East African Medical Journal Vol. 97 No. 8 August 2020
RISK FACTORS FOR MATERNAL MORTALITY AMONG WOMEN WHO HAD A CAESAREAN SECTION DELIVERY IN KENYA: A CASE-CONTROL STUDY
Nelly Pato Dindi, Pumwani Maternity Hospital, Ministry of Health, P.O. BOX 42849-00100 Nairobi, Kenya, Pamela Godia, Liverpool School of Tropical Medicine, P.O. BOX 24672-00100 Nairobi Kenya, Helen Allott, Emergency Obstetric Care and Quality of Care Unit, Liverpool School of Tropical Medicine, Liverpool, L3 5QA United Kingdom, Charles Ameh PhD, FRCOG, FRSPH, MPH, DSRH, SFHEA, Senior Clinical Lecturer and Deputy Head International Public Health Department, Emergency Obstetric Care and Quality of Care Unit, Department of International Public Health, Liverpool School of Tropical Medicine.

Corresponding author: Charles Ameh PhD, FRCOG, FRSPH, MPH, DSRH, SFHEA,Senior Clinical Lecturer and Deputy Head International Public Health Department, Emergency Obstetric Care and Quality of Care Unit, Department of International Public Health, Liverpool School of Tropical Medicine

RISK FACTORS FOR MATERNAL MORTALITY AMONG WOMEN WHO HAD A CAESAREAN SECTION DELIVERY IN KENYA: A CASE-CONTROL STUDY

N. P. Dindi , P. Godia, H. Allott and C. Ameh

ABSTRACT

Objectives: **To determine the risk factors associated with caesarean section (CS)-related deaths in Kenya.**
Design: **We used a case-control study design with a sample size of 360 (80% power) women who had CS in 2014. Fully adjusted and parsimonious odds ratios (OR) with 95% confidence intervals (CI) and significance levels (p-value ≤0.05) was reported based on multiple regression analysis.**
Setting: **96 Kenya referral hospitals.**
Outcome measures: **The dependent variable was death after CS, while the independent variables were sociodemographic factors, antenatal care profile indicators, clinical parameters, and post-CS management.**
Results: **Patient referral (OR 2.68, 95% CI:1.22-5.89), postpartum hemorrhage (OR 27.50, 95% CI:8.40-90.13), blood transfusion (OR 14.59, 95% CI: 3.95-53.91), referral to Intensive Care Unit (OR 27.50, 95% CI:8.40-90.13), and general anesthesia use (OR 11.45, 95% CI:4.56-28.74), were the risk factors for death amongst women who had CS.**
Conclusion: **Mitigating these risk factors by prioritizing interventions that include early identification and treatment of women at risk of postpartum haemorrhage, use of regional anaesthesia where possible, CS performed by experienced staff, early referral and adequate blood transfusion services, are likely to improve the quality of care.**

INTRODUCTION

At the end of the Millennium Development Goals, the World Health Organization (WHO), reported that 830 largely preventable pregnancy and childbirth-related deaths occur globally every day. (1) The majority of these deaths occur in low and middle-income countries because of limited access to skilled routine and emergency obstetric care (EmOC). The Maternal Mortality Ratio (MMR) in Kenya was 362/100,000 live births in 2014, with no significant change recorded in the last 5 years of the Millennium Development Goals. (1) In line with the global strategies to end preventable maternal mortality, the Government of Kenya designed several policies to reduce MMR from 488 deaths per 100,000 live births in 2009 to 200 deaths per 100,000 live births by 2030. (2,3) A 2018 assessment of the effectiveness of the Government of Kenya policy on free maternal health services showed significantly increased access to maternal and newborn health services but no reduction in MMR. (4)

Caesarean section (CS) is a critical EmOC procedure usually performed for medical reasons to prevent the death of a pregnant woman and/or her baby. However, population CS rates above 10% are unlikely to improve maternal and perinatal outcomes. The global population CS rate has almost doubled, from 12.1% (95% uncertainty interval 10.9-13.3) in 2000 to 21.1% (95% uncertainty interval 19.9-22.4) in 2015. (5) However, there is a huge disparity in CS rates, with rates varying from less than 5% in sub-Saharan Africa to about 60% in parts of Latin America. Women who live in urban areas, who are educated beyond secondary school and who receive care in private facilities are more likely to have a CS. (5)

CS significantly increases the risk of death for women and their babies, the risk of both short- and long-term morbidity. This is of particular concern if the caesarean was medically unnecessary. (6) Several strategies have been proposed to ensure that women who need CS get them while women without medical indications are not put at risk of morbidity or mortality. (7) The WHO has proposed the Robson 10 Group Classification (RTGC), as a global standard for assessing, monitoring and comparing CS rates within and between health facilities. (8) The RTGC has 10 mutually exclusive groups based on 5 basic obstetric characteristics (parity, the number of foetuses, previous CS, the onset of labour, gestational age and foetal presentation). The routine use and analysis of the RTGC can also help assess the quality of care and clinical management practices within and between facilities. (8)

A national Confidential Enquiry into Maternal Deaths (CEMD) in Kenya that included 51% (484) of facility reported deaths in 2014, reported that about 37% (138) of women that died had a CS birth. (9) The CS rate amongst women who died was disproportionately higher than the mean CS rate in the included facilities (n=96, mean:19.4%, standard deviation:7.5%). To improve the quality of care during childbirth, it is essential to understand the factors that increase the risk of death in women undergoing CS.

