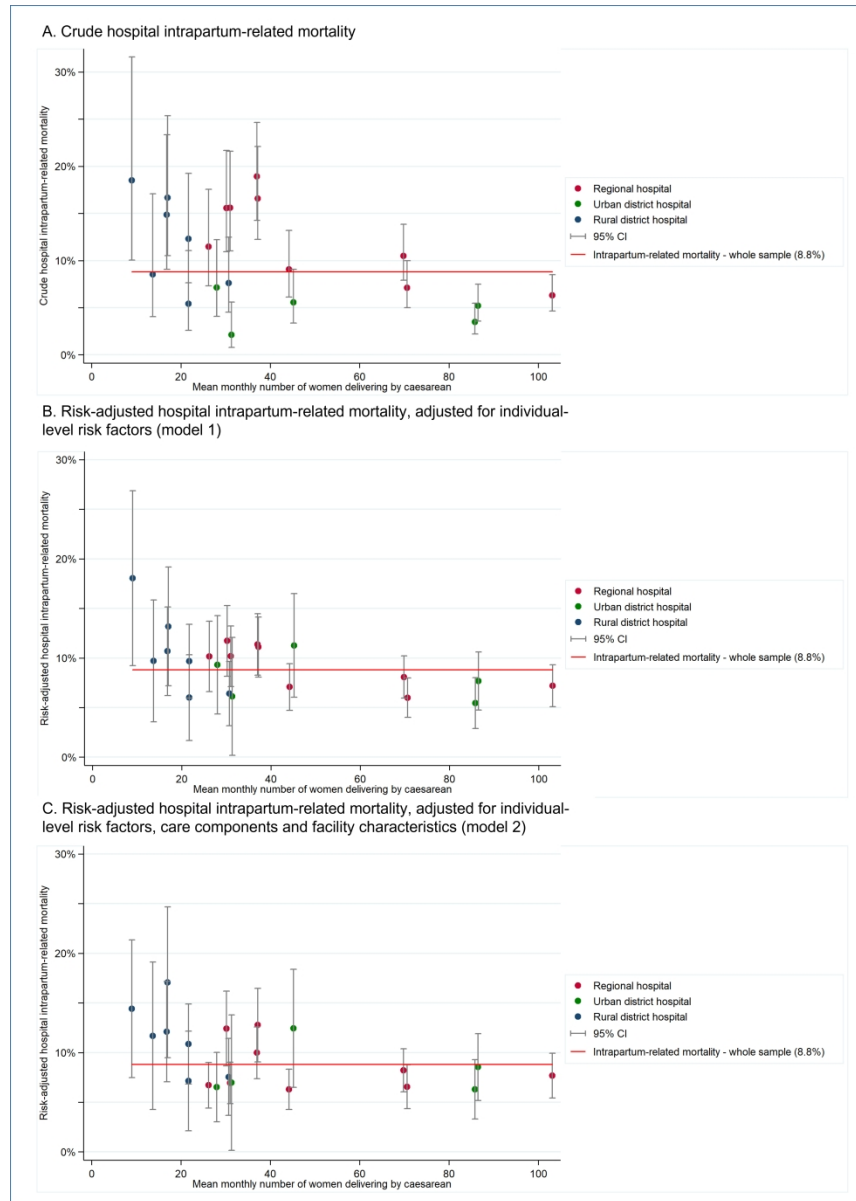


Figure 1. Crude and risk-adjusted hospital inpatient-related mortality rates among women giving birth by caesarean section in 21 hospitals, according to mean monthly number of caesareans – Burkina Faso, 2016

355x496mm (330 x 330 DPI)

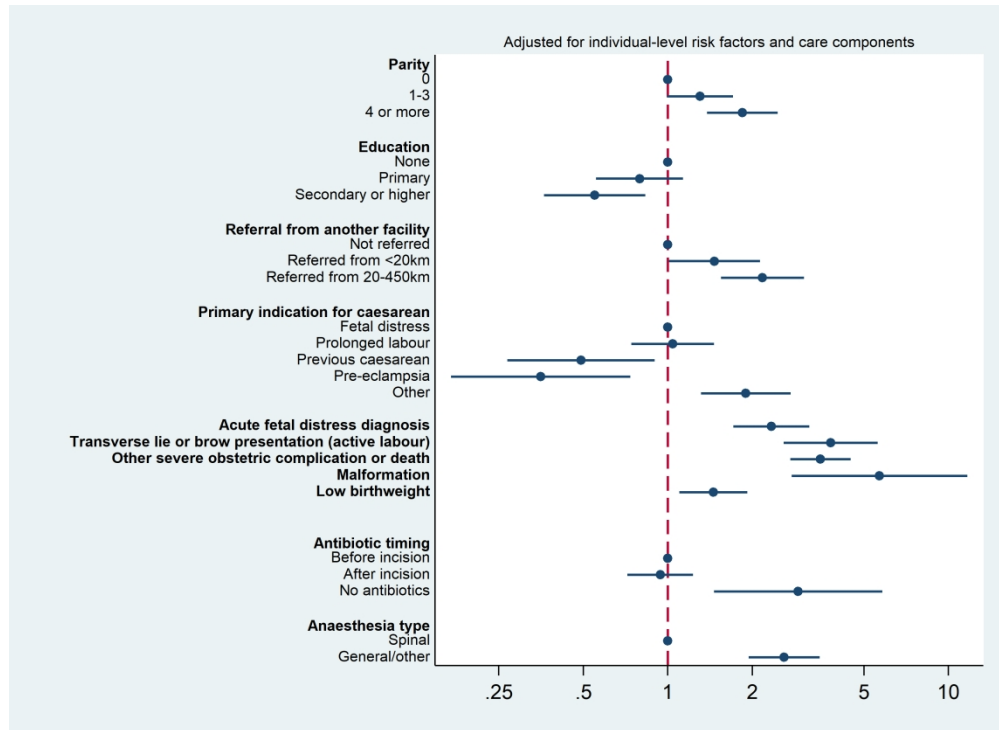


Figure 2. Odds ratios and 95% confidence intervals for risk factors for intrapartum-related mortality among women giving birth by caesarean section in 21 hospitals (model 2) – Burkina Faso, 2016

1058x769mm (72 x 72 DPI)

Supplementary materials

Supplementary Figure 1. Odds ratios and 95% confidence intervals for individual-level risk factors for intrapartum-related mortality (model 1)

$$\text{median OR} = \exp[\sqrt{2 \times \tau^2 \times 0.6745}]$$

where τ^2 is the hospital-level variance.

Supplementary Table 1. Missing data for risk factors for intrapartum-related perinatal mortality among 5,134 women in sample

Variable	N total expected	N missing	% missing (whole sample)	% missing (sub-sample)
Risk factors for which all women are expected to have data				
Maternal age	5,134	102	2.0	-
Parity	5,134	10	0.2	-
Education	5,134	74	1.4	-
Previous caesarean	5,134	0	0	-
Number of antenatal visits	5,134	382	7.4	-
Multiple pregnancy	5,134	0	0	-
Malformation	5,134	396	7.7	-
Birthweight	5,134	253	4.9	-
Acute fetal distress diagnosis	5,134	496	9.7	-
Transverse lie or brow presentation	5,134	0	0	-
Other severe obstetric complication or maternal death	5,134	0	0	-
Neonatal resuscitation	5,134	242	4.7	-
Labour phase	5,134	0	0	-
Referral status	5,134	0	0	-
Primary indication for caesarean	5,134	0	0	-
Provider deciding to perform caesarean	5,134	7	0.1	-
Provider performing caesarean	5,134	71	1.4	-
Decision-incision interval	5,134	1212	23.6	-
Anaesthesia type	5,134	39	0.8	-
Skin incision type	5,134	176	3.4	-
Antibiotic prophylaxis administration	5,134	149	2.9	-
Hospital type	5,134	0	0	-
Monthly caesarean volume	5,134	0	0	-
Risk factors for which a subset of women are expected to have data				
Birthweight for second baby among multiple pregnancies	301	91	1.8	30.2
Referral distance among referred women	3,429	1039	20.2	30.3
Timing of antibiotic administration among women receiving antibiotic prophylaxis	4,918	1159	22.6	23.6
Variable used in the imputation model but not in the risk factor analysis				
Gestational age at birth	5,134	2808	54.7	-

Supplementary Table 2. Characteristics of women with missing data on risk factors among 5,134 women in sample

Risk factor	N	Missing data for 0 risk factors (row %)	Missing data for 1-3 risk factors (row %)	Missing data for 4 or more risk factors (row %)
Maternal age				
13-19	883	31	65	4
20-29	2,376	33	63	4
30-39	1,612	33	63	4
40-49	161	26	70	4
Missing	102	0	90	10
Parity				
0	1,784	33	64	4
1-3	2,358	32	64	4
4 or more	982	29	67	4
Missing	10	0	70	30
Education				
None	3,256	31	65	4
Primary	724	29	66	4
Secondary or higher	1,080	38	60	2
Missing	74	0	88	12
Previous caesarean				
No	3,776	31	65	4
Yes	1,308	33	64	3
Missing	50	24	54	22
Number of antenatal care visits				
0	42	19	76	5
1-3	1,899	32	65	3
4 or more	2,811	36	61	3
Missing	382	0	87	13
Multiple pregnancy				
No	4,833	32	64	4
Yes	301	20	71	9
Congenital malformation				
No	4,694	35	64	2
Yes	44	14	77	9
Missing	396	0	73	27
Gestational age at birth				
Preterm	286	26	69	6
Term	2,040	36	61	3
Missing	2,715	30	66	4
Birthweight				
Birthweight \geq 2,500g	4,071	35	63	2
Birthweight $<$ 2,500g	775	28	68	3
Missing	288	0	72	28
Acute fetal distress				
No	3,168	34	64	2
Yes	1,470	37	61	2
Missing	496	0	81	19
Transverse lie or brow presentation in active labour				
No	4,922	32	65	4
Yes	212	29	63	8

1	Other severe obstetric complication or maternal death				
2	No	4,125	32	64	3
3	Yes	1,009	29	66	5
4	Neonatal resuscitation				
5	No	4,273	34	63	2
6	Yes	619	27	70	3
7	Missing	242	0	70	30
8	Labour phase				
9	Pre-labour	1,031	29	67	4
10	Latent phase	1,577	36	61	3
11	Active phase	2,526	30	66	4
12	Referral status				
13	Not referred before caesarean	1,705	39	58	3
14	Referred before caesarean	3,429	28	68	4
15	Referral distance				
16	<20km	911	43	55	3
17	20-450km	1,479	39	58	4
18	Distance unknown	1,039	0	94	6
19	Primary indication for caesarean				
20	Fetal distress	1,125	36	61	3
21	Prolonged labour	1,695	31	66	4
22	Previous caesarean	830	30	66	3
23	Pre-eclampsia	193	28	67	5
24	Other	1,291	31	64	5
25	Provider cadre deciding to perform caesarean				
26	Obstetrician	3,129	37	60	3
27	Generalist doctor with emergency surgical training	936	27	68	4
28	Generalist doctor	446	21	74	5
29	Midwife	500	24	73	3
30	Non-physician provider with surgical skills	116	7	86	7
31	Missing	7	0	71	29
32	Provider cadre performing caesarean				
33	Obstetrician	1,905	32	63	5
34	Generalist doctor	895	28	67	5
35	Non-physician provider with obstetrics skills	224	18	81	0
36	Non-physician provider with surgical skills	2,039	36	62	3
37	Missing	71	0	92	8
38	Decision-to-incision interval				
39	<60min	878	36	61	2
40	≥60min	3,044	43	56	1
41	Missing	1,212	0	89	11
42	Anaesthesia type				
43	Spinal	4,505	32	64	3
44	General/other	590	29	66	5
45	Missing	39	0	46	54
46	Skin incision type				
47	Joel-Cohen	4,128	34	63	3
48	Pfannenstiel	730	27	70	4
49	Midline/other	100	25	72	3
50	Missing	176	0	78	22
51	Uterine incision type				
52	Lower segment	4,921	33	64	3
53	Other	161	11	86	2
54	Missing	52	0	60	40

1	Antibiotic prophylaxis administration				
2	Antibiotics before incision	1,434	43	56	1
3	Antibiotics after incision	2,325	43	56	1
4	Antibiotics, timing unclear	1,159	0	90	10
5	No recorded antibiotics	67	24	75	1
6	Missing	149	0	74	26
7	Hospital type				
8	Regional hospital	2,693	39	58	2
9	Urban district hospital	1,659	26	70	4
10	Rural district hospital	782	18	75	7
11	Mean monthly caesarean volume				
12	<30	923	25	70	4
13	30-60	1,717	20	74	5
14	60-105	2,494	42	56	2

