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# Emergency Obstetrical Complications in a Rural African Setting (Kayes, Mali): The Link Between Travel Time and In-Hospital Maternal Mortality

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**Abstract** The West African country of Mali implemented referral systems to increase spatial access to emergency obstetrical care and lower maternal mortality. We test the hypothesis that spatial access- proxied by travel time during the rainy and dry seasons- is associated with in-hospital maternal mortality. Effect modification by caesarean section is explored. All women treated for emergency obstetrical complications at the referral hospital in Kayes, Mali were considered eligible for study. First, we conducted descriptive analyses of all emergency obstetrical complications treated at the referral hospital between 2005 and 2007. We calculated case fatality rates by obstetric diagnosis and travel time. Key informant interviews provided travel times. Medical registers provided clinical and demographic data. Second, a matched case–control study assessed the independent effect of travel time on maternal mortality. Stratification was used to explore effect modification by caesarean section. Case fatality rates increased with increasing travel time to the hospital. After controlling for age, diagnosis, and date of arrival, a travel time of four or more hours was significantly associated with in-hospital maternal mortality (OR: 3.83; CI: 1.31–11.27). Travel times between 2 and 4 h were associated with increased odds of maternal mortality (OR 1.88), but the relationship was not significant. The effect of travel time on maternal mortality appears to be modified by caesarean section. Poor spatial access contributes to maternal mortality even in women who reach a health facility. Improving spatial access will help women arrive at the hospital in time to be treated effectively.

**Keywords** Maternal mortality · Emergency obstetrical care · Referral system · Access · West Africa

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## Introduction

The highest rates of maternal mortality in the world (≥1,000 maternal deaths per 100,000 live births) are in sub-Saharan Africa. According to the World Health Organisation (WHO), Mali has the eighth highest rate of maternal mortality, with approximately 1,200 deaths per 100,000 live births. A Malian woman has a 1 in 10 lifetime chance of succumbing to a maternal death; in developed regions of the world it is 1 in 2,800 [1].

Differences in maternal mortality rates between developed and developing countries (20/100,000 versus 440/100,000 respectively) reflect disparate levels of access to obstetrical care [1, 2]. While past lessons have shown that most fatal complications cannot be predicted or prevented [3–5], they can be treated with a few well-known technologies known as emergency obstetrical care (EmOC). EmOC is a proven strategy for reducing maternal mortality [6]; however, a plethora of social, economic, and political factors prevent widespread access to EmOC in many developing countries [7, 8]. These factors create significant barriers to women seeking care in a timely manner. In the case of obstetrical complications, spatial access, which describes physical barriers to care such as distance or the availability of transportation, may be one of the most important determinants of EmOC utilisation [8–11] as, "in true emergencies the location and number of providers assume greater importance than the psychosocial and economic barriers" [11, p. 64].

The majority of maternal deaths can be prevented with timely medical treatment [8], not the least of which is access to cesarean section. Ecological evidence shows that, in low-income countries such as Mali, where only two percent of women give birth by caesarean section, as the numbers of caesarean sections increase, maternal and neonatal mortality rates decrease [12]. When medically justified, such interventions are effective at reducing maternal mortality when compared to vaginal delivery [12, 13]. This is particularly true in settings with low rates of caesarean section, as they likely reflect access to life saving care [14].

Numerous authors have stated that spatial barriers to life-saving interventions such as caesarean section, such as long travel distances, must be reduced to lower maternal mortality rates [10, 15–21]. To our knowledge, only two studies have quantitatively addressed this question. The first of these works showed that maternal mortality could be reduced by 29–65% with improvements in spatial access [10], while the second obtained an odds ratio of 7.4 for women living more than 25 km from a hospital [22]. As both studies were population-based, little is known as to how spatial access influences maternal mortality in women who actually receive treatment. Where interventions exist to improve access to EmOC, it is important to know whether spatial access continues to be a contributing factor to maternal mortality.