Factors associated with a higher risk of death after CS have been identified in several studies. These factors include the socioeconomic status (6), woman's medical condition (6), poverty and lack of formal education (10), maternal age above 35 years (11), emergency CS (11) and general anaesthesia. (12) However, no such studies have been reported from Kenya.

Identifying these risk factors will complement the Kenya CEMD report and

provide context-specific recommendations for improving the quality of intrapartum care. The objectives of this study were to determine the risk factors associated with CS-related deaths and to assess the feasibility of applying the Robson Ten Group Classification System in Kenya.

MATERIAL AND METHODS

Study design

We conducted a retrospective case-control study. Cases were all reported maternal deaths who had CS in 2014. Controls were a sample of women who had a CS but did not die in 2014.

Study setting and population

The study setting was 96 comprehensive EmOC (CEmOC) facilities in Kenya, where 79% (465) per cent of all maternal deaths recorded in 2014 through the District Health Information System-2, occurred (9). These facilities recorded 869, 468 births and 109, 968 (12.6%) CS in 2014. We conveniently selected CEmOC facilities that contributed to about 7% (59, 933) of all births and about 10% (10, 934) of CS performed in the 96 CEmOC facilities, to sample controls. The control sites were public health facilities had specialists obstetricians, trainee obstetricians and medical interns or medical officers. All control sites were managed by the national government or county government.

Sample size

Based on a ratio of 2:1 for controls to cases, a significance threshold of 0.05 and 80% power, a sample size of 120 cases and 240 controls were calculated using the G-Power software. (13)

Dependent and independent study variables

The dependent variable was maternal death after CS, while the independent variables were sociodemographic factors (age, education level, marital status), Antenatal care (ANC) profile (ANC attendance, pre-op haemoglobin), CS and clinical parameters (onset of labour, gestational age, parity, blood transfusion timing, referral status) and post CS management (previous scar, type of CS, type of anaesthesia used, cadre performing CS, indication for CS, intensive unit care, highest cadre involved in care) (**Table 1**).

Data collection

Over 4 weeks (April to May 2018), data were extracted from the clinical records of cases and controls. We matched each case with two controls: one from each control site, based on the calendar month when the death occurred. We designed a comprehensive data extraction tool on Microsoft Excel spreadsheet. The tool had categorical responses with drop-down menus to minimise researcher bias related to all variables of interest to enhance content validity.

A sampling frame comprising hospital registration numbers of all women who had CS and did not die was used for the controls. We selected controls, by simple random sampling to minimise sampling bias, by using a random number generator to identify the number of participants for each month. To enhance quality control and minimise systematic data entry errors, one researcher checked the data from 15% of the study population and that was re-entered by a different researcher weekly. This also ensured accuracy and study reliability.

Statistical analysis

Data from the study tool spreadsheet was imported into to Stata v12.0 (College Station, TX:StataCorp LP). Descriptive statistics were produced for women's' sociodemographic, obstetric and clinical characteristics using frequencies and percentages, and grouped by cases and controls. A missing category was included for each variable as relevant. The association between each variable and maternal outcome after CS was tested, through univariate analysis using Pearson's chi-square test. To build the multivariate model, all variables significant at α=0.2 in the univariate analysis were considered in the model. Robust parsimonious model was

developed using backward stepwise selection method. We put all relevant variables in the model, and removed one at a time, starting with the least significant variable, until all remaining factors were significant at α=0.05 significance level. We report odds ratios (OR), 95% confidence intervals (95%CI) and p-values for univariate and multivariate analyses.

Ethics

Deidentified data from medical records were used. Ethics approval was obtained from the research and ethics committees of the University of Nairobi (KNH-ERC/A/197) and Liverpool School of Tropical Medicine (M1811). The study is reported in line with the STRengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for case-control studies.