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Supplementary Table 3. Maternal and perinatal outcomes among women giving birth by caesarean section in 21 hospitals – Burkina Faso, 2016

	N women	Perinatal outcomes						
		Macerated stillbirths (per 1,000)	Fresh stillbirths (per 1,000)	Apgar score <3, live birth (per 1,000)	Neonatal death within 24 hrs of birth (per 1,000)	Neonatal death after 24 hrs, before discharge (per 1,000)	Intrapartum-related perinatal death (per 1,000)	Total perinatal death before discharge (per 1,000)
Total	5,134	7 [5-9]	65 [58-72]	24 [20-29]	23 [20-28]	3 [2-5]	88 [81-96]	98 [90-107]
Range across hospitals	5,134	0-23	16-135	0-90	0-90	0-32	21-189	32-243
Facility type								
Regional hospital	2,693	9 [6-14]	78 [68-89]	32 [26-39]	30 [24-37]	4 [2-7]	108 [97-120]	121 [109-134]
Urban district hospital	1,659	3 [1-7]	36 [28-46]	9 [5-15]	10 [06-16]	2 [1-6]	46 [37-57]	51 [42-63]
Rural district hospital	782	5 [2-14]	81 [63-102]	31 [21-45]	29 [20-44]	4 [1-12]	110 [90-134]	119 [98-144]
P-value	-	0.08	<0.001	0.029	0.016	0.793	0.001	0.001

Supplementary table 4. Risk factors for intrapartum-related deaths among 5,134 women giving birth by caesarean section in 21 hospitals – Burkina Faso, 2016

Risk factor	Unadjusted OR (95% CI)	Model 1 ^a (95% CI)	Model 2 ^b (95% CI)
Individual-level clinical risk factors			
Maternal age			
13-19	1 [ref]	-	-
20-29	1.31 (0.98-1.76)	-	-
30-39	1.56 (1.15-2.10)	-	-
40-54	2.09 (1.21-3.58)	-	-
Parity			
0	1 [ref]	1 [ref]	1 [ref]
1-3	1.15 (0.90-1.47)	0.80 (0.56-1.13)	1.30 (0.99-1.71)
4 or more	2.46 (1.91-3.18)	0.52 (0.34-0.78)	1.84 (1.38-2.46)
Education			
None	1 [ref]	1 [ref]	1 [ref]
Primary	0.64 (0.46-0.89)	0.89 (0.61-1.31)	0.79 (0.56-1.13)
Secondary or higher	0.31 (0.21-0.46)	0.53 (0.34-0.85)	0.55 (0.36-0.83)
Number of previous caesareans			
0	1 [ref]	-	-
1 or more	0.39 (0.29-0.52)	-	-
Number of ANC visits			
0	1 [ref]	1 [ref]	-
1-3	0.58 (0.24-1.36)	0.54 (0.19-1.48)	-
4 or more	0.35 (0.15-0.81)	0.43 (0.16-1.18)	-
Multiple pregnancy			
No	1 [ref]	-	-
Yes	1.43 (0.99-2.07)	-	-
Malformation			
No	1 [ref]	1 [ref]	1 [ref]
Yes	7.15 (3.75-13.64)	6.01 (2.95-12.23)	5.67 (2.79-11.55)
Birthweight			
Birthweight ≥2,500g	1 [ref]	1 [ref]	1 [ref]
Birthweight <2,500g	1.77 (1.39-2.25)	1.50 (1.14-1.97)	1.45 (1.10-1.92)
Diagnosis of acute fetal distress			
No	1 [ref]	1 [ref]	1 [ref]
Yes	2.26 (1.79-2.86)	2.42 (1.80-3.26)	2.34 (1.72-3.17)
Transverse lie or brow presentation in active labour			
No	1 [ref]	1 [ref]	1 [ref]
Yes	3.69 (2.65-5.13)	3.56 (2.43-5.22)	3.81 (2.59-5.59)
Other severe obstetric complication or maternal death			
No	1 [ref]	1 [ref]	1 [ref]
Yes	3.49 (2.84-4.29)	3.88 (3.04-4.95)	3.50 (2.73-4.49)
Labour phase			
Pre-labour	1 [ref]	-	-
Latent phase	1.20 (0.84-1.71)	-	-
Active phase	2.12 (1.53-2.92)	-	-

Referral status			
Not referred	1 [ref]	1 [ref]	1 [ref]
Referred from <20km	2.17 (1.51-3.11)	1.52 (1.04-2.21)	1.46 (1.01-2.13)
Referred from 20-450km	4.24 (3.10-5.80)	2.17 (1.55-3.04)	2.18 (1.55-3.06)
Decision-to-delivery interval			
<60 minutes	1 [ref]	-	-
≥60 minutes	0.85 (0.65-1.11)	-	-
Primary indication for caesarean			
Fetal distress	1 [ref]	1 [ref]	1 [ref]
Prolonged labour	1.10 (0.85-1.43)	1.14 (0.81-1.59)	1.04 (0.74-1.46)
Previous caesarean	0.23 (0.13-0.39)	0.51 (0.28-0.92)	0.49 (0.27-0.90)
Pre-eclampsia	0.59 (0.31-1.13)	0.38 (0.19-0.80)	0.35 (0.17-0.74)
Other	1.37 (1.04-1.80)	2.08 (1.44-3.00)	1.90 (1.31-2.74)
Caesarean care components and hospital characteristics			
Provider cadre deciding the caesarean			
Obstetrician	1 [ref]		-
Generalist doctor with emergency surgical training	1.20 (0.84-1.73)		-
Generalist doctor	1.20 (0.73-1.96)		-
Midwife	1.78 (1.07-2.96)		-
Non-physician provider with surgical skills ^c	1.87 (0.82-4.28)		-
Provider cadre performing the caesarean			
Obstetrician	1 [ref]		-
Generalist doctor	0.94 (0.62-1.44)		-
Non-physician provider with obstetrics skills ^d	1.47 (0.81-2.68)		-
Non-physician provider with surgical skills ^c	1.01 (0.68-1.49)		-
Type of anaesthesia			
Spinal	1 [ref]		1 [ref]
General/other	4.46 (3.41-5.84)		2.60 (1.94-3.47)
Type of skin incision			
Joel-Cohen	1 [ref]		-
Other	0.89 (0.62-1.28)		-
Type of uterine incision			
Lower segment	1 [ref]		-
Other	1.23 (0.69-2.19)		-
Antibiotics administration			
Antibiotics before incision	1 [ref]		1 [ref]
Antibiotics after incision	0.99 (0.74-1.31)		0.94 (0.72-1.23)
No recorded antibiotics	2.31 (1.25-4.25)		2.91 (1.46-5.81)
Neonatal resuscitation			
No	1 [ref]		-
Yes	1.71 (1.31-2.24)		-
Hospital type			
Regional hospital	1 [ref]		-
Urban district hospital	0.36 (0.23-0.58)		-
Rural district hospital	0.96 (0.62-1.47)		-
Hospital caesarean volume (per month)			

1			
2	<30	1 [ref]	-
3	30-60	0.93 (0.55-1.57)	-
4	60-105	0.53 (0.30-0.94)	-

5 ^aModel 1 was built by manual backward elimination of individual-level risk factors with $p > 0.1$ in a model
 6 including all variables with $p < 0.25$ in the unadjusted model, with the exception of maternal age which had
 7 $p < 0.25$ in the unadjusted model but was removed due to collinearity with parity
 8

9 ^bModel 2 was built by adding all care components and hospital characteristics with $p < 0.25$ to model 1, followed
 10 by manual backward selection until all remaining variables had $p < 0.1$
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12 ^cNurses or midwives with additional 3-year training in surgery
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14 ^dMidwives with additional 3-year training in obstetrics and gynaecology, including performing caesareans
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Reporting checklist for cross sectional study.

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			Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	#3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	#4	Present key elements of study design early in the paper	4
Setting	#5	Describe the setting, locations, and relevant dates, including periods of	4

		recruitment, exposure, follow-up, and data collection	
1			
2	Eligibility criteria	#6a Give the eligibility criteria, and the sources and methods of selection of	4
3		participants.	
4			
5			
6		#7 Clearly define all outcomes, exposures, predictors, potential	5
7		confounders, and effect modifiers. Give diagnostic criteria, if applicable	
8			
9			
10	Data sources /	#8 For each variable of interest give sources of data and details of methods	4-5
11	measurement	of assessment (measurement). Describe comparability of assessment	
12		methods if there is more than one group. Give information separately	
13		for for exposed and unexposed groups if applicable.	
14			
15			
16			
17	Bias	#9 Describe any efforts to address potential sources of bias	5-6
18			
19	Study size	#10 Explain how the study size was arrived at	4
20			
21	Quantitative	#11 Explain how quantitative variables were handled in the analyses. If	5-7
22	variables	applicable, describe which groupings were chosen, and why	
23			
24			
25	Statistical	#12a Describe all statistical methods, including those used to control for	5-7
26	methods	confounding	
27			
28			
29	Statistical	#12b Describe any methods used to examine subgroups and interactions	N/A
30	methods		
31			
32			
33	Statistical	#12c Explain how missing data were addressed	5-6
34	methods		
35			
36			
37	Statistical	#12d If applicable, describe analytical methods taking account of sampling	6-7
38	methods	strategy	
39			
40			
41	Statistical	#12e Describe any sensitivity analyses	N/A
42	methods		
43			
44	Results		
45			
46	Participants	#13a Report numbers of individuals at each stage of study—eg numbers	7
47		potentially eligible, examined for eligibility, confirmed eligible,	
48		included in the study, completing follow-up, and analysed. Give	
49		information separately for for exposed and unexposed groups if	
50		applicable.	
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55	Participants	#13b Give reasons for non-participation at each stage	N/A
56			
57	Participants	#13c Consider use of a flow diagram	N/A
58			
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60			

1	Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	9-10
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5				
6	Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	7, 9-10
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10	Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	7-8
11				
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14	Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7, 11-12
15				
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19	Main results	#16b	Report category boundaries when continuous variables were categorized	7-12
20				
21	Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
22				
23				
24				
25	Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	12
26				
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29	Discussion			
30				
31	Key results	#18	Summarise key results with reference to study objectives	12
32				
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34	Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	13-14
35				
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39	Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	12-13
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44	Generalisability	#21	Discuss the generalisability (external validity) of the study results	14-15
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47	Other			
48	Information			
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51	Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15
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Does hospital variation in intrapartum-related perinatal mortality among caesarean births reflect differences in quality of care? Cross-sectional study in 21 hospitals in Burkina Faso

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1 **Does hospital variation in intrapartum-related perinatal mortality among caesarean births**
2 **reflect differences in quality of care? Cross-sectional study in 21 hospitals in Burkina Faso**

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20 Word count: 4,342

Abstract

Objectives. To examine hospital variation in crude and risk-adjusted rates of intrapartum-related perinatal mortality among caesarean births

Design. Secondary analysis of data from the DECIDE cluster randomised trial post-intervention phase

Setting. 21 district and regional hospitals in Burkina Faso

Participants. All 5,134 women giving birth by caesarean section in a 6-month period in 2016

Primary outcome measure. Intrapartum-related perinatal mortality (fresh stillbirth or neonatal death within 24 hours of birth)

Results. Almost one in ten of 5,134 women giving birth by caesarean experienced an intrapartum-related perinatal death. Crude mortality rates varied substantially from 21-189 per 1,000 between hospitals. Variation was markedly reduced after adjusting for case mix differences (the median odds ratio decreased from 1.9 [95% CI: 1.5-2.5] to 1.3 [1.2-1.7]). However, higher and more variable adjusted mortality persisted among hospitals performing fewer caesareans per month. Additionally adjusting for caesarean care components did not further reduce variation (median odds ratio = 1.4 [1.2-1.8]).

Conclusions. There is a high burden of intrapartum-related perinatal deaths among caesarean births in Burkina Faso, and sub-Saharan Africa more widely. Variation in adjusted mortality rates indicates likely differences in quality of caesarean care between hospitals, particularly lower-volume hospitals. Improving access to and quality of emergency obstetric and newborn care is an important priority for improving survival of babies at birth.

Keywords: caesarean section, stillbirth, perinatal mortality, hospital variation, Burkina Faso

Strengths and limitations of this study

- This is the first study to examine hospital variation in intrapartum-related perinatal mortality among women giving birth by caesarean section in a sub-Saharan African country.
- Our study benefited from inclusion of all caesarean sections performed in a six-month period in 21 regional and district hospitals in Burkina Faso.
- We used high-quality clinical data from the DECIDE cluster-randomised trial, including standardised definitions for diagnoses and indications for caesarean, although some misclassification of obstetric complication severity was likely.
- More than 20% of data were missing for three risk factors (decision-to-incision interval, timing of antibiotics, and referral distance); we used multiple imputation to avoid a loss of power.

