

# Cost-Effectiveness of Emergency Obstetric Care in rural Kenya: Comparing Ambulance transfer and Self-referral

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## Research article

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# Abstract

## Background

Obstetric complications are difficult to predict and may require referral, expedited by ambulance use. We conducted a cost-effectiveness analysis comparing ambulance transfers and self-referrals in obstetric emergencies in a predominantly rural setting in Kenya.

## Methods

A retrospective cross-sectional cost-effectiveness analysis using a healthcare system perspective was conducted of parturient women transferred by ambulance to a higher level hospital compared with self-referrals between January to June 2019. Direct costs needed for ambulance, self-referral and clinical care were calculated. Every woman admitted with a pregnancy-related complication was assessed using the adapted sub-Saharan African Maternal Near Miss (MNM) criteria. Each referred woman was categorized as: 'necessary referral' meaning that they were managed for either MNM or potentially life-threatening complications (PLTC) and 'unnecessary referral' meaning those with no obstetric complications. Incremental cost effectiveness ratio (ICER) for referral was considered attractive or very attractive interventions when costs per life years gained (LYG) were below \$150 and \$30, respectively.

## Results

Overall, 2804 women (96.3%) were self-referrals, while 108 ambulance transfers occurred (3.7%). Main indications for ambulance transfer were prolonged labor ( $n = 21$ ; 19.4%), pre-eclampsia/eclampsia ( $n = 19$ ; 17.6%) and sepsis/peritonitis following cesarean section ( $n = 15$ ; 13.9%). Necessary referrals were considered to have occurred in 81/108 (75%) for ambulance transfers versus 239/2804 (9.3%) self-referrals. If all necessary referral cases had exclusively used ambulance services (ambulance + self-referrals), then the total intervention costs would be \$90,112 and LYG 6095, equivalent to ICER of \$14.8 per LYG. Women with unnecessary referrals by ambulance were 27/108 (25%) versus self-referrals in 2565/2804 (91.5%) indicating that these women could have been managed in sub-county hospitals or health centers.

## Conclusions

Cost-effectiveness of reasonably well-targeted ambulance services on women with MNM or PLTC in our setting was very attractive.

## Background

Approximately 295,000 women died during pregnancy and childbirth in 2017 globally, most of them in low-income countries (LICs) [1–3]. This has been attributed to delays in seeking, reaching and obtaining adequate care upon arrival in health facilities [4]. Early detection of high risk pregnancies, management of complications and provision of skilled birth attendance (SBA) have emerged as strategies to reduce maternal mortality ratios (MMR) [5, 6]. Transport barriers have generally been neglected [6, 7].

The World Health Organization (WHO) reports that reductions in MMR may be attributed to timely access to Emergency Obstetric Care (EmOC) [3, 8]. In Tanzania, almost half (48%) of the women with delayed referrals reached appropriate level of health facility in two or more days [9] and in Uganda only half reached health facilities the same day [10]. A systematic review from LICs showed that two-thirds of all pregnant women who used health facilities went to two or more hospitals in the process of seeking care [6]. This could be explained by persistent challenges to provide skilled manpower and equipment in facilities, and by communication breakdowns and insufficient referral systems between facilities in LICs, hampering timely access to care [6].

By 2015, most sub-Saharan African countries (SSA) including Kenya had reduced their MMRs by 30%, short of MDG 5's target of 75% [8]. The Government of Kenya (GoK) joined other countries in expressing political commitment towards increasing access to quality obstetric care as well as improving the health system to achieve the Sustainable Development Goals (SDGs) by 2030 [11, 12]. In June 2013, GoK declared that all maternity services in public health facilities should be provided free of charge whereby the central government would reimburse all birth-related costs to providers. This was followed by the First Lady's launch of the Beyond Zero Campaign in 2014, an initiative that provided fully equipped ambulances to all 47 county governments [13]. Furthermore, in 2018, GoK renewed its commitment to provide free services to all expectant women through a scheme called the Linda Mama Program Benefit Package. This aimed to increase SBA through provision of free antenatal care (ANC), ambulance services, midwifery and surgical services during childbirth and postnatal care [14].