RESULTS

Most of the women who had CS deliveries and died were between 25 – 34 years of age (44.4%, 56) and this was a similar age group for the women who had CS and survived (50.0%, 128). The most common level of educational achievement for both cases (19.0%, 24) and controls (19.4%, 49) was primary school, however the majority of this data was missing. A higher proportion of women who had CS and survived attended ANC (98.8%, 249) compared to those who had CS but died (67.5% , 85). More of the women who had CS related death had severe/life threatening levels of pre-operative haemoglobin (4-8g/dL) (26.2%, 33) compared to those who survived (0.4%, 1). Similarly, more of the cases than controls had preterm births (23.8%, 30 vs 9.9%, 25), had multipara (77.8%, 98 vs 55.2%, 139), received general anaesthesia (50.8%, 64 vs 4.4%, 11), had postpartum haemorrhage (57.9%, 73 vs 2.0%, 5) and had blood transfusion (59.5%, 75) vs 2.0%, 5). In the same manner, more of the cases compared to controls were hypertensive (17.5%, 22) vs 3.6%, 9), were admitted to intensive care unit (19.0%, 24 vs 0), and were referred into the facility for CS from other facilities (47.6%, 60 vs 16.8%, 42). Educational level (62.7%, 79 vs 49.6%, 125), and pre-operative haemoglobin (54.8%, 69 vs 67.5%, 170) had the higest propotions of missing information for both cases vs controls (Table 1). Relatively, the cases had more missing information compared to the controls: marital status (19.8%, 25 vs 1.6%, 4), antenatal care (22.2%, 28 vs 0), gestational age (12.7%, 16 vs 0.8% , 2), previous uterine scar (9.5%, 12 vs 0.4%, 1) and type of anaesthesia used (15.2%, 19) vs 1.2%, 3). For antenatal care, onset of labour, parity, type of CS, health worker who performed CS, post-partum haemorrhage, indications for CS and whether a woman was referred to the facility for CS, all the women with missing information were cases.

Table 1

Descriptive statistics and unadjusted odds ratios for sociodemographic, antenatal care, obstetric and clinical characteristics

Factor		**Cases (N=126) n (%)**	**Controls (N=252) n (%)**	**Unadjusted odds ratio uOR (95% CI) [p-value]**
Age (years)	15 - 24	45 (35.7)	100 (39.7)	1
	25 – 34	56 (44.4)	128 (50.8)	0.97 (0.60 – 1.56) [0.907]
	35 – 44	25 (19.8)	24 (9.5)	**2.31 (1.19 – 4.49) [0.013]**
Education Level	Missing	79 (62.7)	125 (49.6)	**2.40 (1.13 – 5.10) [0.022]**
	No education	4 (3.2)	1 (0.4)	**15.20 (1.52 – 151.97) [0.021]**

Factor		Cases (N=126) n (%)	Controls (N=252) n (%)	Unadjusted odds ratio uOR (95% CI) [p-value]
	Primary	24 (19.1)	49 (19.4)	1.86 (0.79 – 4.36) [0.153]
	Secondary	9 (7.1)	39 (15.5)	0.88 (0.32 - 2.39) [0.798]
	Tertiary	10 (7.9)	38 (15.1)	1
Marital Status	Single	12 (9.6)	38 (15.1)	0.964 (0.503 - 1.845) [0.912]
	Widowed	1 (0.8)	0 (0.0)	
	Separated	2 (1.6)	0 (0.0)	
	Married	86 (68.3)	210 (83.3)	1
	Missing	25 (19.8)	4 (1.6)	**15.26 (5.15 – 45.23) [<0.001]**
Antenatal care	Yes	85 (67.5)	249 (98.8)	1
	No	13 (10.3)	3 (1.2)	**12.69 (3.52 - 45.70) [<0.001]**
	Missing	28 (22.2)	0 (0.0)	---
Pre-operative Haemoglobin level (g/dL)	Mild anaemia/ no anaemia (9-18g/dL)	24 (19.0)	81 (32.1)	1
	Severe/life threatening anaemia (4-8g/dL)	33 (26.2)	1 (0.4)	**111.38 (14.43 – 850.65) [<0.001]**
	Missing	69 (54.8)	170 (67.5)	1.37 (0.80 – 2.33) [0.249]
Onset of Labour	Induced	7 (5.6)	10 (4.0)	1.30 (0.43 - 3.92) [0.641]
	Spontaneous	76 (60.3)	203 (80.6)	0.69 (0.38 - 1.26) [0.230]
	No labour	21 (16.7)	39 (15.4)	1
	Missing	22 (17.5)	0 (0.0)	---
Gestational age	Preterm (<37 weeks)	30 (23.8)	25 (9.9)	**3.58 (1.87 - 6.08) [<0.001]**
	Term (≥37 weeks)	80 (63.5)	225 (89.3)	1
	Missing	16 (12.7)	2 (0.8)	**22.5 (5.05 – 100.22) [<0.001]**
Previous uterine scar	Yes	36 (28.6)	81 (32.1)	0.98 (0.60 - 1.56) [0.896]
	No	78 (61.9)	170 (67.5)	1
	Missing	12 (9.5)	1 (0.4)	26.15 (3.33 – 205.25) [0.002]
Parity	Multipara	98 (77.8)	139 (55.2)	**2.95 (1.80 - 4.83) [<0.001]**
	Nulliparous	27 (21.4)	113 (44.8)	1
	Missing	1 (0.8)	0 (0.0)	---
Type of caesarean section	Emergency	120 (95.2)	231 (91.7)	5.45 (1.26 – 23.70) [0.024]
	Elective	2 (1.6)	21 (8.3)	1
	Missing	4 (3.2)	0 (0.0)	---
Type of anaesthesia used	General	64 (50.8)	11 (4.4)	**32.20 (15.70 – 66.05) [<0.001]**
	Spinal	43 (34.1)	238 (94.4)	1
	Missing	19 (15.1)	3 (1.2)	**35.05 (9.92 - 123.81) [<0.001]**