- Our hospital sample size and limited available information prevented us from examining hospital characteristics as risk factors for perinatal mortality.

Introduction

While facility births have increased over the past few decades in sub-Saharan Africa,¹ improvements in maternal and perinatal health have been limited, raising questions about the quality of care in health facilities.¹⁻³ In particular, although facility births have increased substantially, increases in population-based caesarean section rates have been small. Persisting low caesarean rates indicate that improvements in access to emergency obstetric care have been limited.^{4 5} Globally, the slowest rise was observed in West and Central Africa, from 3.0% caesarean births in 2000 to 4.1% in 2015.⁵ The absolute number of caesareans performed has increased more rapidly due to a rise in total number of births – 3- to 5-fold in Senegal, Tanzania and Uganda over the past few decades.^{4 6 7}

Increases in caesarean births raise concerns in health systems with limited resources and capacity to provide high-quality caesarean care. Caesarean sections account for one third of all surgeries in Africa, where post-operative morbidity and mortality is higher than in other regions.⁸ A recent meta-analysis found over 1% mortality among women who deliver by caesarean in sub-Saharan Africa, 100 times higher than in the UK.⁹ Perinatal mortality is also very high in sub-Saharan Africa, with one in 10 mothers delivering by caesarean experiencing a stillbirth or early neonatal death.⁹ This high mortality is driven both by severe complications before reaching health facilities and low capacity within facilities to provide high-quality care. Indeed, low capacity to provide caesarean section care has been reported in Burkina Faso^{10 11} and elsewhere in the region.^{6 12 13}

In the context of rising caesareans, there is a need to better understand why perinatal mortality is so high among women giving birth by caesarean in sub-Saharan Africa. Limited evidence is available on inter-hospital variation in outcomes among caesarean births. Hospital type (district, regional, or national) is independently associated with perinatal mortality in some studies but not others,^{9 14} however severe restrictions in material and human resources restrict capacity to provide high-quality care in lower-level and rural facilities.^{4 6} Comparing variation in crude and risk-adjusted outcome rates between hospitals is a commonly used approach to determine whether differences between hospitals are entirely explained by heterogeneity in case mix. Any remaining variation in risk-adjusted rates suggest differences in quality of patient care.¹⁵⁻¹⁷ In this study, we examined variation in crude and adjusted rates of intrapartum-related perinatal mortality among women giving birth by caesarean in 21 district and regional hospitals in Burkina Faso for a six month period in 2016. We used high-quality data from the DECIDE trial to assess the evidence that differences in intrapartum-related mortality between individual hospitals and hospital types were driven in part by variation in quality of care.

89 **Methods**

90 This study is a secondary analysis of the DECIDE cluster-randomised controlled trial, which
91 assessed the effectiveness of a multicomponent intervention including provider training, caesarean
92 audits, and SMS reminders to reduce non-medically indicated caesarean sections. The trial included
93 three phases: six-month pre-intervention, one-year intervention, and six-month post-intervention. It
94 was conducted in all 22 regional and district hospitals in Burkina Faso performing more than 200
95 caesareans per year in 2012; university hospitals in Ouagadougou and Bobo-Dioulasso were
96 excluded. Detailed trial methods are described elsewhere.¹⁸

97 *Health system context*

98 Similar to other West African countries, the caesarean rate in Burkina Faso is below 5% (3.7% in
99 2010-15),¹⁹ with large urban-rural, wealth and educational differentials.^{20 21} Although 85% of births
100 take place in health facilities, 70% occur in primary care facilities without surgical capacity.²² Women
101 who develop complications requiring a caesarean are referred to medical centres with surgical
102 capacity (*centres médicaux avec antenne chirurgicale*, referred to as district hospitals hereafter) or
103 regional hospitals. Women with severe complications may be referred onwards to tertiary university
104 hospitals in the capital Ouagadougou and second largest city Bobo-Dioulasso. Most – but not all –
105 district and regional hospitals have at least one obstetrician or generalist doctor trained in emergency
106 obstetric care. Task-shifting of caesarean care has been supported in Burkina Faso through
107 additional three-year training of nurses and midwives as non-physician providers with surgical skills
108 (*attachés en chirurgie*) and obstetrics skills (*attachés en gynéco-obstétrique*). Most anaesthesia care
109 is provided by nurses with additional training in anaesthesia. More than three quarters of study
110 hospitals did not have Doppler ultrasounds, CTG monitors or ultrasound capacity, relying on Pinard
111 stethoscopes for assessment of fetal wellbeing. Fetal scalp pH was only available in one hospital.¹⁸

112 Emergency obstetric care has been subsidised to improve access since 2006, initially with an 80%
113 subsidy of the cost of caesareans, which were made free to women from 2016 onwards. Hospitals
114 are reimbursed according to the number of caesareans and vaginal births. This policy absorbed
115 around 3.5% of total health expenditure in 2011.²³ However, some costs (formal or informal) not
116 included in the “free” package continue to be borne by households, and remain unaffordable for
117 some.^{24 25} Women express fears around caesarean birth related primarily to poor quality of care and
118 economic burden.²⁶

119 *Participants*

120 We included all 5,134 women giving birth by caesarean section in the 21 study hospitals with
121 caesarean capacity in the post-intervention phase (2nd May-2nd November 2016). One study
122 hospital's operating theatre was no longer functional in the post-intervention phase. These 21
123 hospitals accounted for 45% of all caesarean sections performed nationally in 2016.²⁷ Women
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1 124 delivering by caesarean were included regardless of gestational age, whether they were referred to
2 125 the study hospital before the caesarean, or referred to another hospital after birth.

3 126 *Data source*

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7 127 Patient medical records were used in the DECIDE trial, with prospective data collection in the post-
8 128 intervention phase using data extraction forms and standardised clinical definitions (including for
9 129 labour dystocia, acute fetal distress, and indications for caesarean).¹⁸ We used post-intervention data
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11
12 130 to provide the most recent description for a larger sample.

13 14 15 131 *Outcome*

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17 132 We defined intrapartum-related perinatal mortality as the rate of fresh stillbirths and very early
18 133 neonatal deaths (within 24 hours of birth) per 1,000 caesareans.^{28 29} Intrapartum-related mortality is
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20 134 recommended by the WHO as an indicator of the quality of emergency obstetric and newborn care.³⁰

21 22 135 *Risk factors and conceptual approach*

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24 136 We examined two groups of risk factors for intrapartum-related mortality: individual-level clinical risk
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26 137 factors, and caesarean care components and hospital characteristics.

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28 138 We conceptualised case mix as the hospital prevalence of clinical risk factors for intrapartum-related
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30 139 mortality (maternal age, parity, highest educational level achieved, previous caesarean, multiple
31 140 pregnancy, number of antenatal visits, birthweight, congenital malformation, referral status and
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33 141 distance, labour phase, diagnosis of acute fetal distress, transverse lie/brow presentation in active
34 142 labour, other severe obstetric complication or maternal death, and primary indication for caesarean).
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36 143 “Other severe obstetric complications” included severe pre-eclampsia or eclampsia, retro-placental
37 144 haematoma, uterine (pre-)rupture, and placenta praevia in active labour. Uterine pre-rupture was
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39 145 defined as women with severe dystocia and signs of pre-rupture, such as Bandl’s ring. Acute fetal
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41 146 distress was defined as fetal heart rate <120 or >160 bpm, either persistent after oxygen
42 147 administration and lateral decubitus position, or with IUGR, placental abruption, prolonged labour,
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44 148 maternal fever, or meconium-stained amniotic fluid. Some women diagnosed with acute fetal distress
45 149 had a primary indication for caesarean other than “fetal distress” (e.g. pre-eclampsia), while some
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47 150 women had a caesarean with “fetal distress” recorded as the primary indication despite not having
48
49 151 met the diagnostic criteria for acute fetal distress.

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51 152 We conceptualised components of caesarean care (provider cadre deciding and performing the
52 153 caesarean, decision-to-incision interval, anaesthesia type, skin/uterine incision type, and antibiotic
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54 154 prophylaxis administration) and hospital characteristics (hospital type and monthly caesarean
55
56 155 volume) as potential indicators of quality of patient care. Monthly caesarean volume was calculated
57 156 as the mean number of caesareans performed per month in the study period, per hospital.

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59 157 We used these risk factors to derive two sets of risk-adjusted mortality rates per hospital: adjusting
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158 for case mix only, and additionally adjusting for components of care and hospital characteristics,

1 159 because some of these variables might capture unmeasured differences in case mix. For example,
2 160 women receiving general anaesthesia are more likely to have complications requiring urgent surgery.
3 161 Including these additional variables also allowed us to identify whether any care components (e.g.
4 162 decision-to-incision interval) were strongly associated with mortality. We included care components
5 163 prior to delivery as risk factors even when they were not hypothesised to causally affect perinatal
6 164 mortality, since they may be proxies for quality of care.
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11 *Multiple imputation of missing data among risk factors*

12 165 Data were complete for the outcome and nine risk factors, including multiple gestation, indication for
13 166 caesarean, and referral status (Supplementary Table 1). 11 risk factors had <5% missing values; six
14 167 risk factors had >5% missing data, including decision-to-incision interval (24%) and timing of antibiotic
15 168 administration (23%). Overall, 68% of women had at least one risk factor missing, and 4% had at
16 169 least four risk factors missing (Supplementary Table 2). Missing information on previous caesarean
17 170 was assumed to indicate no previous caesarean (n=40), and missing deciding provider cadre was
18 171 imputed as the hospital mode for seven women.
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25 173 Multiple imputation by chained equations was used for other variables to avoid a loss in efficiency,
26 174 because missing values were likely to be missing at random given known risk factors, including
27 175 referral status and severe obstetric complication.³¹ Five imputed datasets were created using the mi
28 176 package in Stata v14.2, including all risk factors and intrapartum-related mortality in the imputation
29 177 model. The same model was used for all hospitals, with hospital type included as a risk factor.
30 178 Missing values for continuous risk factors (age, parity, number of antenatal care visits, referral
31 179 distance, birthweight, and decision-to-incision interval) were imputed from linear regression models,
32 180 missing values for binary risk factors (acute fetal distress, antibiotic prophylaxis, incision type,
33 181 anaesthesia type, congenital malformation, and neonatal resuscitation) were imputed from logistic
34 182 regression models, and categorical risk factors (education, provider cadre performing the caesarean,
35 183 and timing of antibiotic administration) were imputed from multinomial regression models. Gestational
36 184 age at birth had >50% missing data; it was not considered as a risk factor in the analysis model,
37 185 since it is highly correlated with low birthweight, which was more complete and likely to be more
38 186 accurate in a setting without routine ultrasound in the first trimester. However, we included
39 187 gestational age at birth in the imputation model to improve the prediction of birthweight. Distributions
40 188 of imputed values were compared with observed values for variables with >5% missing data.
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51 *Hospital variation in intrapartum-related mortality rates*

52 189 First, we calculated crude hospital intrapartum-related mortality rates with 95% confidence intervals,
53 190 and described perinatal outcomes according to hospital type. Differences in hospital case mix were
54 191 assessed by describing the prevalence of clinical risk factor for intrapartum-related mortality among
55 192 women giving birth by caesarean, stratified by hospital and hospital type. We similarly described
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1 194 differences in components of care received. Chi-square tests accounted for clustering of women by
2 195 hospital using the svyset package in Stata.

5 196 Next, we built two multivariable models for intrapartum-related death among caesarean births using
6 multi-level logistic regression models of women, nested in hospitals to account for clustering. The first
7 197 model (model 1) adjusted for case mix only, and included all individual-level clinical risk factors for
8 198 intrapartum-related mortality with Wald test $p\text{-value} \leq 0.25$ in bivariate associations, using manual
9 backward selection to retain only variables with $p\text{-values} < 0.1$. The second model (model 2) built upon
10 199 model 1 by additionally including all care components and hospital characteristics with bivariate Wald
11 200 test $p\text{-value} \leq 0.25$, and similarly using backward selection to retain only $p\text{-values} < 0.1$. Multicollinearity
12 201 was examined by reviewing Spearman correlations and model standard errors. In building model 2,
13 202 provider cadre deciding the caesarean met the criteria for inclusion, however its inclusion reduced
14 the hospital-level estimate almost to zero, indicating that this variable acted as a proxy for broader
15 203 differences between hospitals. Further inspection showed that deciding providing cadre was highly
16 204 clustered within hospitals, with one category accounting for $>90\%$ of women in 13 of 21 hospitals. We
17 therefore removed it from risk factors considered for model 2.