Together with those national efforts, in 2015, the County government of Bomet had a lease agreement with the Kenya Red Cross Society (KRCS) to offer comprehensive services including a fully-serviced ambulance, combined with emergency medical equipment and paramedic availability in each ambulance, which resulted in increased SBA (S1 Fig). For pregnant women who reside in rural areas like Bomet County, free transport to health facilities is paramount to save them several hours walking to access EmOC. As part of evaluating the implementation of this ambulance intervention, we conducted a cost-effectiveness analysis comparing ambulance transfers and self-referrals in obstetric emergencies in a predominantly rural setting in Kenya.

## Methods

This study was conducted from Bomet county located in the south rift valley region of Kenya and occupies an area of 1,630 km<sup>2</sup>. It is comprised of five constituencies (Bomet East, Chepalungu, Bomet Central, Konoin and Sotik), with a combined estimated population of 891,390 inhabitants and a fertility

rate of 4.3 [15]. Rate of skilled birth attendance was 52.2% in 2014 [15]. The total number of 145 health facilities consists of one public referral hospital (Longisa county referral hospital, LCRH), two faith-based hospitals, five sub-county hospitals, 23 health centers and 114 dispensaries. All public health services are financed by the county government of Bomet. In LCRH, services include comprehensive emergency obstetric and newborn care (CEmONC) and 24-hour ambulance services free-of-charge to transfer women from their villages or health centers in case of obstetric complications. The faith-based and sub-county hospitals also provide CEmONC services and have access to the same ambulance services. The county government of Bomet owns two ambulances and hires four from Kenya Red Cross Society; three of the hired ambulances are located in in LCRH of which are our economic evaluation assessment was based. Each ambulance operates independently, covering distances between LCRH and health centers ranging from 2 to 48 km.

This was a facility-based cross-sectional study involving a retrospective chart review among women who had been admitted with obstetric complications brought in either by ambulance or as self-referrals between January, 1st, to June, 30th, 2019 in LCRH, Bomet, Kenya. Eligibility for the study was independent of gestational age: all women who arrived in LCRH with pregnancy related complications were included. Women who developed complications more than 42 days after termination of pregnancy were excluded. Every woman admitted with a pregnancy related complication was assessed using the adapted sub-Saharan African Maternal Near Miss (MNM) criteria [16]. Each referred woman was categorized as: 'necessary referrals' meaning that they were managed for either MNM or potentially life-threatening complications (PLTC) and 'unnecessary referrals' meaning those with no obstetric complications. A necessary referral was assumed to be a woman referred from a lower to a higher level of care, meaning LCRH, where either MNM or PLTC cases were supposed to be managed. An unnecessary referral was assumed to be a woman without obstetric complications who should have received care at lower levels of care including health centers. Additional data included transport costs, clinical care costs and accessibility to LCRH in terms of distance and modes of referral. These were retrieved from obstetric records, ambulance call logbooks, referral registers, perinatal registers and financial records.

Mode of referral was grouped into ambulance transfer and self-referral. Ambulance transfer was a woman brought by ambulance and escorted by health care professionals to LCRH. Self-referral was a woman who arrived in LCRH by other modes of transport such as private car, motorcycle or by foot directly from home. Associated conditions are diseases or conditions that may be relevant to a severe maternal outcome but are not part of the chain of events leading to that severe maternal outcome. Our hypothesis was an increased number of ambulance transfers among women managed for either MNM or PLTC as compared to women without obstetric complications at onset of referral who would opt to use other modes of transport.

Costing analysis was performed from the health care provider's perspective, being the county government of Bomet [17]. All costs falling under the county health system were included. These included ambulance and health services provided in LCRH. Our study did not take into consideration opportunity costs when

accessing health care. These included costs incurred by patients and families, resources used by health care providers from referring agents and other parties like insurance companies and donors.