Factor		Cases (N=126) n (%)	Controls (N=252) n (%)	Unadjusted odds ratio uOR (95% CI) [p-value]
Health worker who performed CS	Medical Officer Intern	7 (5.6)	1 (0.4)	**9.06 (1.01 – 81.08) [0.049]**
	Medical Officer	94 (74.6)	229 (90.9)	0.53 (0.27 - 1.04 [0.067]
	Obstetrician	17 (13.5)	22 (8.7)	1
	Missing	8 (6.3)	0 (0.0)	---
Postpartum Haemorrhage	Yes	73 (57.9)	5 (2.0)	**73.60 (28.24 – 1919.78)** [<0.001]
	No	49 (38.9)	247(98.0)	1
	Missing	4 (3.2)	0 (0.0)	---
Blood transfusion	Yes	75 (59.5)	5 (2.0)	78.51 (30.10 – 204.80) [<0.001]
	No	47 (37.3)	246 (97.6)	1
	Missing	4 (3.2)	1 (0.4)	20.93 (2.28 – 192.06) [0.007]
Pre-operative blood pressure*	Normotensive	75 (59.5)	228 (90.5)	1
	Hypotensive	4 (3.2)	1 (0.4)	**12.16 (1.33 – 110.81) [0.027]**
	Hypertensive	22 (17.5)	9 (3.6)	**7.43 (3.28 – 16.86) [<0.001]**
	Missing	25 (19.8)	14 (5.6)	5.43 (2.68 – 10.99) [<0.001]
CS indication	Maternal	99 (78.6)	146 (57.9)	**3.12 (1.86 – 5.25) [<0.001]**
	Foetal	23 (18.3)	106 (42.1)	1
	Missing	4 (3.2)	0 (0.0)	---
Maternal indication for CS	Cephalopelvic disproportion	20 (15.8)	46 (18.3)	**2.34 (1.06-5.16) [0.035]**
	Previous scar 2	13 (10.32)	70 (27.8)	1
	Failed induction	2 (1.6)	8 (3.2)	1.34 (0.26-7.08) [0.726]
	Hypertensive disorder in pregnancy	22 (17.5)	9 (3.6)	**13.16 (4.96 – 34.96) [<0.001]**
	Antepartum haemorrhage	17 (13.5)	10 (4.0)	**9.15 (3.43 – 24.42) [<0.001]**
	Fetal distress	6 (4.8)	66 (26.2)	0.49 (0.18 – 1.36) [0.172]
	Missing	9 (7.1)	32 (12.7)	1.51 (0.59 – 3.91) [0.391]
	Other maternal indications	37 (29.4)	11 (4.4)	**18.11 (7.38 – 44.44) [<0.001]**
ICU/HDU care	Yes	24 (19.0)	0 (0.0)	---
	No	102 (81.0)	252 (100.0)	1
Highest cadre of health worker involved in care	Medical officer intern	4 (3.2)	0 (0.0)	---
	Medical officer	71 (56.3)	199 (79.0)	0.38 (0.24 - 0.61) [<0.001]
	Obstetrician	50 (39.7)	53 (21.0)	1
	Missing	1 (0.8)	0 (0.0)	---
Patient referred in	Yes	60 (47.6)	42 (16.8)	4.87 (2.99 – 7.93) [<0.001]
	No	61 (48.1)	208 (83.2)	1

Factor		Cases (N=126) n (%)	Controls (N=252) n (%)	Unadjusted odds ratio uOR (95% CI) [p-value]
from other facilities	Missing	5 (4.0)	0 (0.0)	---

CS: Caesarean section; ICU/HDU: Intensive care unit /High dependency unit
**Normotensive: 90/60 to 140/90mmHg, Hypotensive: < 90/60 to 140/90mmHg, Hypertensive: >90/60 to 140/90mmHg*

In the univariate analysis, women who died had higher odds of being aged 35-44 years compared to aged 15-24 years (uOR 2.31; 95% CI (1.19-4.49) *p<0.013*), no education compared to tertiary education (uOR 15.2; 95% (1.51-151.97) p=0.02, not attending ANC compared to those who attended ANC (uOR 12.69; 95% CI (3.52 - 45.70) p<0.001), having severe or life threatening anaemia (4-8g/dL) compared to mild anaemia/no anemia (9-18g/dL) (uOR 111.38; CI 95% (14.43 – 850.65) p<0.001) (Table 1). Similarly, women who had CS but died had higher odds of having preterm birth (<37 weeks) compared to term (≥37 weeks) (uOR 3.58; CI 95% (1.87 - 6.08) p<0.001), being multipara compared to nulliparous (uOR 2.95; CI 95% (1.80 – 4.83) p<0.001), had emergency CS compared to elective CS (uOR 5.45; CI 95% (1.26 – 23.7) p<0.001) and receiving general anaesthesia compared to spinal (uOR 32.2; CI 95% (15.7 – 66.05) p<0.001) Table 1.