26 209 We calculated the median odds ratio (OR) for model 1 and 2 as a measure of inter-hospital variation
27 210 in mortality that is not explained by the model covariates, expressed on the OR scale (see formula in
28 211 Supplementary Figure 1).³² For a multi-level model, the median OR is defined as the median of the
29 212 ORs that could be calculated by comparing two patients with identical individual-level characteristics
30 213 from two, randomly chosen, different hospitals.^{33 34}

35 214 Risk-adjusted mortality enables comparisons in hospital outcomes taking into account differences in
36 215 case mix.¹⁵⁻¹⁷ Risk-adjusted intrapartum-related mortality rates were calculated for each hospital by
37 216 multiplying the intrapartum-related mortality rate across the study sample by the ratio of the number
38 217 of observed deaths to predicted deaths based on model 1 and 2 in each hospital. Bootstrapping with
39 218 1,000 iterations was used to calculate 95% confidence intervals around both sets of risk-adjusted
40 219 hospital mortality rates and found to produce stable estimates. We used the Boot MI percentile
41 220 method to produce confidence intervals with nominal coverage.³⁵ We constructed graphs showing
42 221 risk-adjusted mortality and confidence intervals for each hospital, according to the mean monthly
43 222 number of caesareans in each hospital, to visually assess any associations between risk-adjusted
44 223 mortality and caesarean volume (Figure 1a-c).

51 224 The DECIDE trial found a reduction in avoidable caesareans,³⁶ suggesting changes in caesarean
52 225 decision-making which may affect intrapartum-related mortality. As a secondary analysis, we added
53 226 trial group as a risk factor to model 2 to determine whether it was associated with mortality after
54 227 adjusting for other covariates.

58 *Patient and public involvement*

60 229 No patients were involved in the design, conducting, reporting or dissemination of this study.

Results

Our analysis included 5,134 women giving birth by caesarean in the 21 study hospitals. Women with multiple pregnancies, congenital malformation, transverse lie/brow presentation in active labour, whose caesarean was decided by a non-physician provider with surgical skills, and delivering in a rural district hospital were more likely to have missing data for four or more risk factors (Supplementary Table 2).

Hospital variation in intrapartum-related perinatal mortality among caesarean births

Intrapartum-related perinatal mortality was high among caesarean births at 88 per 1,000 [95% CI: 81-96], including 65 per 1,000 fresh stillbirths and 23 per 1,000 deaths within 24 hours of birth (Table 1). Crude mortality rates varied substantially across hospitals, from 21 to 189 per 1,000. Intrapartum-related mortality tended to be higher in hospitals performing fewer caesarean sections (Figure 1A). Intrapartum-related mortality was higher in regional and rural district hospitals than in urban district hospitals (110 vs 46 per 1,000, $p=0.001$). Other perinatal outcomes showed similar patterns (Supplementary Table 3).

Table 1. Perinatal mortality among women giving birth by caesarean according to hospital type – Burkina Faso, 2016

		Fresh stillbirths (per 1,000)	Neonatal death within 24 hrs of births (live babies, per 1,000)	Intrapartum-related perinatal death (per 1,000) ^a	Intrapartum-related perinatal death – range across hospitals
Total	5,134	65	23	88	21-189
Hospital type					
Regional hospital	2,693	78	30	108	63-189
Urban district hospital	1,659	36	10	46	21-71
Rural district hospital	782	81	29	110	54-185
P-value	-	<0.001	0.016	<0.001	-

^aFresh stillbirth or neonatal death within 24 hours of birth

Note: confidence intervals and additional outcomes are reported in Supplementary Table 3

Hospital variation in clinical risk factors among women giving birth by caesarean section

Case mix varied substantially across hospitals, with a range of 5%-37% for parity of four or more, 2%-29% for birthweight <2500g, and 1%-11% for transverse lie or brow presentation in active labour (Table 2). Regional hospitals and rural district hospitals had higher-risk populations of women giving birth by caesarean than urban district hospitals, with higher proportions of intrapartum caesareans, women with high parity, and referred to the study hospital immediately prior to the caesarean ($p < 0.01$ for all).

1 259 **Table 2. Characteristics of women giving birth by caesarean section, across hospitals and hospital**
 2 260 **types (N=5,134)**
 3

	Range across hospitals	Regional hospital	Urban district hospital ^a	Rural district hospital	Total
N facilities		9	5	7	21
Monthly caesarean volume (median)	9-103	37	45	17	31
N women giving birth by caesarean	54-619	2,693	1,659	782	5,134
Age (%)					
13-19	6-31	20.2	10.1	22	17.2
20-29	37-53	44.8	49.8	43.9	46.3
30-39	22-38	30.1	35.2	27.9	31.4
40-49	0-6	3.2	3.3	2.7	3.1
Missing	0-8	1.7	1.6	3.6	2.0
Educational level (%)					
None	33-88	73.6	41.8	74.0	63.4
Primary	1-38	7.7	24.1	15.0	14.1
Secondary or higher	3-45	17.9	31.2	10.2	21.0
Missing	0-9	0.7	3.0	0.8	1.4
Parity (%)					
0	30-43	34.4	35.2	35.0	34.7
1-3	31-64	42.9	53.8	39.5	45.9
4 or more	5-37	22.5	10.9	25.1	19.1
Missing	0- 2	0.2	0.1	0.4	0.2
Number of previous caesarean sections (%)					
0	60-89	76.3	66.9	78.3	73.5
1	6-31	17.9	22.4	14.8	18.9
2-4	2-13	4.9	9.8	5.8	6.6
Missing	0- 4	0.9	1.0	1.2	1.0
Number of antenatal visits (%)					
0	0-6	0.9	0.4	1.3	0.8
1-3	19-74	36.5	36.4	40.0	37.0
4 or more	21-71	53.5	58.1	52.0	54.8
Missing	1-24	9.1	5.1	6.6	7.4
Multiple pregnancy (%)					
Yes	2-10	5.8	6.1	5.8	5.9
Congenital malformation (%)					
No	30-100	91.3	92.7	89.1	91.4
Yes	0-4	1.2	0.4	0.6	0.9
Missing	0-69	7.5	6.9	10.2	7.7
Birthweight (%)					
Birthweight \geq 2,500g	65-95	77.8	80.6	81.8	79.3
Birthweight $<$ 2,500g	2-29	17.2	13.2	11.9	15.1
Missing	1-16	5.1	6.2	6.3	5.6
Referral for antepartum complications or during labour (%)					
Yes	26-89	74.7	50.7	73.7	66.8
Distance from referring facility (%)					
$<$ 20km	0-85	18.7	47.4	23.4	26.6
20-450km	0-86	48.7	11.8	69.6	43.1
Distance unknown	0-99	32.6	40.8	6.9	30.3
Caesarean during labour (%)					

No	2-49	15	34.1	8.1	20.1
Yes	51-98	85	65.9	91.9	79.9
Primary indication for caesarean (%)					
Fetal distress	7-36	24.5	17.0	23.3	21.9
Prolonged labour	23-67	33.1	28.6	42.1	33.0
Previous caesarean	7-33	12.1	24.3	12.8	16.2
Pre-eclampsia	0- 8	4.2	4.1	1.7	3.8
Other	15-37	26.1	26	20.2	25.1
Diagnosis of acute fetal distress (%)	12-43	32.3	22.8	28.5	28.6
Transverse lie/brow presentation in active labour (%)	1-11	4.8	2.6	5.0	4.1
Other severe obstetric complication or maternal death (%)	6-38	22.6	14.3	19.6	19.5
<i>Severe pre-eclampsia/eclampsia</i>	2-13	6.4	6.1	3.2	5.8
<i>Retro-placental haematoma</i>	0- 5	2.8	1.5	1.4	2.2
<i>Placenta praevia in active labour</i>	0- 5	2	0.7	0.9	1.4
<i>Uterine (pre)-rupture</i>	2-24	12.3	6.4	15.0	10.8
<i>Maternal mortality (per 100,000)</i>	0-637	297	241	256	273

^aIn two largest cities (Ouagadougou and Bobo-Dioulasso)

Hospital variation in caesarean care received

Caesarean care differed between hospitals (Table 3). We found large differences in the type of provider (cadre) deciding for or conducting the caesarean between hospitals, with obstetricians deciding and performing 100% of caesareans in some hospitals, and non-physician providers deciding and performing over 90% of caesareans in others. Rural district hospitals relied primarily on generalist doctors and non-physician providers, while urban district hospitals relied primarily on obstetricians.

Hospitals reported up to 54% of caesareans performed more than one hour after decision. Almost 90% of all caesareans were performed under spinal anaesthesia, however in some hospitals 70% of caesareans were performed under general anaesthesia. General anaesthesia was more common in regional hospitals. Incision technique also showed important variation between hospitals, less so between hospital type. Antibiotic use was almost universal, recorded in 96% of women, but administered after skin incision in at least 41% of caesareans (62% estimated with imputed data, and up to 94% in individual hospitals).

1 278 **Table 3. Caesarean care received by women, across hospitals and hospital types (N=5,134)**

	Range across hospitals	Regional hospital	Urban district hospital	Rural district hospital	Total
N women	54-619	2,693	1,659	782	5,134
Cadre of provider deciding to perform caesarean					
Obstetrician	0-100	69.6	75.5	0.4	60.9
Generalist doctor with emergency surgical training	0-96	5.0	23.5	52.7	18.2
Generalist doctor	0-68	9.0	0.4	26.0	8.7
Midwife	0-100	16.1	0.4	7.5	9.7
Non-physician provider with surgical skills ^a	0-94	0.3	0.1	13.0	2.3
Missing	0-2	0.1	-	0.4	0.1
Cadre of provider who performed caesarean					
Obstetrician	0-100	28.3	68.9	0.1	37.1
Generalist doctor	0-88	13.0	11.8	44.6	17.4
Non-physician provider with obstetrics skills ^b	0-65	8.0	0.2	0.6	4.4
Non-physician provider with surgical skills ^a	0-94	48.3	18.9	54.2	39.7
Missing	0-8	2.4	0.2	0.4	1.4
Decision-to-incision interval					
<60 minutes	3-84	64.1	61.2	31.6	60.3
≥60 minutes	1-54	18.7	11.4	17.0	16.1
Missing	3-97	13.2	27.4	51.4	23.6
Type of anaesthesia					
Spinal	30-100	83.8	91	94.5	87.7
General/other	0-70	16.0	7.7	4.2	11.5
Missing	0-4	0.3	1.3	1.3	0.8
Type of skin incision					
Joel-Cohen	9-100	79.6	83.1	77.5	80.4
Pfannenstiel	0-84	16.8	12.1	9.7	14.2
Midline/other	0-11	2.8	1.1	0.9	1.9
Missing	0-39	0.8	3.7	11.9	3.4
Type of uterine incision					
Lower segment	45-100	94.7	98.3	94.8	95.9
Other	0-55	5.2	0.6	1.3	3.1
Missing	0-12	0.1	1.1	4.0	1.0
Antibiotic administration					
Antibiotics before incision	0-87	32.5	26.6	15.0	27.9
Antibiotics after incision	0-94	49.1	39.0	45.7	45.3
Antibiotics, timing unclear	2-95	12.6	32.9	35.2	22.6
No recorded antibiotics	0-10	2.0	0.5	0.4	1.3
Missing	0-22	3.9	0.9	3.8	2.9

47 279 ^aNurses or midwives with additional 3-year training in surgery; ^bMidwives with additional 3-year training in
 48 280 obstetrics and gynaecology, including performing caesareans

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 52
 53 282 **Risk factors for intrapartum-related mortality and risk-adjusted hospital mortality rates**

54 283 The median OR for crude intrapartum-related mortality was 1.9 [95% CI: 1.5-2.5], indicating that if a
 55 284 woman moved to another, randomly selected, hospital with higher mortality, the median increase in
 56 285 her odds of intrapartum-related mortality would be almost two-fold.

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2 286 In model 1, congenital malformation, diagnosis of acute fetal distress, transverse lie or brow
3 287 presentation in active labour, and other severe obstetric complication or maternal death were strongly
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5 288 associated with intrapartum-related mortality (Supplementary Table 4). Other risk factors retained in
6 289 the model were parity, education, number of antenatal visits, primary caesarean indication, referral
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8 290 immediately prior to caesarean, and birthweight. The median OR was 1.3 [1.2-1.7], indicating that a
9 291 woman moving to a different hospital with higher mortality would experience a 1.3-fold increase in
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11 292 odds of intrapartum-related mortality on average, a modest effect compared with individual-level
12 293 clinical risk factors. Inter-hospital variation in mortality rates was reduced, but not eliminated, after
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14 294 adjusting for individual-level risk factors, with larger variation among hospitals performing less than
15
16 295 50 caesareans per month (Figure 1B).