Recurrent costs included drivers' and paramedics' salaries, allowances for accompanying drivers and paramedics on night/weekend calls, length of hospital stay, laboratory tests, radiology procedures, clinical care costs incurred during vaginal birth, surgical interventions such as cesarean section or laparotomy and management of other obstetric complications. Recurrent costs also included ambulance fuel/insurance/maintenance, electricity, water bills, and cell-phone communication. We computed transport costs incurred among self-referrals using Geo-measure area calculator to estimate distance from home or private clinic to reach LCRH, multiplied by costs of fuel per kilometer. We also assumed that women had been accompanied by one person implying transport doubled the costs incurred per woman. Fuel costs for non-obstetric cases were excluded. Costs were calculated based on the National Health Insurance Fund delivery costs [14]. Data on quantities and costs of recurrent and capital overhead goods were obtained as recommended [17]. Overheads were calculated using the allocated shared costs based on time and units of consumption of each shared input [18]. Capital items were physically enumerated and the actual amount of recurrent items was obtained by reviewing general store records, pharmacy, purchase records, hospital's supplies, accounts and Kenya medical supplies agency records. All costs were presented in Kenya Shillings (KES) and converted into US dollars (1 US\$ = 103 KES). The cost of capital resources such as ambulances appeared as a single large amount at the beginning of an evaluation period. We computed the equivalent annual costs based on WHO regional recommendations through annualizing capital costs [17]. The costs in each cost center were added to obtain total costs. These were divided by the interventions output to provide the unit cost of delivering costs for necessary ambulance transfers and self-referrals. The unit cost per inpatient per day was obtained by dividing total inpatient costs (capital and recurrent costs) by the total number of admission days for women with necessary referral.

Ambulance or self-referral benefits were presented as cost per life years gained (LYG) for every referral of women categorized as necessary referrals based on local life-expectancy tables. This was adopted from the WHO reported 66 years as female life expectancy in Kenya. To calculate life expectancy related to different ages of women, we used the table for "the expectation of life at age" [19]. The table does report the average life expectancy for each age; clustered in age groups each containing four years, from 1 to 4, 5 to 9, 10 to 14, until 100+. The older the woman becomes the lower her life expectancy, the lower the life years gained when ambulance referral or self-referral were 'necessary referrals'. The formula to calculate LYG was as follows: LYG for every MNM or PLTC case categorized as necessary referral was 66 (average life expectancy) minus the expectation of life at the age of the mother (as indicated in the expectation of life for age table). For every categorized case as necessary referral, the same formula was adopted. Therefore, total LYG was the sum of all life years gained for necessary referral cases. Finally, our results were derived from the formulas below:

$$\text{Cost effectiveness ratio for ambulance referrals (CER}_A\text{)} = \frac{\text{Costs incurred among ambulance referrals (KES)}}{\text{Effects among ambulance referrals (LYG)}}$$

$$\text{Cost effectiveness ratio for among self-referrals (CER}_S\text{)} = \frac{\text{Costs incurred among self-referrals (KES)}}{\text{Effects among self-referrals (LYG)}}$$

$$\text{ICER} = \frac{\text{Costs incurred among ambulance referrals} - \text{Costs incurred among self-referrals (KES)}}{\text{Effects among ambulance referrals} - \text{Effects among self-referrals (LYG)}}$$

Sensitivity analysis was performed using discount rates of 3% and 6%. First, we discounted costs and life years gained (LYG) by 3% for the proportion necessary referrals and later increased the discount of life years gained to 6%. Finally, incremental cost effectiveness ratios (ICER) for the referral intervention were considered acceptable, attractive, or very attractive interventions when costs per gained life years were below Kenya's GDP per person of 1507.8 USD; attractive when < 150 USD and very attractive when < 30 USD [19].

## Results

During the 6-months study period, 2804 women with obstetric complications admitted in LCRH were self-referrals (96.3%) and 108 were transferred by ambulance (3.7%). Their median age and parity were 26 ± 6.7 years and 2 ± 0.7. Main indications for ambulance transfer were prolonged labor ( $n = 21$ ; 19.4%), pre-eclampsia/ eclampsia ( $n = 19$ ; 17.6%) and sepsis/peritonitis following cesarean section ( $n = 15$ ; 13.9%) (Table.1).