Additionally, the cases had higher odds of a CS performed by medical officer intern compared to an obstetrician (uOR 9.06; CI 95% (1.01 – 81.08) p=0.049), having post-partum haemorrhage (p<0.001), receiving blood transfusion (uOR CI 3.60 (28.24 – 1919.78) p<0.001), having pre-operative hypotension (p=0.027) or hypertensive (p<0.001) compared to being normotensive, having maternal indications for caesarean section compared to foetal indications (uOR 3.12, 95% CI (1.86 – 5.25) p<0.001) and having been referred into the facility from other facilities (uOR 4.87, 95% CI (2.99 – 7.93) p<0.001) (Table 1). This pattern remained for women with missing information specifically women who died had higher odds of death if the education level was unknown (p=0.022), marital status was unknown (p<0.001), gestational age was unknown (p<0.001), it was unknown if she had a previous uterine scar (p=0.002), blood transfusion while on admission was unknown (p=0.007) and if the pre-operative blood pressure was unknown (p<0.001). Table 1

In the multivariate analysis, the odds of being single/widowed/separated was nine times higher among women with CS related death compared to those who survived (OR:8.86; 95% CI 1.72,45.73; p=0.009) (Table 2). Similarly, women with CS related death had higher odds of having severe or life threatening anaemia compared to women who survived (OR:333.30; 95% CI 26.27,4227.86; p<0.001). The odds of a previous uterine scar was 14 times higher among women who died compared to those who did not (OR:14.19; 95% CI 2.67,75.46; p=0.002). Also women who died had higher odds of missing information about previous uterine scar (OR:331.52; 95% CI 11.98,9171.00; p=0.001). (Table 2)

The odds of a woman receiving a general anaesthesia was 13 times higher among cases than controls (OR:13.45; 95% CI 3.66, 49.42; p<0.001) (Table 2). Similarly, women with CS related dealth had higher odds of missing information concerning type of anaesthesia used compared to those who survived CS (OR:36.03; 95% CI 2.44, 532.31; p=0.009). Women with CS related death had higher odds of postpartum haemorrhage (OR:234.56; 95% CI 20.61, 2668.53; p<0.001)

and blood transfusion (OR:34.01; 95% CI 1.28,901.80; p=0.035) compared to women who survived. Cases had higher odds of being hypotensive (OR:148.49; 95% CI 12.47,1768.46; p<0.001) or hypertensive (OR:166.90; 95% CI 8.42,3307.64; p=0.001) compared to controls. Similarly, cases had high odds of experiencing antepartum haemorrhage (OR:19.44; 95% CI 1.49,253.79; p=0.024]) and being referred from other facilities (OR:4.22; 95% CI 1.17,15.21; p=0.028) compared to controls.

Table 2

Parsimonious adjusted odds ratios (95% confidence intervals) [p-value] for the combined significant risk factors

Sample size: Cases = 126 Controls = 252		**Parsimonious adjusted AOR (95% CI) [p-value]**
Marital Status	Single/widowed/separated	**8.86 (1.72 – 45.73) [0.009]**
	Married	1
	Missing	**25.93 (4.08 – 164.88) [0.001]**
Pre-operative Haemoglobin level (g/dl)	Mild anaemia/no anaemia (9-18g/dL)	1
	Severe/life threatening anaemia (4-8g/dL)	**333.30 (26.27 – 4227.86) [<0.001]**
	Missing	1.77 (0.35 – 8.73) [0.482]
Previous uterine scar	Yes	**14.19 (2.67 – 75.46) [0.002]**
	No	1
	Missing	331.52 (11.98 – 9171.00) [0.001]
Type of Anaesthesia	General	**13.45 (3.66 – 49.42) [<0.001]**
	Spinal	1
	Missing	36.03 (2.44 – 532.31) [0.009]
Postpartum haemorrhage	Yes	**234.56 (20.61 – 2668.53) [<0.001]**
	No	1
	Missing	---
Blood Transfusion	Yes	**34.01 (1.28 – 901.80) [0.035]**
	No	1
	Missing	6.07 (0.33 – 113.14) [0.227]
Pre-operative blood pressure*	Normotensive	1
	Hypotensive	**148.49 (12.47 – 1768.46) [<0.001]**
	Hypertensive	**166.90 (8.42 – 3307.64) [0.001]**
	Missing	0.04 (0.00 -3.28) [0.156]
Maternal cesaraen section indications	Cephalopelvic disproportion	**62.81 (2.72 – 1450.61) [0.010]**
	Previous scar	1
	Failed induction	---
	Hypertensive disorder in pregnancy	0.75 (0.04 – 15.22) [0.854]
	Antepartum haemorrhage	**19.44 (1.49 – 253.79) [0.024]**
	Fetal indications	0.83 (0.03 – 25.09) [0.917]
	Other maternal indications	**76.00 (5.73 – 1006.45) [0.001]**
	Missing	10.4 (0.57 – 188.85) [0.113]
Patient referred in from other facilities	Yes	**4.22 (1.17 – 15.21) [0.028]**
	No	1
	Missing	---

**Normotensive: 90/60 to 140/90mmHg, Hypotensive: < 90/60 to 140/90mmHg, Hypertensive: >90/60 to 140/90mmHg*

DISCUSSION

Given the inequity in the availability of CS globally, the short-term and long-term complications associated with this otherwise lifesaving procedure, this study contributes to context-specific knowledge to improve the quality of care during childbirth (5,6).