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18 296 In model 2, all clinical risk factors except for number of antenatal visits were retained in the model
19
20 297 with similar effect sizes, and two care component risk factors were identified – general anaesthesia,
21 298 and not receiving antibiotic prophylaxis (Figure 2, Supplementary Table 4). Decision-to-incision
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23 299 interval, hospital type and monthly caesarean volume were not independently associated with
24 300 intrapartum-related mortality. There was no meaningful change in inter-hospital variation after adding
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26 301 care components, compared with model 1 (median OR=1.4 [1.2-1.8], Figure 1C).

27
28 302 There was no evidence that adding trial arm improved the fit of model 2 ($p=0.78$).
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30 31 32 33 34 304 **Discussion**

35
36 305 Our study fills an important gap in the evidence by examining hospital variation in intrapartum-related
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38 306 perinatal mortality among caesarean births in sub-Saharan Africa, a region with a high burden of
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40 307 perinatal deaths. Almost one in ten women giving birth by caesarean in regional and district hospitals
41 308 in Burkina Faso experienced an intrapartum-related perinatal death. The substantial hospital variation
42 309 in crude mortality rates, ranging between 21-189 per 1,000, was markedly reduced after adjusting for
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44 310 individual-level differences in case mix between hospitals. However, important variation remained,
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46 311 with lower-volume hospitals tending to have higher and more variable adjusted mortality than
47 312 hospitals performing more caesareans per month. Additionally adjusting for caesarean care
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49 313 components did not further reduce variation. Remaining variation in adjusted rates indicate likely
50 314 differences in quality of caesarean care between hospitals, particularly those with low or moderate
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52 315 monthly caesarean volumes.

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54 316 Some of the remaining differences in risk-adjusted mortality rates between hospitals may be due to
55
56 317 unmeasured confounding by case mix, since the accuracy of obstetric complication measurement
57
58 318 using hospital records was likely limited. However, this is unlikely to explain all the variation in
59 319 adjusted mortality between lower-volume hospitals. Caesarean volume and hospital type were not
60
61 320 independently associated with intrapartum-related mortality in our study, although the number of

1 321 hospitals in our analysis (n=21) was too small to detect such effects. Hospitals performing more
2 322 caesareans likely differ from lower-volume hospitals in multiple ways affecting quality of perinatal
3 323 care, including presence of obstetricians or paediatricians, resources available for care of small and
4 324 sick newborns, as well as differences in access to care for the population they serve.
5 325

6 326 We identified two care components associated with intrapartum-related mortality: general
7 327 anaesthesia and not receiving antibiotic prophylaxis, each associated with a doubling of mortality,
8 328 compared with spinal anaesthesia and receiving antibiotics before incision. These odds ratios may
9 329 reflect unmeasured confounding by complication severity in the association with intrapartum-related
10 330 mortality, or differences in quality of care. Indeed, although general anaesthesia is independently
11 331 associated with perinatal mortality,³⁷ women undergoing general anaesthesia are also likely to be in
12 332 poorer clinical condition at the time of the caesarean, with independently higher risk of perinatal
13 333 death. Antibiotics may indicate very urgent caesareans without sufficient time to administer
14 334 antibiotics, or poor organisation of care, with up to 10% of women not receiving antibiotics in some
15 335 hospitals. Maternal antibiotic prophylaxis is unlikely to affect intrapartum-related survival.^{38 39} It is not
16 336 possible to disentangle the relative contributions of unmeasured confounding and quality of care for
17 337 these two care components with our data.
18 338

19 339 High rates of fresh stillbirths among caesarean births – 65 per 1,000 in our study, 60 per 1,000 total
20 340 stillbirths in a previous systematic review⁹ – indicate that many caesareans are performed too late in
21 341 Burkina Faso. Limited access to caesarean section contributes to these poor outcomes: a higher
22 342 proportion of women in sub-Saharan Africa arrive at the surgical hospital with severe complications
23 343 and more caesareans are performed in the second stage of labour, with higher associated
24 344 complications.⁹ Some babies may die before arrival at the hospital, but nonetheless are delivered by
25 345 caesarean. Indeed, our data indicate poor identification of stillbirths using the Pinard stethoscope in
26 346 this setting: one third of babies with no audible fetal heart rate were born alive, while one quarter of
27 347 macerated stillbirths had a recorded audible fetal heart rate. Other babies die *in utero* after arrival at
28 348 the hospital, due to delayed diagnosis of fetal distress or long waiting times between decision and
29 349 caesarean. We estimated a median decision-to-incision interval of 81 minutes for caesareans for fetal
30 350 distress, based on imputed data.
31 351

32 352 To our knowledge, this is the first study to examine hospital variation in crude and risk-adjusted
33 353 perinatal mortality in sub-Saharan Africa. A major strength of our study was the use of a novel
34 354 dataset with high-quality, detailed clinical information on all women delivering by caesarean section in
35 355 a six-month period in all Burkinabe regional and district hospitals with >200 caesareans per year. Our
36 356 21 study hospitals accounted for 45% of all caesareans performed in Burkina Faso in 2016.
37 357 University hospitals and lower-volume district hospitals accounted for 26% each, with only 3% in the
38 358 private sector.²⁷ While our results cannot be generalised to tertiary or private hospitals in Burkina
39 359 Faso, higher and more variable perinatal mortality is also likely to occur in lower-caesarean volume
40 360 hospitals in other West African countries.

1 358 Some data limitations are worth noting. Missing data were common for several risk factors. We used
2 359 multiple imputation to preserve statistical power, and the distribution of imputed variables was similar
3 360 to non-missing data. Moreover, like other studies using hospital records, some misclassification in
4 361 obstetric complication severity was likely, leading to residual unmeasured confounding in case mix
5 362 between hospitals. Indeed, limited granularity was available for severity (within pre-eclampsia, for
6 363 example), and previous studies indicate obstetric complications may be incompletely recorded or
7 364 overestimated in caesarean indications.⁴⁰⁻⁴² As a result, reported odds ratios for risk factors should be
8 365 interpreted as measures of association within our study population, rather than causal effects. The
9 366 number of hospitals in our sample was too small to enable us to examine hospital characteristics as
10 367 risk factors. We were also unable to examine hospital variation in maternal outcomes since post-
11 368 caesarean morbidity was not collected. Nonetheless, these prospectively collected trial data likely
12 369 represent the best available clinical data for caesarean sections in sub-Saharan Africa, and it would
13 370 have been difficult to further reduce complication misclassification.

14 371 Several recommendations for improving the quality of caesarean care stem from our findings. Two-
15 372 thirds of women were referred immediately prior to the caesarean, and those referred from further
16 373 away had higher rates of perinatal mortality. There is an urgent need to strengthen emergency
17 374 referral systems by minimising delays in women reaching surgical facilities, through shared
18 375 ambulances and maternity waiting homes, for example.⁴³ Delays in receiving treatment after arrival
19 376 should also be reduced, including through pre-referral notification and patient referral notes.⁴³
20 377 Improved antenatal care would help identify women needing an elective caesarean before labour.
21 378 Monitoring of labour should be improved for all women, including those with risk factors for
22 379 intrapartum-related mortality, to enable early intervention and prevent perinatal deaths among vaginal
23 380 and caesarean births. Provider training in fetal monitoring, supportive supervision, and making low-
24 381 cost Doppler ultrasounds widely available in hospitals would help improve identification of fetal
25 382 distress and stillbirths.⁴⁴ Many stillbirths can be delivered vaginally at lower risk of maternal
26 383 complications;⁹ however, suspected stillbirths should be confirmed with ultrasound scans, where
27 384 available, to avoid misdiagnosis. The decision-to-incision interval was not associated with
28 385 intrapartum-related mortality in our study, likely because of successful prioritisation of higher-risk
29 386 women and delayed decision to perform some caesareans. This mirrors the mixed results reported in
30 387 the literature, which is based on limited observational data only.⁴⁵ Nonetheless, the estimated median
31 388 81 minute interval for caesareans for fetal distress should be reduced closer to the 30 minutes
32 389 recommended in the UK and USA,^{46 47} wherever possible. Lastly, improving care for small and sick
33 390 newborns – including neonatal resuscitation and intensive care through the Helping babies breathe⁴⁸
34 391 programme and Every Newborn Action Plan⁴⁹ – is essential to increase survival after birth. Provider
35 392 training in newborn care has been shown to be cost-effective in other African countries.^{50 51}

36 393 Our data also suggest sub-optimal surgical technique which may affect maternal outcomes: although
37 394 the Joel-Cohen incision has advantages over the Pfannenstiel technique,⁵² the latter was used in at

1 395 least 14% of caesareans. An estimated 62% of women received antibiotics only after incision based
2 396 on imputed data, contrary to WHO recommendations.⁵³ Universal administration of antibiotic
3 397 prophylaxis before incision could help reduce the incidence of surgical site infection and sepsis,
4 398 which accounts for 10% of maternal deaths in sub-Saharan Africa.⁵⁴ The Lancet Global Surgery
5 399 commission recommendations for improving access to and the safety of essential surgical services in
6 400 low-resource settings should be followed,⁵⁵ first and foremost the creation of a national surgical plan
7 401 including provisions for healthcare delivery, human resources, financing, and information
8 402 management.

14 403 *Conclusions*

15 404 Women giving birth by caesarean section in Burkina Faso face a high risk of perinatal death. Our
16 405 study found variation in intrapartum-related perinatal mortality between hospitals remained after
17 406 adjustment for case mix, indicating that differences in quality of care contribute to variation in
18 407 perinatal mortality. Improving access to caesareans and the quality of caesarean care in the region is
19 408 a considerable challenge for Ministries of Health and reproductive health partners in West Africa;
20 409 improving training and resources for fetal distress monitoring, reducing decision-to-incision intervals,
21 410 and improving resuscitation and care of newborns seem important priorities to enable more babies to
22 411 survive at birth.

30 412 **Footnotes**

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Author contributions: FC conceptualised the study, with help from CR. CK and AD designed the DECIDE trial and oversaw data collection. FC designed the analyses and analysed the data, with support from RP, RB and AD. All authors, including SS and APB, contributed to the interpretation of results and writing of the final manuscript.

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Ethics Approval Statement: The DECIDE trial received ethical approval from the National Ethics Committee in Burkina Faso (#2014-02-016) and the Ethics Committee of the University of Montreal

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2 428 Hospital Research Centre in Canada (#13.356).³⁶ As a secondary analysis of de-identified data, this
3 429 study did not require ethical approval from the UCL Ethics Committee.
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2 **433 List of figures**

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6 435 **Figure 1. Crude and risk-adjusted hospital intrapartum-related mortality rates among women giving**
7 436 **birth by caesarean section in 21 hospitals, according to mean monthly number of caesareans – Burkina**
8 437 **Faso, 2016**

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12 439 **Figure 2. Odds ratios and 95% confidence intervals for risk factors for intrapartum-related mortality**
13 440 **among women giving birth by caesarean section in 21 hospitals (model 2) – Burkina Faso, 2016**