Necessary referrals were considered to have occurred in 81/108 (75%) of the ambulance transfers versus 239/2804 (9.3%) of the self-referrals. Ambulance referrals also differed for different causes as compared to self-referrals: for uterine rupture 6/108 (5.6%) versus 1/2804 (0.04%), ectopic pregnancy 8/108 (7.4%) versus 8/2804 (0.3%), postpartum hemorrhage 7/108 (6.5%) versus 42/2804 (1.5%) and pre-eclampsia/eclampsia 20/108 (18.5%) versus 35/2804 (1.2%). Women with unnecessary referrals by ambulance were 27/108 (25%) versus self-referrals in 2565/2804 (91.5%) indicating that these women could have been managed at sub-county hospitals or health centers (Table 2).

Table 1  
**Characteristics of women admitted in LCRH, Bomet county.**

Characteristics		Self-referral	Ambulance
		2804 (%)	108 (%)
Age (years) (median $\pm$ SD; 26 $\pm$ 6.7)	15–19	586 (20.9)	18 (16.7)
	20–29	1834 (64.5)	53 (49.1)
	$\geq$ 30	384 (13.7)	37 (34.2)
Parity (median $\pm$ SD; 2 $\pm$ 0.7)	1	695 (24.8)	21 (19.4)
	2–4	1890 (67.4)	63 (58.3)
	$\geq$ 5	219 (7.8)	24 (22.2)
Residence (Constituency)	Bomet East	1360 (48.5)	37 (34.2)
	Bomet Central	776 (27.7)	26 (24.1)
	Chepalungu	431 (15.3)	23 (21.3)
	Sotik	128 (4.6)	15 (13.9)
	Konoin	109 (3.9)	7 (6.5)
Provisional diagnosis	Prolonged labor	137 (4.9)	21 (19.4)
	Pre-eclampsia/Eclampsia	35 (1.2)	19 (17.6)
	Sepsis/Peritonitis post-CS	34 (1.2)	15 (13.9)
	Other complications	39 (1.4) <sup>a</sup>	13 (12) <sup>b</sup>
	Abortion complications	296 (10.6)	11 (10.2)
	Postpartum hemorrhage	42 (1.5)	9 (8.3)
	Uterine rupture	1 (0.04)	6 (5.6)
	Severe malaria	1 (0.04)	4 (3.7)
	Abnormal fetal presentation	118 (4.2)	4 (3.7)
	Road traffic accident	-	2 (1.9)
	Antepartum hemorrhage	24 (0.9)	14 (0.5)

<sup>a</sup> Other complications Pyelonephritis (9), Asthmatic attack (1), Hyperemesis (13), Choriamnionitis (8), Endometritis (5), Postpartum psychosis (3)

<sup>b</sup> Other complications Pyelonephritis (3), Asthmatic attack (3), HIV encephalopathy (1), Peripartum cardiomyopathy (1), Postpartum psychosis (1), epilepsy (1), Attempted suicide (1), Idiopathic thrombocytopenia purpura (1), Road traffic accident (1)

	Previous CS	71 (2.5)	8 (0.3)
<sup>a</sup>	Other complications Pyelonephritis (9), Asthmatic attack (1), Hyperemesis (13), Choriamnionitis (8), Endometritis (5), Postpartum psychosis (3)		
<sup>b</sup>	Other complications Pyelonephritis (3), Asthmatic attack (3), HIV encephalopathy (1), Peripartum cardiomyopathy (1), Postpartum psychosis (1), epilepsy (1), Attempted suicide (1), Idiopathic thrombocytopenia purpura (1), Road traffic accident (1)		

Table 2  
Underlying causes, associated conditions and critical interventions done among women admitted in  
LCRH, Bomet county<sup>∞</sup>

