Université de Montréal

Emergency obstetrical complications in a rural African setting (Kayes, Mali): The link between spatial access and maternal mortality

par

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Mémoire présenté à la Faculté des études supérieures en vue de l'obtention du grade du MSc. en Santé Communautaire

Août 2007

Université de Montréal
Faculté des études supérieures

Ce mémoire intitulé :

Emergency obstetrical complications in a rural African setting (Kayes, Mali): The link between spatial access and maternal mortality

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RÉSUMÉ

Contexte: La recherche sur la mortalité maternelle indique que les barrières à l'accessibilité spatiale contribuent aux taux élevés de la mortalité maternelle observés dans les pays en développent. Il n'est pas clair comment l'accessibilité spatiale peut être mesurée.

Objectif: 1) Déterminer une mesure appropriée de l'accessibilité spatiale dans un contexte rural et isolé en Afrique de l'Ouest (Kayes, Mali). 2) Tester l'hypothèse selon laquelle l'accessibilité spatiale- mesuré par le temps requis pour recevoir des soins pendant la saison des pluies et la saison sèche- est associée avec la mortalité maternelle hospitalière à Kayes.

Méthodes: La justesse de deux mesures de l'accessibilité spatiale (distance en kilomètres et le temps de voyage pendant la saison des pluies et la saison sèche) a été examinée dans le contexte de Kayes. Une étude cas-témoin avec appariement a été effectuée sur les femmes traitées à l'hôpital régional pour des complications obstétricales entre 2005 et 2006. Un registre médical a fourni les détails cliniques et démographiques utilisés pour l'appariement. Des informateurs-clés ont fourni les données concernant l'exposition.

Résultats: Le temps de voyage était la meilleure mesure de l'accessibilité spatiale. L'accessibilité spatiale limitée était significativement associée avec la mortalité (OR: 2.97; CI: 1.16-7.57). Elle n'était plus significatif une fois l'intervention obstétricale majeure (i.e. césarienne) a été ajoutée au modèle ; l'intervention a eu un effet protecteur significatif (OR: 0.19; CI: 0.05-0.75).

Conclusion: Notre étude contribue aux travaux précédents qui ont démontré qu'une mauvaise accessibilité spatiale augmente la mortalité maternelle; cependant les interventions obstétricales, telles que les césariennes, peuvent réduire les effets néfastes d'une accessibilité spatiale limitée.

Mots clés : cas-témoin, césarien, pays en développent

SUMMARY

Background: Research on maternal mortality indicates that barriers to spatial access contribute to the high maternal mortality rates witnessed in developing countries. It is unclear how to measure spatial access in such contexts.

Objectives: 1) Determine an appropriate proxy of spatial access in a rural and remote region of West Africa (Kayes, Mali) 2) Test the hypothesis that spatial access- proxied by travel time during the rainy and dry seasons- is associated with in-hospital maternal mortality in Kayes.

Methods: Two measures of spatial access (physical distance in kilometres and travel time during the dry and rainy seasons) were assessed for their appropriateness in the context of Kayes. A matched case-control study, analysed with conditional logistic regression, was conducted on women treated at the regional hospital for obstetrical complications in 2005 and 2006. A medical registry provided clinical and demographic details used for matching. Key informant interviews provided exposure data on spatial access.

Results: Spatial access was best proxied by travel time. Poor spatial access was significantly associated with mortality (OR: 2.97; CI: 1.16-7.57). Spatial access was no longer significant once major obstetric intervention (e.g. caesarean section) was added to the model; it had a significant protective effect against mortality (OR: 0.19; CI: 0.05-0.75).

Conclusions: This study expands upon previous evidence demonstrating that poor spatial access leads to increased maternal mortality; however, protective interventions, such as caesarean section, militate against the deleterious effects of limited spatial access.

Key words: case-control, caesarean section, developing countries

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LIST OF ABBREVIATIONS

Abbreviation	Definition	Page first mentioned
CHC	Community health centre	7
dKm	Distance measured in kilometres	43
dTD	Distance measured by time during the dry season	43
dTR	Distance measured by time during the rainy season	43
DHS	Demographic health survey	8
EmOC	Emergency obstetrical care	3
FCA	Floating catchment area	30
MCH	Maternal and child health	13
MDG	Millennium Development Goal	1
MOI	Major obstetrical intervention	36
RHC	Reference health centre	7
RHA	Regional health authority	39
SMI	Safe motherhood initiative	13
WHO	World Health Organisation	5

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To my grandmother

At the end of every experience, including suffering, there is gratitude.