Throughout Mali, referral systems have been implemented to improve spatial access. A woman will first visit her community health centre (CHC) and if necessary, will be referred to a higher-level facility- generally the district or regional hospital. Transfers are conducted by ambulance with 4-wheel drive. In the region of this study- Kayes- the health authority has made referral and treatment of all obstetrical complications free of charge (for a detailed description of this system, see 20). The referral system in Kayes has been shown to significantly reduce the number of maternal deaths for women treated at hospital; yet, despite the system, concern persists that spatial barriers to care have not been sufficiently reduced in the region. Thus, the objectives of this study are: (1) to describe the association between poor spatial access (measured by travel time) and maternal mortality in women treated for obstetrical emergencies in Kayes, Mali.; (2) to assess if time travelled to EmOC predicts mortality independently of age, obstetrical complication, and date of arrival; and (3) to explore the possibility of effect modification by caesarean section.

## Methods

### Study Design

There are two design components to this study. The first is a descriptive case-series and the second is a matched case–control design. For both designs, women treated at the regional hospital in Kayes, Mali were analyzed. The study base of the matched case–control was defined geographically (the district of Kayes) and temporally (January 2005 to December 2007).

### Study Site and Context

This study was conducted in the administrative district of Kayes, located in the extreme West of Mali, bordering Mauritania and Senegal. It is a rural region with a fairly homogeneous population. Specifically pertaining to the socio-demographics of women in the region, 86% have had no education and an additional 10% did not complete primary school. Nearly all women (80%) are employed in subsistence agriculture or livestock breeding [23].

The terrain in the district of Kayes, of the region of the same name, is geographically heterogeneous, ranging from arid Sahel in the North to semitropical in the South. The district has a surface area of 22,190 $km^2$ and is the most populous district in the region. There is only one paved road in the district. It also houses the region's capital, a rural town also named Kayes, where the regional hospital can be found. The regional hospital is the only site in the district that provides comprehensive EmOC; thus, it is the *sole* location where caesarean sections and blood transfusions legally occur. All obstetrical emergencies in the district are thus referred to this hospital. The district of Kayes contains 46 health zones, each of which theoretically houses a CHC. In reality, 29 health zones contain CHCs, another seven contain private or religious structures, and 10 are devoid of any. Overall, referrals are conducted by ambulance from 36 of the 46 health zones.

### Population and Sample

Two inclusion criteria were used in this study: (1) the woman resided in the district of Kayes and (2) she was diagnosed with an obstetrical complication. Cases were all maternal deaths occurring at the hospital within 42 days of birth, as defined by the WHO [1]. Cases were identified through a regional Obstetrical Emergency Monitoring System, or OEMS (described in detail below).

Controls were matched to cases on the basis of age, diagnosis, and date of arrival, using a three-to-one ratio. They were identified through the OEMS. For a given case, matches had the same diagnosis and were plus or minus

5 years of age. A wide age range was chosen to avoid overmatching and because it has been shown that age is a risk factor for maternal mortality in women of young age (<19) and above 35 years old [3, 24]. Diagnosis was chosen as a matching variable because of greatly differing case-fatality rates between diagnoses [25]. Categories of diagnoses included (1) uterine rupture or obstructed labour with pre-uterine rupture syndrome, (2) haemorrhage, (3) pre-eclampsia or eclampsia, (4) obstructed labour (excluding pre-uterine rupture syndrome), (5) infection, (6) miscarriage/abortion, (7) other direct cause, (8) indirect cause (anaemia, HIV/AIDS, other indirect cause). The third matching criterion was date of arrival; when more than three controls could be matched to a case, we chose those who arrived at the hospital closest in date to the case. This was done to limit temporal changes in case management and quality of care over the study period.

### Variables

The main outcome variable was maternal death. The exposure variable of interest was spatial access, measured by travel time. Spatial access was coded categorically with two cut-off points at ≥2 h and ≥4 h of travel time. The first cut-off point was determined according the literature (the estimated gap between modal time to death for post-partum haemorrhage is 2 h) [10, 26]. The second cut-off was chosen because many women had travel-times much greater than 4 h and it was believed that even for much less fatal complications, such as obstructed labour, these longer travel times could contribute to maternal mortality as the complication became more severe with time.