	Self-referrals			Ambulance		
	No complications ∂	PLTC <sup>α</sup>	MNM <sup>α</sup>	No complications ∂	PLTC <sup>α</sup>	MNM <sup>α</sup>
	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)
<b>Overall</b>	2565	213	26	27	49	32
Underlying causes*						
Severe hemorrhage						
Abortion	271 (10.6)	15 (7.0)	-	8 (29.6)	12 (24.4)	1 (3.1)
Ectopic pregnancy	-	6 (2.8)	2 (7.7)	-	2 (4.1)	6 (18.8)
Placental abruption	-	8 (3.8)	-	3 (11.1)	1 (2.0)	-
Placenta previa	-	12 (5.6)	4 (15.4)	4 (14.8)	4 (8.2)	2 (6.3)
Postpartum hemorrhage	-	30 (14.1)	12 (46.2)	2 (7.4)	3 (6.1)	4 (12.5)
Uterine rupture	-	-	1 (3.8)	-	-	6 (18.8)
Hypertensive disorders						
Severe pre-eclampsia	-	22 (10.3)	3 (11.5)	-	6 (8.2)	3 (9.4)
Eclampsia	-	9 (4.2)	1 (3.8)	-	9 (18.4)	2 (6.2)
Pregnancy related infections <sup>a</sup>	-	36 (16.9)	1 (3.8)	1 (3.7)	2 (4.1)	3 (9.4)
Sepsis/peritonitis post-CS	-	27 (12.7)	2 (7.7)	3 (11.1)	9 (18.4)	3 (9.4)
Coincidental conditions <sup>b</sup>	-	-	-	-	-	1 (3.1)
Other complications <sup>c</sup>	-	2 (0.9)	-	4 (14.8)	3 (6.1)	-
<b>Associated conditions</b>						

	Self-referrals			Ambulance		
	No complications ∂	PLTC <sup>α</sup>	MNM <sup>α</sup>	No complications ∂	PLTC <sup>α</sup>	MNM <sup>α</sup>
	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)
Anemia	58 (2.3)	37 (17.4)	8 (30.8)	5 (18.5)	11 (22.4)	9 (28.1)
HIV	193 (7.5)	9 (4.2)	-	1 (3.7)	5 (10.2)	3 (9.4)
Previous CS	44 (1.7)	21 (9.9)	6 (23.1)	3 (11.1)	3 (6.1)	2 (6.3)
Prolonged labor	69 (2.7)	27 (12.7)	3 (11.5)	1 (3.7)	4 (8.2)	5 (15.6)
<b>Critical interventions</b>						
Cesarean section	241 (9.4)	38 (17.8)	13 (50.0)	14 (51.9)	22 (44.9)	7 (21.9)
Laparotomy	-	1 (0.5)	3 (11.5)	2 (7.4)	12 (24.5)	17 (53.1)
Blood transfusion	-	8 (3.8)	12 (46.2)	-	10 (20.4)	22 (68.8)
HDU admission	-	-	9 (34.6)	-	1 (2.0)	17 (53.1)
∞ Values given as number (percentages). α and ∂ represents necessary and unnecessary referrals						
Abbreviations: CS, Cesarean section; HDU, High Dependency Unit; PLTC, Potentially life-threatening conditions; MNM, Maternal Near Miss						
*One woman could have experienced more than one cause						
<sup>a</sup> Pyelonephritis (12), Hyperemesis (13), Choriamnionitis (8), Endometritis (5), severe malaria (5), HIV encephalopathy (1)						
<sup>b</sup> Road traffic accident (1)						
<sup>c</sup> Asthmatic crisis (4), Attempted suicide (1), Epilepsy (1), Idiopathic thrombocytopenia purpura (1), Peripartum cardiomyopathy (1), postpartum psychosis (1)						

Ambulance referral as compared to self-referral also differed among associated conditions in women categorized as 'necessary referrals': anemia (20/108; 18.5% versus 45/2804; 1.6%), prolonged labor (9/108; 8.3% versus 30/2804; 1.1%) and HIV (8/108; 7.4% versus 9/2804; 0.3%). Critical interventions

among those women categorized as necessary referrals in the two groups were blood transfusion (32/108; 29.6% versus 20/2804; 0.7%) and laparotomy (29/108; 26.9% versus 4/2804; 0.1%) (Table 2).

Costs of operating ambulance services for women admitted with obstetric complications are detailed in Table 3. We assumed that if all necessary referral cases (ambulance + self-referrals) would have exclusively used ambulance services, then total intervention costs and LYG would be \$90,112 and LYG 6095. This translates to an ICER of \$14.8 per LYG, which is below the \$30 WHO cost-effectiveness threshold. The studied intervention can therefore be considered as very cost-effective (Table.4).