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References

1. Montagu D, Sudhinaraset M, Diamond-Smith N, et al. Where women go to deliver: understanding the changing landscape of childbirth in Africa and Asia. *Health Policy and Planning* 2017;32(8):1146-52. doi: 10.1093/heapol/czx060
2. Gabrysch S, Nesbitt RC, Schoeps A, et al. Does facility birth reduce maternal and perinatal mortality in Brong Ahafo, Ghana? A secondary analysis using data on 119 244 pregnancies from two cluster-randomised controlled trials. *The Lancet Global Health* 2019;7(8):e1074-e87. doi: [https://doi.org/10.1016/S2214-109X\(19\)30165-2](https://doi.org/10.1016/S2214-109X(19)30165-2)
3. Kunkel M, Marete I, Cheng ER, et al. Place of delivery and perinatal mortality in Kenya. *Seminars in Perinatology* 2019;43(5):252-59. doi: <https://doi.org/10.1053/j.semperi.2019.03.014>
4. Cavallaro FL, Benova L, Dioukhane EH, et al. What the percentage of births in facilities does not measure: readiness for emergency obstetric care and referral in Senegal. *BMJ Global Health* 2020;5(3):e001915. doi: 10.1136/bmjgh-2019-001915
5. Boerma T, Ronsmans C, Melesse DY, et al. Global epidemiology of use of and disparities in caesarean sections. *The Lancet* 2018;392(10155):1341-48. doi: 10.1016/S0140-6736(18)31928-7
6. Cavallaro FL, Pembe AB, Campbell O, et al. Caesarean section provision and readiness in Tanzania: analysis of cross-sectional surveys of women and health facilities over time. *BMJ Open* 2018;8(9):e024216. doi: 10.1136/bmjopen-2018-024216
7. Benova L, Dennis ML, Lange IL, et al. Two decades of antenatal and delivery care in Uganda: a cross-sectional study using Demographic and Health Surveys. *BMC Health Services Research* 2018;18(1):758. doi: 10.1186/s12913-018-3546-3
8. Biccard BM, Madiba TE, Kluyts HL, et al. Perioperative patient outcomes in the African Surgical Outcomes Study: a 7-day prospective observational cohort study. *Lancet* 2018 doi: 10.1016/s0140-6736(18)30001-1
9. Sobhy S, Arroyo-Manzano D, Murugesu N, et al. Maternal and perinatal mortality and complications associated with caesarean section in low-income and middle-income countries: a systematic review and meta-analysis. *The Lancet* 2019;393(10184):1973-82. doi: [https://doi.org/10.1016/S0140-6736\(18\)32386-9](https://doi.org/10.1016/S0140-6736(18)32386-9)
10. Compaoré GD, Sombié I, Ganaba R, et al. Readiness of district and regional hospitals in Burkina Faso to provide caesarean section and blood transfusion services: a cross-sectional study. *BMC Pregnancy and Childbirth* 2014;14(1):158. doi: 10.1186/1471-2393-14-158
11. Richard F, Ouédraogo C, De Brouwere V. Quality cesarean delivery in Ouagadougou, Burkina Faso: A comprehensive approach. *Int J Gynecol Obstet* 2008;103(3):283-90. doi: <http://dx.doi.org/10.1016/j.ijgo.2008.08.008>
12. Nyamtema A, Mwakatundu N, Dominico S, et al. Increasing the availability and quality of caesarean section in Tanzania. *Bjog* 2016;123(10):1676-82. doi: 10.1111/1471-0528.14223
13. Kasongo S, Mukuku O, Kinenkinda X, et al. Kakoma JB. Quality of Caesarean Delivery and its Determinants in Lubumbashi, Democratic Republic of Congo. *Ann Obstet Gynecol* 2020;1:1014.
14. Bishop D, Dyer RA, Maswime S, et al. Maternal and neonatal outcomes after caesarean delivery in the African Surgical Outcomes Study: a 7-day prospective observational cohort study. *The Lancet Global Health* 2019;7(4):e513-e22. doi: 10.1016/S2214-109X(19)30036-1
15. Bragg F, Cromwell DA, Edozien LC, et al. Variation in rates of caesarean section among English NHS trusts after accounting for maternal and clinical risk: cross sectional study. *BMJ* 2010;341:c5065. doi: 10.1136/bmj.c5065
16. Schemann K, Patterson JA, Nippita TA, et al. Variation in hospital caesarean section rates for women with at least one previous caesarean section: a population based cohort study. *BMC Pregnancy and Childbirth* 2015;15(1):179. doi: 10.1186/s12884-015-0609-x
17. Bailit JL, Love TE, Dawson NV. Quality of obstetric care and risk-adjusted primary cesarean delivery rates. *Am J Obstet Gynecol* 2006;194(2):402-7. doi: 10.1016/j.ajog.2005.07.045
18. Kabore C, Ridde V, Kouanda S, et al. DECIDE: a cluster randomized controlled trial to reduce non-medically indicated caesareans in Burkina Faso. *BMC Pregnancy Childbirth* 2016;16(1):322. doi: 10.1186/s12884-016-1112-8
19. Global Health Observatory. Births by caesarean section - Data by country. 2018 [Available: <http://apps.who.int/gho/data/view.main.BIRTHSBYCAESAREANv> accessed December 2019]
20. Institut National de la Statistique et de la Démographie (INSD) and ICF International. Enquête Démographique et de Santé et à Indicateurs Multiples du Burkina Faso 2010. Calverton, Maryland, USA: ISND and ICF International; 2012 [Available: <https://dhsprogram.com/pubs/pdf/FR256/FR256.pdf> accessed December 2019]
21. Boatin AA, Schlottheuber A, Betran AP, et al. Within country inequalities in caesarean section rates: observational study of 72 low and middle income countries. *BMJ* 2018;360:k55. doi: 10.1136/bmj.k55
22. INSD. Enquête multisectorielle continue (EMC) 2014 - Santé générale et santé de la reproduction. Institut national de la statistique et de la démographie [Burkina Faso]; 2015 [Available:

- 1 [http://www.insd.bf/n/contenu/enquetes_recensements/Enq EMC/Sante generale et Sante de la r%](http://www.insd.bf/n/contenu/enquetes_recensements/Enq EMC/Sante generale et Sante de la r%e9production.pdf)
 2 [e9production.pdf](http://www.insd.bf/n/contenu/enquetes_recensements/Enq EMC/Sante generale et Sante de la r%e9production.pdf) accessed October 2019]
- 3 508 23. Witter S, Boukhalfa C, Cresswell JA, et al. Cost and impact of policies to remove and reduce fees for
 4 509 obstetric care in Benin, Burkina Faso, Mali and Morocco. *International Journal for Equity in Health*
 5 510 2016;15(1):123. doi: 10.1186/s12939-016-0412-y
- 6 511 24. Ganaba R, Ilboudo PGC, Cresswell JA, et al. The obstetric care subsidy policy in Burkina Faso: what are
 7 512 the effects after five years of implementation? Findings of a complex evaluation. *BMC Pregnancy and*
 8 513 *Childbirth* 2016;16(1):84. doi: 10.1186/s12884-016-0875-2
- 9 514 25. Ridde V, Richard F, Bicaba A, et al. The national subsidy for deliveries and emergency obstetric care in
 10 515 Burkina Faso. *Health Policy Plan* 2011;26 Suppl 2:ii30-40. doi: 10.1093/heapol/czr060
- 11 516 26. Richard F, Zongo S, Ouattara F. Fear, guilt, and debt: an exploration of women's experience and
 12 517 perception of cesarean birth in Burkina Faso, West Africa. *Int J Womens Health* 2014;6:469-78. doi:
 13 518 10.2147/ijwh.S54742
- 14 519 27. Ministère de la Santé du Burkina Faso. Annuaire Statistique 2016, 2017.
- 15 520 28. Goldenberg RL, McClure EM, Kamath BD. Intrapartum perinatal mortality. *Indian pediatrics* 2012;49(3):187-
 16 521 88. doi: 10.1007/s13312-012-0050-4
- 17 522 29. MEASURE Evaluation. Intrapartum and very early neonatal death rate. [Available:
 18 523 [https://www.measureevaluation.org/prh/rh_indicators/womens-health/nb/intrapartum-and-very-early-](https://www.measureevaluation.org/prh/rh_indicators/womens-health/nb/intrapartum-and-very-early-neonatal-death-rate)
 19 524 [neonatal-death-rate](https://www.measureevaluation.org/prh/rh_indicators/womens-health/nb/intrapartum-and-very-early-neonatal-death-rate) accessed March 2020]
- 20 525 30. WHO, UNFPA, UNICEF, et al. Monitoring emergency obstetric care: a handbook. Geneva, Switzerland:
 21 526 World Health Organisation. 2009 [Available:
 22 527 <https://www.who.int/reproductivehealth/publications/monitoring/9789241547734/en/> accessed
 23 528 November 2019]
- 24 529 31. Sterne JAC, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical
 25 530 research: potential and pitfalls. *BMJ* 2009;338:b2393. doi: 10.1136/bmj.b2393
- 26 531 32. Sanagou M, Wolfe R, Forbes A, et al. Hospital-level associations with 30-day patient mortality after cardiac
 27 532 surgery: a tutorial on the application and interpretation of marginal and multilevel logistic regression.
 28 533 *BMC Medical Research Methodology* 2012;12(1):28. doi: 10.1186/1471-2288-12-28
- 29 534 33. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health: integrating random
 30 535 and fixed effects in multilevel logistic regression. *Am J Epidemiol* 2005;161(1):81-8. doi:
 31 536 10.1093/aje/kwi017
- 32 537 34. Larsen K, Petersen JH, Budtz-Jørgensen E, et al. Interpreting parameters in the logistic regression model
 33 538 with random effects. *Biometrics* 2000;56(3):909-14. doi: 10.1111/j.0006-341x.2000.00909.x
- 34 539 35. Bartlett JW, Hughes RA. Bootstrap inference for multiple imputation under uncongeniality and
 35 540 misspecification. *Statistical Methods in Medical Research* 2020;29(12):3533-46. doi:
 36 541 10.1177/0962280220932189
- 37 542 36. Kaboré C, Ridde V, Chaillet N, et al. DECIDE: a cluster-randomized controlled trial to reduce unnecessary
 38 543 caesarean deliveries in Burkina Faso. *BMC Medicine* 2019;17(1):87. doi: 10.1186/s12916-019-1320-y
- 39 544 37. Fenton PM, Whitty CJM, Reynolds F. Caesarean section in Malawi: prospective study of early maternal and
 40 545 perinatal mortality. *BMJ* 2003;327(7415):587. doi: 10.1136/bmj.327.7415.587
- 41 546 38. Smaill FM, Grivell RM. Antibiotic prophylaxis versus no prophylaxis for preventing infection after cesarean
 42 547 section. *Cochrane Database Syst Rev* 2014;2014(10):Cd007482. doi:
 43 548 10.1002/14651858.CD007482.pub3
- 44 549 39. Bollig C, Nothacker M, Lehane C, et al. Prophylactic antibiotics before cord clamping in cesarean delivery: a
 45 550 systematic review. *Acta Obstet Gyn Scan* 2018;97(5):521-35. doi: <https://doi.org/10.1111/aogs.13276>
- 46 551 40. Kabore C, Ridde V, Kouanda S, et al. Determinants of non-medically indicated cesarean deliveries in
 47 552 Burkina Faso. *Int J Gynaecol Obstet* 2016;135 Suppl 1:S58-s63. doi: 10.1016/j.ijgo.2016.08.019
- 48 553 41. Landry E, Pett C, Fiorentino R, et al. Assessing the quality of record keeping for cesarean deliveries: results
 49 554 from a multicenter retrospective record review in five low-income countries. *BMC Pregnancy and*
 50 555 *Childbirth* 2014;14(1):139.
- 51 556 42. Cavallaro FL, Hurt LS, Cresswell JA, et al. Testing the assumptions of an indicator of unmet need for
 52 557 obstetric surgery in Ghana: A cross-sectional study of linked hospital and population-based delivery
 53 558 data. *Birth* 2019;46(4):638-47. doi: <https://doi.org/10.1111/birt.12452>
- 54 559 43. Pittalis C, Brugha R, Gajewski J. Surgical referral systems in low- and middle-income countries: A review of
 55 560 the evidence. *PLOS ONE* 2019;14(9):e0223328. doi: 10.1371/journal.pone.0223328
- 56 561 44. Byaruhanga R, Bassani DG, Jagau A, et al. Use of wind-up fetal Doppler versus Pinard for fetal heart rate
 57 562 intermittent monitoring in labour: a randomised clinical trial. *BMJ Open* 2015;5(1):e006867. doi:
 58 563 10.1136/bmjopen-2014-006867
- 59 564 45. Cavallaro FL, Marchant TJ. Responsiveness of emergency obstetric care systems in low- and middle-
 60 565 income countries: a critical review of the "third delay". *Acta Obstet Gyn Scan* 2013;92(5):496-507. doi:
 61 566 10.1111/aogs.12071
- 62 567 46. RCOG. Classification of urgency of caesarean section - a continuum of risk. Royal College of Obstetricians
 63 568 and Gynaecologists, Royal College of Anaesthetists; 2010 [Available:

- 1 569 <https://www.rcog.org.uk/globalassets/documents/guidelines/goodpractice11classificationofurgency.pdf>
2 570 accessed November 2019]
- 3 571 47. ACOG. Standards for Obstetric Services. Sixth ed. In: The College, ed. Washington, DC, 1988.
- 4 572 48. Versantvoort JMD, Kleinhout MY, Ockhuijsen HDL, et al. Helping Babies Breathe and its effects on
5 573 intrapartum-related stillbirths and neonatal mortality in low-resource settings: a systematic review.
6 574 *Archives of Disease in Childhood* 2020;105(2):127-33. doi: 10.1136/archdischild-2018-316319
- 7 575 49. WHO, UNICEF. Every Newborn: an action plan to end preventable deaths. Geneva: World Health
8 576 Organization; 2014 [Available: [https://www.healthynewbornnetwork.org/hnn-](https://www.healthynewbornnetwork.org/hnn-content/uploads/Every_Newborn_Action_Plan-ENGLISH_updated_July2014.pdf)
9 577 [content/uploads/Every_Newborn_Action_Plan-ENGLISH_updated_July2014.pdf](https://www.healthynewbornnetwork.org/hnn-content/uploads/Every_Newborn_Action_Plan-ENGLISH_updated_July2014.pdf) accessed May 2021]
- 10 578 50. Bogdewic S, Ramaswamy R, Goodman DM, et al. The cost-effectiveness of a program to reduce
11 579 intrapartum and neonatal mortality in a referral hospital in Ghana. *PLOS ONE* 2020;15(11):e0242170.
12 580 doi: 10.1371/journal.pone.0242170
- 13 581 51. Manasyan A, Chomba E, McClure EM, et al. Cost-effectiveness of essential newborn care training in urban
14 582 first-level facilities. *Pediatrics* 2011;127(5):e1176-e81. doi: 10.1542/peds.2010-2158
- 15 583 52. Mathai M, Hofmeyr GJ, Mathai NE. Abdominal surgical incisions for caesarean section. *Cochrane Database*
16 584 *Syst Rev* 2013(5):Cd004453. doi: 10.1002/14651858.CD004453.pub3
- 17 585 53. WHO. WHO recommendations for prevention and treatment of maternal peripartum infections. Geneva:
18 586 World Health Organization; 2015 [Available:
19 587 https://apps.who.int/iris/bitstream/handle/10665/186171/9789241549363_eng.pdf?sequence=1
20 588 accessed June 2019]
- 21 589 54. Seale AC, Mwaniki M, Newton CRJC, et al. Maternal and early onset neonatal bacterial sepsis: burden and
22 590 strategies for prevention in sub-Saharan Africa. *The Lancet Infectious Diseases* 2009;9(7):428-38. doi:
23 591 [https://doi.org/10.1016/S1473-3099\(09\)70172-0](https://doi.org/10.1016/S1473-3099(09)70172-0)
- 24 592 55. Meara JG, Leather AJM, Hagander L, et al. Global Surgery 2030: evidence and solutions for achieving
25 593 health, welfare, and economic development. *The Lancet* 2015;386(9993):569-624. doi: 10.1016/S0140-
26 594 6736(15)60160-X

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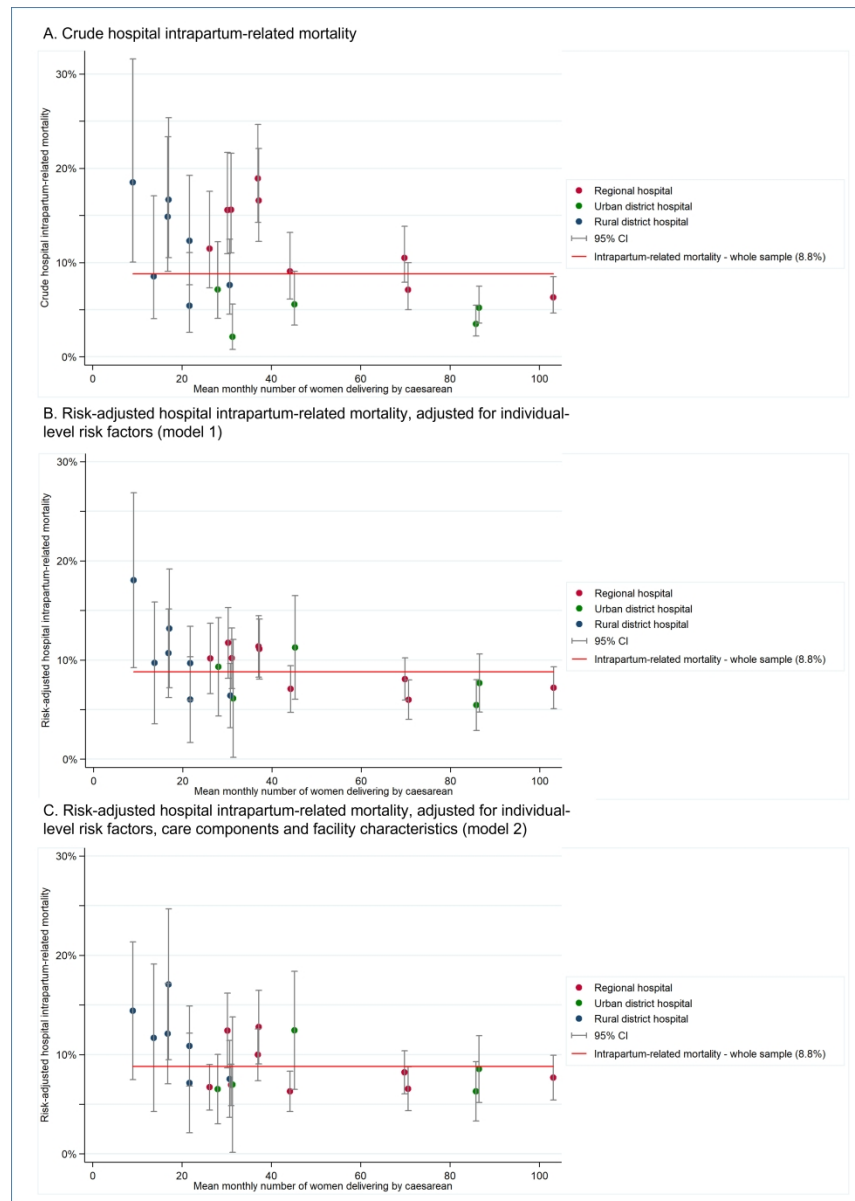


Figure 1. Crude and risk-adjusted hospital inpatient-related mortality rates among women giving birth by caesarean section in 21 hospitals, according to mean monthly number of caesareans – Burkina Faso, 2016

355x496mm (330 x 330 DPI)

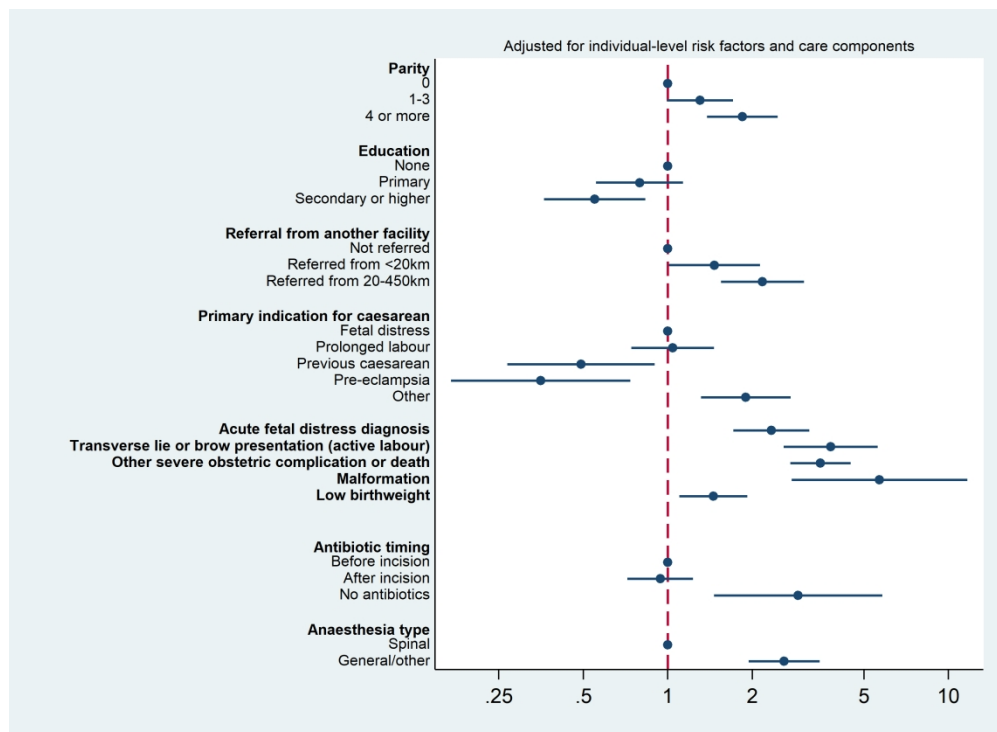


Figure 2. Odds ratios and 95% confidence intervals for risk factors for intrapartum-related mortality among women giving birth by caesarean section in 21 hospitals (model 2) – Burkina Faso, 2016

1058x769mm (72 x 72 DPI)

Supplementary materials

Supplementary Figure 1. Odds ratios and 95% confidence intervals for individual-level risk factors for intrapartum-related mortality (model 1)

$$\text{median OR} = \exp[\sqrt{2 \times \tau^2 \times 0.6745}]$$

where τ^2 is the hospital-level variance.

Supplementary Table 1. Missing data for risk factors for intrapartum-related perinatal mortality among 5,134 women in sample

Variable	N total expected	N missing	% missing (whole sample)	% missing (sub-sample)
Risk factors for which all women are expected to have data				
Maternal age	5,134	102	2.0	-
Parity	5,134	10	0.2	-
Education	5,134	74	1.4	-
Previous caesarean	5,134	0	0	-
Number of antenatal visits	5,134	382	7.4	-
Multiple pregnancy	5,134	0	0	-
Malformation	5,134	396	7.7	-
Birthweight	5,134	253	4.9	-
Acute fetal distress diagnosis	5,134	496	9.7	-
Transverse lie or brow presentation	5,134	0	0	-
Other severe obstetric complication or maternal death	5,134	0	0	-
Neonatal resuscitation	5,134	242	4.7	-
Labour phase	5,134	0	0	-
Referral status	5,134	0	0	-
Primary indication for caesarean	5,134	0	0	-
Provider deciding to perform caesarean	5,134	7	0.1	-
Provider performing caesarean	5,134	71	1.4	-
Decision-incision interval	5,134	1212	23.6	-
Anaesthesia type	5,134	39	0.8	-
Skin incision type	5,134	176	3.4	-
Antibiotic prophylaxis administration	5,134	149	2.9	-
Hospital type	5,134	0	0	-
Monthly caesarean volume	5,134	0	0	-
Risk factors for which a subset of women are expected to have data				
Birthweight for second baby among multiple pregnancies	301	91	1.8	30.2
Referral distance among referred women	3,429	1039	20.2	30.3
Timing of antibiotic administration among women receiving antibiotic prophylaxis	4,918	1159	22.6	23.6
Variable used in the imputation model but not in the risk factor analysis				
Gestational age at birth	5,134	2808	54.7	-

Supplementary Table 2. Characteristics of women with missing data on risk factors among 5,134 women in sample

Risk factor	N	Missing data for 0 risk factors (row %)	Missing data for 1-3 risk factors (row %)	Missing data for 4 or more risk factors (row %)
Maternal age				
13-19	883	31	65	4
20-29	2,376	33	63	4
30-39	1,612	33	63	4
40-49	161	26	70	4
Missing	102	0	90	10
Parity				
0	1,784	33	64	4
1-3	2,358	32	64	4
4 or more	982	29	67	4
Missing	10	0	70	30
Education				
None	3,256	31	65	4
Primary	724	29	66	4
Secondary or higher	1,080	38	60	2
Missing	74	0	88	12
Previous caesarean				
No	3,776	31	65	4
Yes	1,308	33	64	3
Missing	50	24	54	22
Number of antenatal care visits				
0	42	19	76	5
1-3	1,899	32	65	3
4 or more	2,811	36	61	3
Missing	382	0	87	13
Multiple pregnancy				
No	4,833	32	64	4
Yes	301	20	71	9
Congenital malformation				
No	4,694	35	64	2
Yes	44	14	77	9
Missing	396	0	73	27
Gestational age at birth				
Preterm	286	26	69	6
Term	2,040	36	61	3
Missing	2,715	30	66	4
Birthweight				
Birthweight \geq 2,500g	4,071	35	63	2
Birthweight $<$ 2,500g	775	28	68	3
Missing	288	0	72	28
Acute fetal distress				
No	3,168	34	64	2
Yes	1,470	37	61	2
Missing	496	0	81	19
Transverse lie or brow presentation in active labour				
No	4,922	32	65	4
Yes	212	29	63	8