This was the first study in Kenya to look at the risk of death associated with CS considering socio-demographic, antenatal care, clinical and health service delivery factors. We found that the odds of death after CS was significantly lower in women aged 15-34 years and those who attended ANC. However, these were not significant risk factors in our final model. This is comparable to a previous observational study conducted in Kenya that included 58,151 obstetric admissions and 158 maternal deaths from 16 public hospitals, reported risk factors associated with deaths irrespective of the mode of birth. The study found that risk of mortality was significantly lower in women aged 20-24 years, who attended antenatal care and had secondary education or above (15). However, the only independent variables included in that study were socio-demographic factors and antenatal attendance (15). The significantly increased access to maternity services since 2013 may explain these differences (4).

In our study, we found that women who died had higher odds of being single/widowed or separated, had severe/ life threatening anaemia, a previous uterine scar, had antepartum haemorrhage as an indication for the CS delivery, postpartum haemorrhage, had blood transfusion post-operatively and being a referral. These findings are different to those reported in an observational study from the Demographic Republic of Congo that included 34,199 deliveries, 3, 643 CS and 50 CS-related maternal deaths in 5 CEmOC facilities (11). Kinenkinda et al. reported that ANC attendance, prematurity, multiparity, maternal hypertension, emergency CS and blood transfusion are significant risk factors for death after CS (11). All the variables except blood transfusion that were significant in the Congolese study were not risk factors in this study. This could partly be because up to 20% of the cases (those who died) in our study had missing information for variables like antenatal care attendance and gestational age.

We also found that severe/life threatening anaemia was a significant risk factor for death after CS. This degree of anaemia predisposes a woman to mortality and increases the risk of postpartum haemorhage, which is the leading cause of maternal death (16). These results are similar to other studies done in LMICs (10,11,12). If anaemia is detected in the antenatal period, then it is to be managed appropriately with haematinics or blood transfusion depending on the severity. If it is detected pre-operatively, then pre-operative blood transfusion is indicated. However, from our findings, none of the women who were anaemic pre-operatively were transfused pre-operatively. Majority of the women who died (75%), were transfused post-operatively. This implies inadequate resuscitation pre-operatively. There is also the possibility that transfusing post-operatively may have been too late. This is also reflected by the finding that blood transfusion was a significant risk factor for mortality after CS delivery. The 2014 Kenya Demographic and Health Survey Report, showed that ANC attendance has improved from 92% in 2008-09 to 96% in 2014, but only 58% of women received good quality ANC (counselling on danger signs, iron and folic acid supplementation, detection, and treatment of anaemia) received. Implementation of dietary interventions, folic and folate supplementation as recommended in the WHO guidelines for a positive pregnancy experience, may improve the quality of ANC.

Our findings on PPH are consistent with a WHO multi-country multivariate analysis that included 274, 985 births from 28 countries. That study reported that a significant risk for PPH was CS (16). We found out that being hypotensive, or hypertensive or receiving blood transfusion were risk factors associated with

death. Hypotension is a late sign but with adequate resources, it can be effectively managed with good outcomes. Modified obstetric early warning systems have been used effectively to identify women likely to deteriorate and prevent further morbidity.

There are several possible pathways to death when CS is associated with PPH. Pre-surgical factors such as antenatal anaemia, the volume of bleeding and adequacy of resuscitation before CS, the surgical factors such as appropriate skills and experience to perform difficult CS and adequate blood transfusions, and post-surgical factors such as appropriate post-operative care including ICU care and blood transfusion as needed. All these factors are all modifiable, therefore ensuring women are not anaemic before birth, early recognition and treatment of PPH and efficient blood transfusion services by competent health care workers, can result in a significant reduction in the risk of death.

Health service indicators with the greatest risk for death after CS were medical officer intern as the highest cadre involved in providing care and a patient having been referred. However only referral status was significant in the final regression model. This was similar to the finding by Mclean et al, in Mali (17). Some reasons for late referrals associated with maternal mortality identified by other studies included a late decision to refer and long travel distances (17).

Adequate experience is essential for making an accurate diagnosis, an early decision to refer, to perform effective resuscitation, to provide adequate surgical and post-surgical management. Care provision was led by medical officer interns for four women in our study population, all of whom died after CS. A 2016 systematic review comparing 24-hour obstetric consultant presence versus other models of care, included 6 studies of overall poor quality, found no evidence of improved intrapartum outcomes (CS rates, instrumental delivery rate, perinatal morbidity, and mortality) with 24-hour obstetric consultant presence (18). However, none of the included studies in the systematic review had maternal death as an outcome. The study concluded that early involvement of specialist obstetricians may be of benefit for risk management (18). In our study, all 96 sites had specialist obstetricians and their consistent leadership in the management of all obstetric emergencies is likely to make a positive impact.