Table 3. Cost of Ambulance services among obstetric cases delivered during 6-months period, LCRH, Bomet County

Expenses	Cost per unit	Maternal near miss <sup>α</sup>	Potentially life-threatening conditions <sup>α</sup>	No complications <sup>∂</sup>
		N = 32	N = 49	N = 27
Car (Toyota land cruiser) <sup>a</sup> (n = 3)	53,725	464	711	392
Lease agreement cost per ambulance which covers for; (n = 3) Fuel Car tax/insurance Car maintenance Damage repair Tyre repair/ substitution	194/day	3,936	6,027	3,321
Driver's gross salaries (n = 3)	340/month	227	348	192
Paramedic gross salaries (n = 3)	340/month	227	348	192
Driver's allowances (n = 36)	29/night	522	435	87
Paramedic's allowances (n = 36)	29/night	522	435	87
Ambulance coordinator's allowance	145/month	32	49	27
Driver's airtime (n = 3)	45/month	30	46	25
Total		5,960	8,399	4,323
Costs are expressed in USD, exchange rate of 1 USD = 103 Kenyan shillings				
<sup>a</sup> Calculation of ambulance cost was based on the following; replacement cost (\$53,725), useful life years (7), scrap value (\$2,500), discount rate (3%) resulting into equivalent annual cost of one ambulance (\$8,297). Therefore 3 ambulance costs incurred in 6 months were \$12,446.				
<sup>α</sup> and <sup>∂</sup> represents necessary and unnecessary referrals				

Table 4. Total and Incremental costs (US\$, year 2019 values), Life years gained, CEA and Sensitivity Analysis among necessary referrals admitted at LCRH.

Sensitivity Parameters	Ambulance		Self-referral		Incremental		ICER
	Costs	LYG	Costs	LYG	Costs	LYG	
Discounting	Costs	LYG	Costs	LYG	Costs	LYG	
3% discount	22143	1217	17075	3337	5068	-2120	- 2.4
0% discount	22808	1657	17587	4438	5221	-2781	- 1.9
6% discount	21517	933	16592	2602	4925	-1669	- 3.0
Effectiveness							
Ambulance only (75)	22808	1657	17587	4438	5221	-2781	- 1.9
Ambulance + self (85.3)	90112	6095	-	-	90112	6095	14.8
Ambulance + self (85.3)	-	-	23552	6095	-23552	-6095	3.9
Formula used to discount = $(1 - e^{-r \cdot LYsXi}) / r$ where e is function of exponential, r responds to 3% or 6% discount							
rate and LYsXi are the life years gained for each mother.							

## Discussion

Our main findings reveal that implementing an effective ambulance service for emergency obstetric care in Bomet County was highly cost-effective with \$14.8 per life year gained, far below the \$30 WHO cost-effectiveness threshold [19, 20]. Further sensitivity analyses conducted on the rate of necessary referrals, ambulance costs and discount rate emphasized the robustness of this conclusion, similar to other studies in Uganda and Ethiopia, and demonstrating the significance of effective ambulance transfer systems for emergency obstetric care in remote African settings [7, 21–23].

In our setting, ambulances were mainly used to transfer pregnant women from low to higher level health facilities [21–24]. Our ambulance obstetric transfer rate of 3.7% was lower than those in other African studies that reported rates between 5% and 66% [21, 24, 25]. This could be explained by accompanying paramedics on ambulances providing support and triage of patients at the referring health facilities, preventing unnecessary referrals. Nonetheless, still one-quarter of women transferred by ambulance, together with nine out of ten who had come to LCRH as self-referrals, were unnecessary referrals. These women could have been managed in sub-county hospitals and health centers without any use of ambulance services. This highlights the importance of implementing an ambulance obstetric referral protocol, educational interventions in health centers (*i.e* drills, simulations, continuing professional development), strengthening supervision in lower level health facilities, improving drug availability and equipping lower health facilities with drugs and essential supplies in order to prevent unnecessary inter-facility referrals which lead to increased workload in higher level facilities and avoidable costs for families and health systems [26, 27].

Main indications for ambulance transfer were prolonged labor and hypertensive disorders, comparable to other studies from LICs [24, 28]. This may be explained by poor quality of ANC leading to suboptimal knowledge of obstetric danger signs and low levels of birth preparedness and complication readiness (BP/CR) [29, 30]. Health promotion regarding BP/CR at all stages of women's reproductive life with support from community members is needed. The other indication for referral was sepsis/peritonitis following cesarean section. This could be explained by poor sterilization procedures and inappropriate use of antibiotics prescribed by inexperienced medical officers working in sub-county hospitals, which calls for strengthening of quality and continuum of obstetric care in those health facilities [31].