1	Other severe obstetric complication or maternal death				
2	No	4,125	32	64	3
3	Yes	1,009	29	66	5
4	Neonatal resuscitation				
5	No	4,273	34	63	2
6	Yes	619	27	70	3
7	Missing	242	0	70	30
8	Labour phase				
9	Pre-labour	1,031	29	67	4
10	Latent phase	1,577	36	61	3
11	Active phase	2,526	30	66	4
12	Referral status				
13	Not referred before caesarean	1,705	39	58	3
14	Referred before caesarean	3,429	28	68	4
15	Referral distance				
16	<20km	911	43	55	3
17	20-450km	1,479	39	58	4
18	Distance unknown	1,039	0	94	6
19	Primary indication for caesarean				
20	Fetal distress	1,125	36	61	3
21	Prolonged labour	1,695	31	66	4
22	Previous caesarean	830	30	66	3
23	Pre-eclampsia	193	28	67	5
24	Other	1,291	31	64	5
25	Provider cadre deciding to perform caesarean				
26	Obstetrician	3,129	37	60	3
27	Generalist doctor with emergency surgical training	936	27	68	4
28	Generalist doctor	446	21	74	5
29	Midwife	500	24	73	3
30	Non-physician provider with surgical skills	116	7	86	7
31	Missing	7	0	71	29
32	Provider cadre performing caesarean				
33	Obstetrician	1,905	32	63	5
34	Generalist doctor	895	28	67	5
35	Non-physician provider with obstetrics skills	224	18	81	0
36	Non-physician provider with surgical skills	2,039	36	62	3
37	Missing	71	0	92	8
38	Decision-to-incision interval				
39	<60min	878	36	61	2
40	≥60min	3,044	43	56	1
41	Missing	1,212	0	89	11
42	Anaesthesia type				
43	Spinal	4,505	32	64	3
44	General/other	590	29	66	5
45	Missing	39	0	46	54
46	Skin incision type				
47	Joel-Cohen	4,128	34	63	3
48	Pfannenstiel	730	27	70	4
49	Midline/other	100	25	72	3
50	Missing	176	0	78	22
51	Uterine incision type				
52	Lower segment	4,921	33	64	3
53	Other	161	11	86	2
54	Missing	52	0	60	40

Antibiotic prophylaxis administration				
Antibiotics before incision	1,434	43	56	1
Antibiotics after incision	2,325	43	56	1
Antibiotics, timing unclear	1,159	0	90	10
No recorded antibiotics	67	24	75	1
Missing	149	0	74	26
Hospital type				
Regional hospital	2,693	39	58	2
Urban district hospital	1,659	26	70	4
Rural district hospital	782	18	75	7
Mean monthly caesarean volume				
<30	923	25	70	4
30-60	1,717	20	74	5
60-105	2,494	42	56	2

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Supplementary Table 3. Maternal and perinatal outcomes among women giving birth by caesarean section in 21 hospitals – Burkina Faso, 2016

	N women	Perinatal outcomes						
		Macerated stillbirths (per 1,000)	Fresh stillbirths (per 1,000)	Apgar score <3, live birth (per 1,000)	Neonatal death within 24 hrs of birth (per 1,000)	Neonatal death after 24 hrs, before discharge (per 1,000)	Intrapartum-related perinatal death (per 1,000)	Total perinatal death before discharge (per 1,000)
Total	5,134	7 [5-9]	65 [58-72]	24 [20-29]	23 [20-28]	3 [2-5]	88 [81-96]	98 [90-107]
Range across hospitals	5,134	0-23	16-135	0-90	0-90	0-32	21-189	32-243
Facility type								
Regional hospital	2,693	9 [6-14]	78 [68-89]	32 [26-39]	30 [24-37]	4 [2-7]	108 [97-120]	121 [109-134]
Urban district hospital	1,659	3 [1-7]	36 [28-46]	9 [5-15]	10 [06-16]	2 [1-6]	46 [37-57]	51 [42-63]
Rural district hospital	782	5 [2-14]	81 [63-102]	31 [21-45]	29 [20-44]	4 [1-12]	110 [90-134]	119 [98-144]
P-value	-	0.08	<0.001	0.029	0.016	0.793	0.001	0.001

Supplementary table 4. Risk factors for intrapartum-related deaths among 5,134 women giving birth by caesarean section in 21 hospitals – Burkina Faso, 2016

Risk factor	Unadjusted OR (95% CI)	Model 1 ^a (95% CI)	Model 2 ^b (95% CI)
Individual-level clinical risk factors			
Maternal age			
13-19	1 [ref]	-	-
20-29	1.31 (0.98-1.76)	-	-
30-39	1.56 (1.15-2.10)	-	-
40-54	2.09 (1.21-3.58)	-	-
Parity			
0	1 [ref]	1 [ref]	1 [ref]
1-3	1.15 (0.90-1.47)	0.80 (0.56-1.13)	1.30 (0.99-1.71)
4 or more	2.46 (1.91-3.18)	0.52 (0.34-0.78)	1.84 (1.38-2.46)
Education			
None	1 [ref]	1 [ref]	1 [ref]
Primary	0.64 (0.46-0.89)	0.89 (0.61-1.31)	0.79 (0.56-1.13)
Secondary or higher	0.31 (0.21-0.46)	0.53 (0.34-0.85)	0.55 (0.36-0.83)
Number of previous caesareans			
0	1 [ref]	-	-
1 or more	0.39 (0.29-0.52)	-	-
Number of ANC visits			
0	1 [ref]	1 [ref]	-
1-3	0.58 (0.24-1.36)	0.54 (0.19-1.48)	-
4 or more	0.35 (0.15-0.81)	0.43 (0.16-1.18)	-
Multiple pregnancy			
No	1 [ref]	-	-
Yes	1.43 (0.99-2.07)	-	-
Malformation			
No	1 [ref]	1 [ref]	1 [ref]
Yes	7.15 (3.75-13.64)	6.01 (2.95-12.23)	5.67 (2.79-11.55)
Birthweight			
Birthweight ≥2,500g	1 [ref]	1 [ref]	1 [ref]
Birthweight <2,500g	1.77 (1.39-2.25)	1.50 (1.14-1.97)	1.45 (1.10-1.92)
Diagnosis of acute fetal distress			
No	1 [ref]	1 [ref]	1 [ref]
Yes	2.26 (1.79-2.86)	2.42 (1.80-3.26)	2.34 (1.72-3.17)
Transverse lie or brow presentation in active labour			
No	1 [ref]	1 [ref]	1 [ref]
Yes	3.69 (2.65-5.13)	3.56 (2.43-5.22)	3.81 (2.59-5.59)
Other severe obstetric complication or maternal death			
No	1 [ref]	1 [ref]	1 [ref]
Yes	3.49 (2.84-4.29)	3.88 (3.04-4.95)	3.50 (2.73-4.49)
Labour phase			
Pre-labour	1 [ref]	-	-
Latent phase	1.20 (0.84-1.71)	-	-
Active phase	2.12 (1.53-2.92)	-	-

Referral status			
Not referred	1 [ref]	1 [ref]	1 [ref]
Referred from <20km	2.17 (1.51-3.11)	1.52 (1.04-2.21)	1.46 (1.01-2.13)
Referred from 20-450km	4.24 (3.10-5.80)	2.17 (1.55-3.04)	2.18 (1.55-3.06)
Decision-to-delivery interval			
<60 minutes	1 [ref]	-	-
≥60 minutes	0.85 (0.65-1.11)	-	-
Primary indication for caesarean			
Fetal distress	1 [ref]	1 [ref]	1 [ref]
Prolonged labour	1.10 (0.85-1.43)	1.14 (0.81-1.59)	1.04 (0.74-1.46)
Previous caesarean	0.23 (0.13-0.39)	0.51 (0.28-0.92)	0.49 (0.27-0.90)
Pre-eclampsia	0.59 (0.31-1.13)	0.38 (0.19-0.80)	0.35 (0.17-0.74)
Other	1.37 (1.04-1.80)	2.08 (1.44-3.00)	1.90 (1.31-2.74)
Caesarean care components and hospital characteristics			
Provider cadre deciding the caesarean			
Obstetrician	1 [ref]		-
Generalist doctor with emergency surgical training	1.20 (0.84-1.73)		-
Generalist doctor	1.20 (0.73-1.96)		-
Midwife	1.78 (1.07-2.96)		-
Non-physician provider with surgical skills ^c	1.87 (0.82-4.28)		-
Provider cadre performing the caesarean			
Obstetrician	1 [ref]		-
Generalist doctor	0.94 (0.62-1.44)		-
Non-physician provider with obstetrics skills ^d	1.47 (0.81-2.68)		-
Non-physician provider with surgical skills ^c	1.01 (0.68-1.49)		-
Type of anaesthesia			
Spinal	1 [ref]		1 [ref]
General/other	4.46 (3.41-5.84)		2.60 (1.94-3.47)
Type of skin incision			
Joel-Cohen	1 [ref]		-
Other	0.89 (0.62-1.28)		-
Type of uterine incision			
Lower segment	1 [ref]		-
Other	1.23 (0.69-2.19)		-
Antibiotics administration			
Antibiotics before incision	1 [ref]		1 [ref]
Antibiotics after incision	0.99 (0.74-1.31)		0.94 (0.72-1.23)
No recorded antibiotics	2.31 (1.25-4.25)		2.91 (1.46-5.81)
Neonatal resuscitation			
No	1 [ref]		-
Yes	1.71 (1.31-2.24)		-
Hospital type			
Regional hospital	1 [ref]		-
Urban district hospital	0.36 (0.23-0.58)		-
Rural district hospital	0.96 (0.62-1.47)		-
Hospital caesarean volume (per month)			

1			
2	<30	1 [ref]	-
3	30-60	0.93 (0.55-1.57)	-
4	60-105	0.53 (0.30-0.94)	-

5 ^aModel 1 was built by manual backward elimination of individual-level risk factors with $p > 0.1$ in a model
6 including all variables with $p < 0.25$ in the unadjusted model, with the exception of maternal age which had
7 $p < 0.25$ in the unadjusted model but was removed due to collinearity with parity

8
9 ^bModel 2 was built by adding all care components and hospital characteristics with $p < 0.25$ to model 1, followed
10 by manual backward selection until all remaining variables had $p < 0.1$

11 ^cNurses or midwives with additional 3-year training in surgery

12 ^dMidwives with additional 3-year training in obstetrics and gynaecology, including performing caesareans

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Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

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			Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	#3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	#4	Present key elements of study design early in the paper	4
Setting	#5	Describe the setting, locations, and relevant dates, including periods of	4

		recruitment, exposure, follow-up, and data collection	
1			
2	Eligibility criteria	#6a Give the eligibility criteria, and the sources and methods of selection of participants.	4
3			
4			
5			
6		#7 Clearly define all outcomes, exposures, predictors, potential	5
7		confounders, and effect modifiers. Give diagnostic criteria, if applicable	
8			
9			
10	Data sources /	#8 For each variable of interest give sources of data and details of methods	4-5
11	measurement	of assessment (measurement). Describe comparability of assessment	
12		methods if there is more than one group. Give information separately	
13		for for exposed and unexposed groups if applicable.	
14			
15			
16	Bias	#9 Describe any efforts to address potential sources of bias	5-6
17			
18			
19	Study size	#10 Explain how the study size was arrived at	4
20			
21	Quantitative	#11 Explain how quantitative variables were handled in the analyses. If	5-7
22	variables	applicable, describe which groupings were chosen, and why	
23			
24			
25	Statistical	#12a Describe all statistical methods, including those used to control for	5-7
26	methods	confounding	
27			
28			
29	Statistical	#12b Describe any methods used to examine subgroups and interactions	N/A
30	methods		
31			
32			
33	Statistical	#12c Explain how missing data were addressed	5-6
34	methods		
35			
36			
37	Statistical	#12d If applicable, describe analytical methods taking account of sampling	6-7
38	methods	strategy	
39			
40			
41	Statistical	#12e Describe any sensitivity analyses	N/A
42	methods		
43			
44	Results		
45			
46	Participants	#13a Report numbers of individuals at each stage of study—eg numbers	7
47		potentially eligible, examined for eligibility, confirmed eligible,	
48		included in the study, completing follow-up, and analysed. Give	
49		information separately for for exposed and unexposed groups if	
50		applicable.	
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55	Participants	#13b Give reasons for non-participation at each stage	N/A
56			
57	Participants	#13c Consider use of a flow diagram	N/A
58			
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60			

1	Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	9-10
2				
3				
4				
5				
6	Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	7, 9-10
7				
8				
9				
10	Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	7-8
11				
12				
13				
14	Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7, 11-12
15				
16				
17				
18				
19	Main results	#16b	Report category boundaries when continuous variables were categorized	7-12
20				
21	Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
22				
23				
24				
25	Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	12
26				
27				
28				
29	Discussion			
30				
31	Key results	#18	Summarise key results with reference to study objectives	12
32				
33				
34	Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	13-14
35				
36				
37				
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39	Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	12-13
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41				
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44	Generalisability	#21	Discuss the generalisability (external validity) of the study results	14-15
45				
46				
47	Other			
48	Information			
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50				
51	Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15
52				
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