We found that the risk of death after CS was about 13.45 times more when general anaesthesia was used compared to regional anaesthesia. This is comparable to results from a multicentre case-control study in Brazil which reported that the most common cause of death after CS was PPH and general anaesthesia (12). This risk is likely to be greater in hospitals with limited availability of experienced staff, anaesthesia options, blood transfusion services, and intensive care units. However, there is a study that showed that there was no difference in maternal outcome when either spinal or general anaesthesia was used (21). The difference could be that the study design, population characteristics, and the health system specifically more advanced infrastructure and medical technology in Egypt compared to Kenya.

Inadequate numbers of competent health workers constrained by working with suboptimal resources decrease the capacity for timely recognition and treatment of women who present with complications during pregnancy and childbirth. Properly funded health systems are more likely to overcome these problems, and this should be a priority through Universal Health Coverage if the ambitious targets for Sustainable Development Goal 3 are to be achieved in Kenya(2).

To optimise the availability of safe CS, quality assurance of labour and childbirth is essential. The WHO has recommended the RTGCS for this purpose (8). The RTGC has 10 mutually exclusive groups based on 5 basic obstetric characteristics (parity, the number of foetuses, previous CS, the onset of labour, gestational age and foetal presentation). The routine use and

analysis of the RTGC can help assess the quality of care and clinical management practices within and between facilities. (8) The ten groups were chosen because of clinical significance, additionally, some groups help to determine data quality (8). Although the RTGCS was not operational in any of the study sites, we found that it could not be applied to only 15.6% (59) of our sample, but with more missing data from the cases (women who died) compared to the control group. The RTGCS can complement efforts to reduce unnecessary CS and promote strategies to achieve this. (7) Poor data quality and management have been reported during maternal death audits in Kenya, this may be due to fear of blame by the health care workers. (20) Prospective use of RTGCS may contribute to improving awareness of poor record-keeping and data management, triggering locally lead improvements.

Majority of the women with missing information were cases (had died). The missing information included antenatal care attendance, gestational age, having a previous uterine scar. This is very important information that helps in the management of the woman during labour, essential for good clinical decisions and management. As part of quality improvement, missing data reduces the opportunities of learning from current practice to improve care provision.

Strengths and limitations

We conducted the first case-control study identifying risk factors associated with death amongst women who had CS in Kenya. One limitation of the study design is that case-control studies report odds ratios and these tend to over-state effect sizes and can be difficult to explain. Cohort studies are ideal for exploring and identifying risk factors, however, they require a considerably longer time to carry out and are expensive. The RTGCS may have complemented the findings of this study. However, the system was not in place at any of the study sites. Given the number of annual births (869, 468) recorded in the study sites, and retrospective application of the RTGCS will have been difficult to achieve within available resources. Prospective studies implementing the RTGCS are needed. Our control sample sites were two large public health facilities (one managed by the national government and one by county government) in the same county and the deaths were from public health facilities from the whole country. The risk factors may be different with more control sites, in private and mission managed hospitals and between counties. However, our study sites represented two types of CEmOC facilities managed by the central government and the 47 county governments, with similar resources and are likely to be representative of the study population, minimising the risk of selection bias. Future studies should include non-government owned hospitals. The categories used for anaemia were not the standard WHO classification categories (<7g/dl-severe, 7-9.9g/dl-moderate, 10-10.9g/dl-mild) but we used a pragmatic cut off 4-8g/dl severe/life threatening and 9-18g/dl as mild/no anaemia that ensured minimum data for analysis given the extent of missing data for this variable.

CONCLUSION

To achieve the more ambitious Sustainable Development Goals targets, a full understanding of factors associated with maternal deaths is required to design appropriate interventions.

Postpartum haemorrhage, blood transfusion, a patient having been referred, Severe/life threatening anaemia and general anaesthesia use, were independent potential risk factors for maternal mortality associated with CS delivery. These along with poor quality of medical records and data management potentially affects the quality of care.

Most of the risk factors identified in our study are modifiable and related. They can, therefore, be mitigated to reduce maternal mortality associated with CS. Mitigating these risk factors requires early identification and treatment of

women at risk of PPH, use of regional anaesthesia where possible, CS by experienced staff, early referral of adequately resuscitated women presenting with complications, adequate blood transfusion services and improved record keeping and data management. Prioritizing these interventions and the prospective use and analysis of RTGCS, combined with maternal and perinatal death audits, is likely to reduce the risk of death from CS in Kenya.