Our findings reveal that postpartum hemorrhage was the commonest PLTC, with one case of uterine rupture among the women who had been admitted as self-referrals. This highlights challenges rural women face due to delays in seeking or reaching basic delivery care in low-income countries [7, 21]. Most women who had been transferred in critical conditions by ambulance, their referring health centers had called prior for ambulance services. This emphasizes the importance to implement the national standard referral guidelines [32]. There was no difference in terms of maternal morbidities between ambulance transfers and self-referrals which could be explained by: i) reduced transport delays, ii) improved clinical conditions upon arrival due to care by paramedics while on board, or iii) improved obstetric care after arrival in LCRH. Additionally, women who presented as self-referral came from less remote areas than those transferred by ambulance or more often from private clinics. Ambulance transfer thus improved survival of women coming from more remote areas who otherwise might have arrived in poorer condition.

Health centers notably used mobile phones to call for ambulance support, which is much cheaper than VHF radio communication reported in other studies [7, 22, 23]. Ambulance transfers were free of charge to parturient women delivered to LCRH. The costs were reimbursed by the county government of Bomet through a fixed lease agreement with Kenya's red cross society, not affected by increased number of referrals covered per day. There is a need to increase awareness on ambulance services through availing toll free numbers so that local people can call them directly as a more friendly and effective means of referral as compared to the current practice which increases uncomplicated births to LCRH [33, 34]. In LICs, mobile phone technology has been associated with significant reductions of maternal and neonatal deaths [33]. Thus, there is a need to advocate for nation-wide mobile phone coverage [34]. Other authors have suggested options like motorcycle ambulances based at health centers, as a cheaper alternative to car ambulances based at the district hospital [5]. Unfortunately, this innovative transport approach may not be replicated in every setting due to cultural acceptance issues [5].

This was the first cost-effective analysis of a referral system comparing ambulance transfers and self-referrals among women admitted with obstetric complications in a rural hospital. We evaluated effectiveness using the adapted sub-Saharan African MNM criteria as a clinical judgement tool, unlike prior studies which used theoretical judgment, raising concerns about WHO MNM criteria being too restrictive [7, 16, 22, 23]. All ambulances stationed in LCRH had accompanying paramedics who provided support and guidance to women while on board. In terms of limitations, the retrospective nature of this study relied on routinely collected obstetric data, and bias may have occurred because of missing

information in the obstetric charts. Our data covered women from remote areas, which render our results and recommendations difficult to generalize to other urban areas in Kenya. Notably, we applied the national life expectancy tables without adjusting for pathologies and regions which may have led to *over*- or *under*-estimation of benefits. Unfortunately, specific life expectancy tables for specific regions are not available. Ambulance services themselves are not the only factor influencing referrals for skilled birth attendance. Other contributing factors are good mobile phone network coverage, cheap communication means, free of charge ambulance services, 24-h availability of ambulances and ability for LCRH to provide CEmONC. We focused mainly on survival and did not consider quality of life and disability that may also be relevant. Delayed cesarean section may indeed also impact on quality of life with vesico-vaginal fistulas and child disabilities as potential complications of that delay [35]; prevention of maternal death may obviously have profound benefits for the women involved and their families [36]. Although ambulance services were meant for women with obstetrical complications, it is inevitable (and desirable!) that these were also used for other, non-obstetric referrals. For example, lower-level health facilities frequently referred critically ill neonates or children or adults with severe anemia who required immediate blood transfusion. These possible further benefits were excluded from our analysis but are presumably consistent.

## Conclusions

Cost-effectiveness of ambulance services in our setting was very attractive. These can even be made more cost-effective when efforts are geared towards training educational interventions (*i.e* drills, simulations, continuing professional development) for health care providers, implementing an ambulance referral protocol, improving drug availability and equipping lower health facilities with drugs and essential supplies in order to prevent unnecessary inter-facility referrals.