What is man? A cry of gratitude.

-Elie Wiesel

ACKNOWLEDGEMENTS

I would like to express my most heartfelt thanks to both my research directors, who have, throughout this project, expressed a most sincere interest in my advancement as well as having provided invaluable insight and direction. Their contribution to this work is impossible to put into words. Similarly, I would like to acknowledge the important contribution of Caroline Tourigny. Her knowledge of Kayes, her accompaniment during my fieldwork, and her continuous advice throughout the research is greatly appreciated. My acknowledgements further extend to Karim Sangaré who opened the doors necessary for my fieldwork to occur and to Thomas, Karim, and Dra who were my partners in crime while in the bush. Further thanks must go to Alexandre Dumont who provided technical feedback on all questions "maternal." Finally, I would like to thank Vinh-Kim Nguyen for his continuous support and advice throughout my degree.

1. INTRODUCTION

Behind every death in pregnancy and childbirth is a personal tragedy... When multiplied many, many times over- nearly once every minute-then it is also a social injustice of massive proportions. When framed by its social profile- when we acknowledge that 99% of maternal deaths happen in developing countries... then it is also a collective badge of shame.
L.P. Freedman (2001)

Each year, an estimated 8 million women worldwide suffer of complications related to pregnancy and birth. Of these, 529 000 die. For every woman who dies, another 30 are estimated to suffer chronic stigmatizing morbidities, notably obstetric fistula [1]. In many countries, maternal mortality is the leading cause of death for women of reproductive age [2]. In the last decade, the tragedy of maternal mortality has moved from the political backburner to the international spotlight. Underscoring this change in global priorities is the inclusion of MDG[1] 5, *Reduce by three quarters the maternal mortality ratio,* in United Nation's Millennium Development Goals, to be reached by 2015 [1, 3].

Maternal death is "almost inevitably, a double tragedy," as it is also an important cause of neonatal and infant mortality [4 p642]. The link between maternal health and child survival has been dramatically illustrated in places such as Bangladesh, where in one study, the authors found that out of 125 maternal deaths preceded by a live-birth[2], more than a third of the newborns died within the first month; half, within three months; and over three-quarters, within a year [5]. The goals of safe motherhood and child survival

[1] Millennium Development Goal number 5
[2] The authors of this study looked at all maternal deaths that occurred in Matlab during the years 1976-1985. 387 maternal deaths were identified during this study period. Of these, 125 mothers had a live birth and died subsequently.

programs go hand an hand, as in both cases, a substantial number of deaths (maternal or child) can be averted with adequate care of the mother during childbirth [6, 7].

MATERNAL MORTALITY: WHO, WHAT, WHERE, WHEN, AND WHY?

Every pregnant woman is at risk of developing life-threatening obstetrical complications. Approximately 15% of pregnant women will develop such complications and of these, 1-3% will die in the absence of a major surgical intervention [8]. While every pregnant woman is at risk of developing complications, the risk of succumbing to them is not equal for every woman, as the rates of maternal mortality and morbidity vary considerably across the globe and in particular, between developing and developed countries [9]. Approximately 99% of worldwide maternal deaths occur in developing countries; 95% of maternal deaths occur in Africa and Asia alone [1, 9]. Of all the human development indicators frequently used, it is with maternal mortality that the widest gap between developing and developed countries is seen; the rate of maternal mortality in developing countries is 100 times higher than in developed countries [10, 11].

It is estimated that 80% of maternal deaths are directly linked to factors attributable to the pregnancy itself and are thus termed direct obstetrical deaths. These are the result of obstetrical complications (e.g. pregnancy, labour, etc), interventions, omissions, incorrect treatments, or a chain of the above factors [12]. Of all the direct causes of maternal mortality, five alone are responsible for two thirds of all maternal deaths. These include: haemorrhage, obstructed labour, sepsis, pre-eclampsia and/or eclampsia, and the complications of unsafe abortion [1]. The other 20% of maternal deaths are attributable to indirect causes, such as anaemia, malaria, and HIV/AIDS [2, 12]. However, with the increasing burden of HIV/AIDS in many sub-Saharan African countries (which already have the highest rates of maternal mortality), indirect causes of maternal mortality may be on the rise [1, 13, 14].