As described above, confounders considered in this study were age, diagnosis and date of arrival at the hospital. Caesarean section was explored as a possible effect modifier. Caesarean section was considered because of its association with maternal survival in women with complications [13, 14, 27, 28]. All caesarean sections included in the OEMS were indicated; none were elective. It was coded dichotomously.

### Data Sources and Collection

Two sources of data were used in this study. The first was the OEMS which has been recording and monitoring all obstetrical complications in the seven districts of Kayes since July, 2004. All women who use the referral system and/or are treated at the hospital for complications are entered into this system. It records demographic and medical details including the woman's age, village of origin, date of arrival, diagnosis, delivery method including treatment, and survival outcome. The OEMS provided the data for our outcome, confounders, and effect modifier. Village of origin was used in conjunction with our second data source to determine exposure (see below).

The second source of data provided information on the exposure variable, spatial access. Spatial access can be proxied by measurements of time-travelled [29]. Data on spatial access were obtained in the field through key informant interviews. Key informants were identified in a pilot study and included ambulance drivers, vaccinators, and health centre directors [30]. Informants at each health centre were asked how long it takes a woman with a complication to reach the hospital from her village during the dry season (November 1 to June 30) and rainy season (July 1 to October 31), depending on the most prevalent form of transportation used to evacuate her. For most women, the travel trajectory was village to CHC and CHC to hospital. The first segment was generally spent in donkey-drawn carriage, while the last segment was spent in an ambulance. Vaccinators and CHC directors provided the travel times between the woman's village and CHC; ambulance drivers provided the travel times between the CHC and hospital. Reported travel times were linked to all women in the OEMS depending on their home village and season of travel (694 possibilities given the 347 villages and 2 seasons). When a range of travel times were given, we used the shortest travel time (*the best-case scenario*).

### Statistics

Descriptive statistics were computed for all women in the OEMS. To address objective one, case-fatality rates were determined for each obstetric diagnosis (number of deaths for that diagnosis over total number of women with that diagnosis) and determined for increasing time-travelled to the hospital. Specifically, the case-fatality rate was calculated for women whose travel time to the hospital was less than 1, 1–2, 2–3, 3–4 h, and four or more hours. To address objective two, associations between time-travelled and in-hospital maternal mortality were tested using conditional logistic regression in STATA 9.1. Confounding for age, diagnosis, and date of arrival was a priori controlled through matching. Finally, to address objective three, case-fatality rates and 95% confidence intervals were calculated across strata of exposure (travel time) and caesarean section (yes or no).

## Results

### Descriptive Data

Between January 2005 and December 2007, 2,359 women were treated for obstetrical complications at the regional hospital. Of these, survival status was known for 2,234; 47

resulted in maternal deaths, yielding a case-fatality rate of 2.1%. The primary diagnoses and case-fatality rates of the maternal deaths were: (pre-) eclampsia ($n = 13$, 6.5%), haemorrhage ($n = 13$, 4.3%), indirect cause ($n = 7$, 4.7%), uterine rupture ($n = 6$, 19.4%), other direct cause ($n = 3$, 0.8%), obstructed labour ($n = 3$, 0.4%), infection ($n = 1$, 5.3%), and miscarriage/abortion ($n = 1$, 0.7%). The average age of a woman was 25 years old (min 12, max 48), 64.7% came from the town of Kayes, the mean time-travelled was 80 min (median 15 min, min 15 min, max 30 h), and 50.6% had a caesarean section.

*Objective 1: To Describe the Association Between Time-Travelled and Maternal Mortality*

Case-fatality rates increased with increasing time-travelled. The case-fatality rate at 2–3 h from the hospital was 2.72% and at greater than or equal to 4 h, it was 5.49% (Fig. 1), compared to 1.72% for those less than 2 h from the hospital.

*Objective 2: To Assess if Time-Travelled is an Independent Predictor of Maternal Mortality*

The case–control study allowed us to assess if time-travelled to the hospital was an independent predictor of maternal mortality. All maternal deaths were classified as cases. The average age of a case was 28 years old (min 16, max 45) and the mean time-travelled was 150 min (median 45 min, min 15 min, max 24 h). The majority of cases came from outside of the town of Kayes; less than half received a caesarean section. We matched 135 controls to 47 cases. On average, controls arrived at the hospital within 1 month of the case (mean 31 days; range 0–161 days). The average age of a control was 27 (min 15, max 43) and the mean time-travelled was 80 min (median 15 min, min 15 min, max 24 h). A minority of controls lived outside of the town of Kayes and more than half had a caesarean section (Table 1).