REFERENCES

1. WHO, UNICEF, UNFPA, World Bank Group, The United Nations Population Division. Trends in Maternal Mortality: 1990 to 2015. Geneva: World Health Organization; 2015.
2. WHO. Strategies toward ending preventable maternal mortality (EPMM). 2015.
3. Government of Kenya. Kenya Vision 2030 | Kenya Vision 2030 [Internet]. [cited 2018 Nov 24]. Available from: http://vision2030.go.ke/
4. Gitobu CM, Gichangi PB, Mwanda WO. The effect of Kenya's free maternal health care policy on the utilization of health facility delivery services and maternal and neonatal mortality in public health facilities. BMC Pregnancy Childbirth [Internet]. 2018 Dec 27 [cited 2018 Nov 24];18(1):77. Available from: https://bmcpregnancychildbirth.biomedcentral.com/articles/10.1186/s12884-018-1708-2
5. Boerma T, Ronsmans C, Melesse DY, Barros AJD, Barros FC, Juan L, et al. Global epidemiology of use of and disparities in caesarean sections. Lancet [Internet]. 2018 Oct 13 [cited 2018 Nov 25];392(10155):1341–8. Available from: https://www.sciencedirect.com/science/article/pii/S0140673618319287?via%3Dihub
6. Sandall J, Tribe RM, Avery L, Mola G, Visser GH, Homer CS, et al. Short-term and long-term effects of caesarean section on the health of women and children. Lancet. 2018;392(10155):1349–57.
7. Betrán AP, Temmerman M, Kingdon C, Mohiddin A, Opiyo N, Torloni MR, et al. Interventions to reduce unnecessary caesarean sections in healthy women and babies. Lancet. 2018;392(10155):1358–68.
8. WHO. WHO | Robson Classification: Implementation Manual. WHO [Internet]. 2018 [cited 2018 Nov 25]; Available from: https://www.who.int/reproductivehealth/publications/maternal_perinatal_health/robson-classification/en/
9. Ministry of Health Kenya. Saving Mothers' Lives 2017. First Confidential Report into Maternal Deaths in Kenya. Vol. 118, Ministry of Health Kenya. 2017.
10. Pasha O, Saleem S, Ali S, Goudar SS, Garces A, Esamai F, et al. Maternal and newborn outcomes in Pakistan compared to other low and middle-income countries in the Global Network's Maternal Newborn Health Registry: an active, community-based, pregnancy surveillance mechanism. Reprod Health. 2015;12(2): S15.
11. Kinenkinda X, Mukuku O, Change F, Kakudji P, Banzulu P, Kakoma J-B, et al. Risk factors for maternal and perinatal mortality among women undergoing cesarean section in Lubumbashi, Democratic Republic of Congo II. PanAfrican Med J. 2017;
12. Esteves-Pereira AP, Deneux-Tharaux C, Nakamura-Pereira M, Saucedo M, Bouvier-Colle M-H, Do M, et al. Caesarean Delivery and Postpartum Maternal Mortality: A Population-Based Case-Control Study in Brazil. PLoS One. 2016;
13. Universität Düsseldorf. G * Power 3.1 manual [Internet]. 2017 [cited 2018 Nov 25]. Available from: http://www.gpower.hhu.de/fileadmin/redaktion/Fakultaeten/Mathematisch-Naturwissenschaftliche_Fakultaet/Psychologie/AAP/gpower/GPowerManual.pdf
14. Gabrysch S, Campbell OM. Still too far to walk: Literature review of the determinants of delivery service use. BMC Pregnancy Childbirth [Internet]. 2009 Dec 11 [cited 2019 Jan 6];9(1):34. Available from: http://bmcpregnancychildbirth.biomedcentral.com/articles/10.1186/1471-2393-9-34
15. Magadi M, Diamond I, Madis N. Analysis of factors associated with maternal mortality in Kenya. J Biosoc Sci. 2001 Jul;33(3): S0021932001003753.
16. Sheldon WR, Blum J, Vogel JP, Souza JP, Gülmezoglu AM, Winikoff B, et al. Postpartum haemorrhage management, risks, and maternal outcomes: findings from the World Health Organization Multicountry Survey on Maternal and Newborn Health. BJOG. 2014;121 Suppl:5–13.
17. Pirkle CM, Fournier P, Tourigny C, Sangaré K, Haddad S. Emergency Obstetrical Complications in a Rural African Setting (Kayes, Mali): The Link

Between Travel Time and In-Hospital Maternal Mortality.
Matern Child Health J. 2011 Oct;15(7):1081-7. doi: 10.1007/s10995-010-0655-y. PMID: 20697934.

18. Henderson J, Kurinczuk JJ, Knight M. Resident consultant obstetrician presence on the labour ward versus other models of consultant cover: a systematic review of intrapartum outcomes. [cited 2018 Dec 13]; Available from: https://doi.org/10.1111/1471-

19. Robson M, Murphy M, Byrne F. Quality assurance: The 10-Group Classification System (Robson classification), induction of labour, and cesarean delivery. Int J Gynecol Obstet [Internet]. 2015 Oct 1 [cited 2018 Nov 25];131:S23–7. Available from: https://www.sciencedirect.com/science/article/pii/S0020729215002337

20. Kongnyuy EJ, van den Broek N. The difficulties of conducting maternal death reviews in Malawi. BMC Pregnancy Childbirth [Internet]. 2008 Dec 11 [cited 2018 Dec 20];8(1):42. Available from: http://bmcpregnancychildbirth.biomedcentral.com/articles/10.1186/1471-2393-8-42

21. Helal Al, A., Abu El Aish, K., Department, P., Helal Al Emirati, A., Tafish, R., Abu El Aish, K. I. and Madi, W. (2018) 'General versus spinal anaesthesia for caesarean section: a quasi-controlled trial', *The Lancet*, 391, p. S33. doi: 10.1016/S0140-6736(18)30399-4.