Most maternal deaths occur between the third trimester and the first week after the end of pregnancy. Mortality can be very high on the first and second days after birth. That is, during and immediately after the birth, when a women should ideally be under the observation of a skilled attendant [13, 15, 16].

The majority of obstetrical complications can be treated with a few well-known technologies that make up a package known as emergency obstetrical care (EmOC) [16]. However, few complications can be predicted or prevented; most women who die of maternal causes were never considered at high-risk for these complications [17, 18]. This means that the vast majority of maternal deaths can only be averted with the timely treatment of obstetrical complications once they have occurred [19].

In developing countries where most births occur at home, health infrastructures are not necessarily well developed, and significant financial and transportation barriers may be present, reaching a health center with EmOC in time to save the mother may be an impossible task [19]. More generally, many of these countries have limited political commitments towards maternal and reproductive health and do little to create an enabling environment for the improvement of maternal health [20].

PROGRESS TOWARDS MDG 5

July 2007 marked the half-way point for achieving the Millennium Development Goals. Sadly, at the current rate of progress, the goals will only be reached in sub-Saharan Africa by 2282- or 275 years from now [21]. To date, assessments of progress indicate that the least headway has been made in MDG 5. This trend is particularly true in sub-Saharan Africa where the maternal mortality ratio for some countries has actually increased [22]. Achieving the health outcomes targeted by the Millennium Development Goals- specifically MDG 5- will not be possible without major improvements in health systems, as well as policies and interventions that move beyond the health sector itself- such as the improvement of rural infrastructures (roads, telephones, etc.) [23].

2. STUDY CONTEXT: MALI, WEST AFRICA

2.0) AMPLITUDE OF PROBLEM

With the sole exception of Afghanistan, the highest rates of maternal mortality in the world ($\geq$1000 maternal deaths per 100 000 live births) are in sub-Saharan Africa and some of the highest of these rates can be found in West Africa (table I). According to the World Health Organisation's (WHO) estimates, Mali has the eighth highest rate of maternal mortality in the world, with approximately 1,200 deaths per 100 000 live births [9]. Based on these estimates, a Malian woman has a 1 in 10 lifetime chance of succumbing to a maternal death. In comparison, the lifetime chance in developed regions of the world is 1 in 2800 [9].

Table I: Maternal mortality (per 100 000 live births) and lifetime maternal death risk for select West African countries in 2000 [adapted from 9]:

COUNTRY	WHO MATERNAL MORTALITY RATIO	LIFETIME MATERNAL DEATH RISK, 1 IN:
BENIN	850	17
BURKINA FASO	1000	12
CÔTE D'IVOIRE	690	25
GUINEA	740	18
MALI	1200	10
MAURITANIA	1000	14
NIGERIA	800	18
SENEGAL	690	22
SIERRA LEONE	2000	6
THE GAMBIA	540	31

2.1) STUDY CONTEXT

Mali is one of the largest countries in West Africa, with a surface area of 1.24 million Km (about the size of California and Texas combined). It is bordered by seven countries, including Mauritania, Senegal, Guinea, Côte d'Ivoire, Algeria, Niger, and Burkina Faso. Mali has a population of 11 680 646 and is divided into 8 administrative regions: Kayes, Koulikoro, Sikasso, Segou, Mopti, Gao, Tombouctou, and Kidal [24]. A third of the population is considered urban, with the majority of urbanites living in the capital city of Bamako [25]. The other two-thirds of Mali's population are rural and engaged in subsistence agriculture, mostly around the Niger and Senegal rivers. Most farmers live in small villages of 150-600 people, helping to explain the country's low population density (9.1 people per sq. km) [24, 26]. In the Northern regions, large portions of the population are nomadic and populations densities are even lower [27].

Mali is a Sahelian country fraught by droughts, made worse in recent years by increasing desertification and land degradation in the Northern regions [28, 29]. Harsh climatic events, including the intense winds and dust storms of brought on by the Harmattan[3] and heavy rains and flooding during the rainy season define the many parts of the country [24, 30]. During the rainy season, it is not unusual for entire villages or even districts to be inundated and inaccessible [24]. Road infrastructures are extremely poor and concentrated in around the capital and to a lesser extent, in regions with significant international investment and migrant remittances. Most roads are not paved and easily become impassable after heavy rains, often doubling or tripling travel times [24].