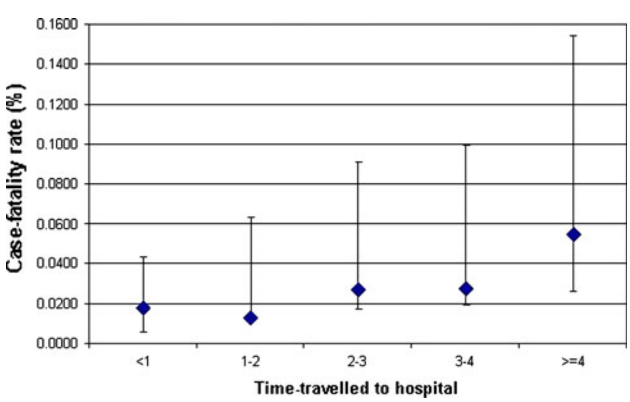


**Fig. 1** Case-fatality rate (%) with increasing time-travelled to the hospital

**Table 1** Descriptive data for cases and controls

| | Case (47) | Control (135) |
|---|---|---|
| Age, years, mean (SD) | 28 (8.4) | 27 (7.2) |
| Time-travelled, minutes, mean (SD)* | 150 (247) | 79 (152) |
| Resides in regional capital (%)* | 22 (47.8) | 90 (67.2) |
| Time-travelled ≥2 h (%)* | 19 (40.4) | 30 (22.2) |
| Caesarean section (%) | 19 (41.3)[§] | 75 (55.6) |

* Difference between cases and controls significant $P < 0.05$

§ 1 missing value

**Table 2** Association between time-travelled and in-hospital mortality controlling for age, diagnosis, and date of arrival

| Exposure category | OR | *P*; CI |
|---|---|---|
| 2–4 h from hospital | 1.88 | 0.17; 0.75–4.72 |
| ≥4 h from hospital | 3.83 | 0.01; 1.31–11.27 |

Conditional logistic regression of the matched cases and controls showed that travel time of greater than or equal to 4 h was significantly associated with being a case (Table 2), but travel times of 2–4 h were not significantly associated.

*Objective Three: Explore Effect Modification by Caesarean Section*

Case-fatality rates differed according to those who received and did not receive a caesarean section (Table 3). For both groups, case-fatality rates increased with increasing time-travelled to the hospital, but the effect was greater in those having not received a caesarean section in the first two exposure categories (less than 2 h, 2–4 h). After 4 h of travel time, the case-fatality rate was higher in those who received a caesarean section than those who did not receive one.

## Discussion

Globally, this study looked at how spatial access, measured by time travelled, affects in-hospital maternal mortality. Given the little quantitative evidence available on the

**Table 3** Case-fatality rate and 95% confidence interval with increasing time-travelled to hospital according to caesarean section

| Exposure category | Caesarean section | No caesarean section |
|---|---|---|
| <2 h | 1.16%; CI: 0.45–1.87% | 2.39%; CI: 1.30–3.48% |
| 2–4 h | 2.21%; CI: 0.00–4.68% | 2.73%; CI: 0.37–5.09% |
| ≥4 h | 7.06%; CI: 1.61–12.51% | 4.26%; CI: 0.18–8.34% |

association between poor spatial access and maternal mortality, and the increasing emphasis on improving access to EmOC [6, 31], this study expands upon previous work by looking at women who succeeded at reaching EmOC. Further, by controlling for key confounders (through matching) not addressed in previous works [10, 22], it shows the independent effect of travel time on maternal mortality. The study also provides evidence to suggest effect modification by caesarean section, which has important implications for EmOC effectiveness, as caesarean section is one of its most powerful components.