## Abbreviations

CEA: cost-effective analysis; ICER: incremental cost-effective analysis; LCRH: Longisa County Referral Hospital; LYG: Life Year Gained; MNM: Maternal Near Miss; WHO: World Health Organization.

## Declarations

## Availability of data and materials

All the necessary data and materials are within this manuscript. In case any more data or materials are needed, they are readily available on request from the corresponding author.

## Competing interests

Two of the authors (TvDA and JvR) are members of the editorial board of this journal: TvDA an associate editor and JvR is a section editor.

### **Consent for publication**

Consent to publish this manuscript from the participants was deemed not applicable since the manuscript does not contain any individual person data.

### **Ethics approval and consent to participate**

The School of Economics, University of Nairobi first approved the research proposal and ethical clearance granted from Institutional Research and Ethics committee of Moi University and Moi Teaching and Referral hospital (Approval number: 0003422). While, LCRH administration gave us permission to proceed with the data collection. Written consent was deemed not necessary, since this study was retrospective analysis of routine clinical practice data. The latter ethical committee therefore waived written consent.

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## **Author contributions**

RK and MKM conceived and designed study protocol. RK supervised data collection, analyzed and draft first manuscript for revision by TvDA, LB, JvR and MKM. TvDA, LB, JvR and MKM contributed significantly to study design, data analysis, interpretation and manuscript writing. All authors read and approved the final manuscript.

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## Figures

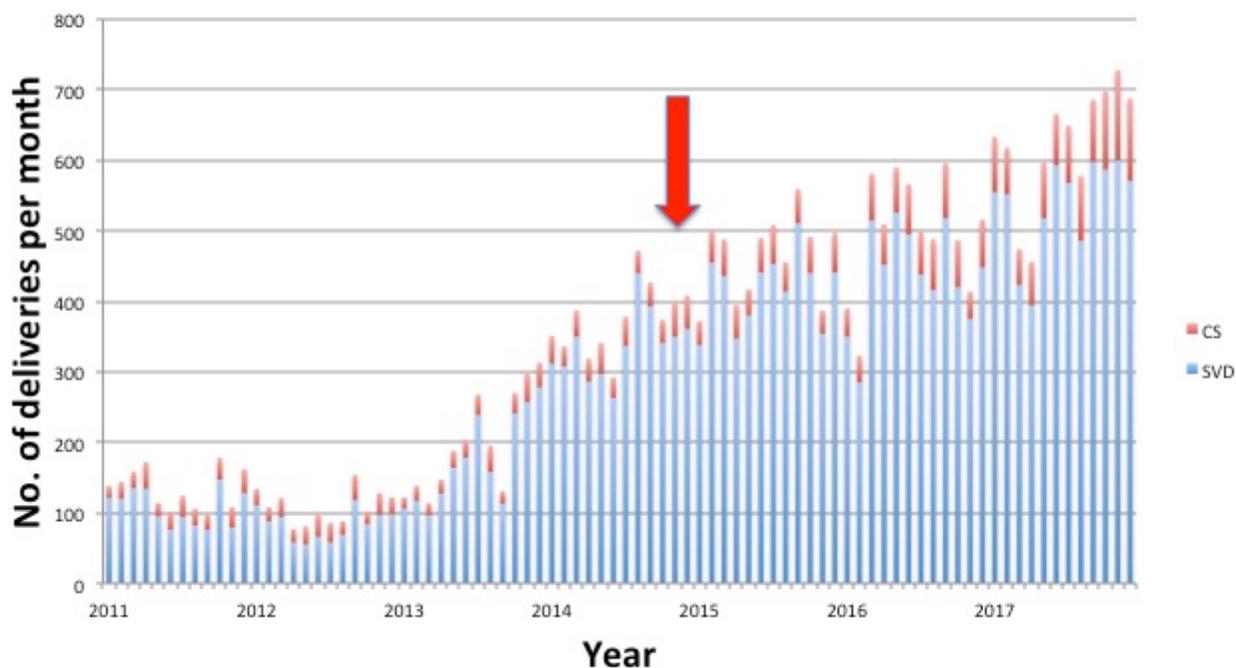


Figure 1

Number of births in LCRH, Bomet; 2011-17. NB: The red arrow shows when Kenya Red Cross Society ambulance service were started

## Supplementary Files

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