Our study supports the hypothesis that even among women who reach EmOC, considerable travel times increase the chances of maternal mortality. Descriptive data computed for all women recorded in the OEMS showed that case-fatality rates increased as the number of hours from the hospital increased. The case–control study further supported this finding, demonstrating that travel time is independently associated with in-hospital maternal mortality. After controlling for age, diagnosis, and date of arrival, we found that women who lived four or more hours from the hospital were 3.83 times more likely to die of an obstetric complication. Those living 2–4 h from the hospital were more likely to be a case than control (OR: 1.88; CI: 0.75–4.72), but the association was not significant at an alpha of 5%. However, the finding is consistent with the maternal health literature in which 2 h is considered an important cut-off for poor spatial access [10, 26].

We believe that we lacked adequate sample size to detect a significant effect for travel times of 2–4 h from the hospital. The sample size was also too small to assess effect modification by caesarean section in the conditional logistic regression. Nevertheless, it should be noted that even in areas with high rates of maternal mortality, maternal deaths are gratefully rare events. This is particularly true for hospital-based studies, as most births in Mali occur in the absence of a healthcare professional [23]. Large sample sizes are difficult, if not impossible, to obtain [6]. Even in the best studies (many population-based), the numbers of recorded maternal deaths rarely surpass double digits and/or have wide confidence intervals around study estimators [2, 17, 18, 22, 32]. Despite sample size limitations, it should be acknowledged that this study has one of the largest samples of in-hospital maternal deaths in the literature.

One additional concern is that errors in the measurement of the exposure variable could account for the lack of association found at the 2-h cut-off. We deliberately chose the “best-case” scenario in attributing travel times to women in the OEMS in order to reduce the possibility of over-estimating the association between travel time and maternal mortality. Nonetheless, measurement of spatial access in this study was more comprehensive than that of previous works [10, 22]. By measuring spatial access in terms of time-travelled, we were able to capture important differences in access due to season, transportation, and geographic barriers that physical distance measures cannot. Finally, as data on the exposure variable were obtained independently of knowledge of cases and control status, we limited the possibility of differential misclassification due to recall or interview bias.

Stratification of exposure and outcome by caesarean section supports effect modification. At less than 2-h of travel time, case fatality rates for those having received a caesarean section were half that of those having not received a caesarean section. This is not surprising, because when medically justified, caesarean section is effective at reducing maternal mortality [12, 13]. However, as Table 3 demonstrates, the case-fatality rate of those who received a caesarean section increased as the number of hours from the hospital increased, particularly at the 4-h threshold. This implies that the protective effect of caesarean section was not equal for everyone, as the benefit was less pronounced in those living further away. In fact, the highest case fatality rates were found in women who received a caesarean section and had travel times of four or more hours from the hospital. These women likely arrived too late for caesarean section to be effective.

In assessing the relationship between spatial access and in-hospital maternal mortality, we could not control for delays in the decision to seek care nor could we control for delays at the CHC or hospital. For example, women and/or their families living further away from the hospital may have delayed seeking care precisely because the hospital was far away, thus compounding the problem of delay and increasing the woman’s chance of maternal death. Once again, because exposure status was assigned independently of case/control status, misclassification error should be non-differential and the bias directed to the null. Finally, this study did not address other potential confounders such as socio-economic status and ethnicity. Because of the relatively homogeneous population in the Kayes district, we believe that the effect of these possible confounders should be minimal but nevertheless believe that future studies should attempt to assess their potential contribution.

## Conclusion

There is general consensus that poor spatial access to EmOC must be reduced in order to limit the high maternal mortality rates found in developing countries. For such efforts to be effective, we must know the relationship between spatial access and maternal mortality, even in women who receive treatment. This study takes a further step towards evaluating this relationship and provides evidence upon which interventions can be built. Specifically, it suggests that while ideally, a woman should be able to access EmOC within 2 h, her chances of maternal death increase dramatically after 4 h of transportation. It also suggests that important, but costly medical interventions such as caesarean section, may be less effective in women who experience long travel times, as these women arrive in very poor condition. This reinforces the fact EmOC is only effective if women arrive in a treatable state. Concretely, future interventions in the region need to improve road and bridge infrastructures, particularly during the rainy season, and work with the community to assure rapid recognition of obstetrical complications, as well as rapid referral.

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