[3] Refers to the Harmattan wind system. These winds dominate during November to April and normally persist until the beginning of the rainy season, transporting dust across West Africa to the Atlantic Ocean.

Mali's population is amongst the poorest in the world with 72.3% of the population living on less than a dollar a day [31]. It has a human development index score of 0.34 and a life expectancy at birth of 49.1 years. The healthy life expectancy in Mali is 38.3 years for women and 37.5 years for men. The adult literacy rate is 19%, with women having a rate of 11.9% and men, 26.7% [32, 33]. Mali's average annual healthcare expenditure is 4.8% of the gross domestic product, a proportion that is on par with other West African countries. Likewise, the number of physicians per 1000 people in Mali is 0.1, a ratio that is also similar to other West African nations [25].

ORGANIZATION OF HEALTH STRUCTURES: The healthcare system in Mali is organised with three levels of public healthcare structures. The first is comprised of community health centres (CHC), the second consists of reference health centres (RHC), and the third is composed of regional or national hospitals. CHCs are theoretically placed 0 to 15km apart and cover populations of 5000 to 15000 inhabitants [27, 34]. In principle, the minimum staff profile of CHC should include a state registered nurse[4], a birth attendant[5], and a pharmacy manager. This, however, is rarely the case, particularly in rural regions. Only about 25% of CHCs are actually staffed with a state registered nurse; the vast majority are run by nurses and medical auxiliaries[6] [27]. Doctors staff approximately 18% of CHCs, but in general, can be found at the RHCs and hospitals located in urban centres. The same is true for midwives who are mostly concentrated in the capital or in secondary and tertiary structures outside the capital [27, 34].

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[4] State registered nurse, or "*infirmier diplomé de l'Etat*", is a nurse with a bachelor's degree; A nurse has 3 years of post-secondary training, but no bachelor's degree.
[5] Similar to a traditional birth attendant.
[6] Medical auxiliaries, or aides, have limited to no formal medical training. They typically obtain experience through on-the-job training. Some are volunteers.

SELECT MATERNAL AND REPRODUCTIVE HEALTH INDICATORS FOR MALI: According to Mali's ministry of health, there is a weak utilisation of curative healthcare services in the country. Between 1998 and 2003, the number of consultations per inhabitant per year only increased from 0.18 to 0.21, despite national projections that it would reach 0.50 consultations/ inhabitant / year [35]. This weak utilisation is reflected in indicators describing the coverage of antenatal care, assisted delivery, and childhood vaccination. According to Mali's 2001 Demographic Health Survey (DHS), only 52.1% of women had received one antenatal consultation, which is considerably lower than the sub-Saharan Africa average of approximately 65%. As for women receiving four or more antenatal consultations, the Malian percentage was 29.9% [36, 37]. Likewise, only 40.6% of women who gave birth had a delivery assisted by a health professional and of those, only 1.5% were assisted by a doctor. Finally, the proportion of children having received complete diphtheria, typhoid, and polio (DPT3) vaccinations by 2001 was 39.6% [38].

According to the *preliminary* 2006 DHS, it appears that there have been improvements in many of the indicators since the 2001 DHS. For example, the proportion of women receiving at least one antenatal visit is now 70.0% and the proportion having assisted deliveries is currently 49.0%; however, this preliminary report does not provide data on the number of women receiving four or more antenatal visits or on those whose delivery was assisted by a doctor. As for the number of children receiving DTP3 vaccinations, it has risen to 67.6% [39]. Nonetheless, these encouraging numbers mask important rural-to-urban and regional differences. According the present report, 86.9% of urban women have at least one antenatal visit- a number well above the sub-Saharan African average- but only 63.8% of rural women have one visit. In the Northern regions of Kidal, Tombouctou, and Gao, these percentages are 32.0%, 42.5%, and 58.0% respectively. Further, the number of women giving birth in a healthcare facility is still starkly below international benchmarks (49.0% versus 80.0%) [3] and among those who reside in rural areas, the percentage is even lower (37.6%). Likewise, DTP3 vaccinations of children in certain regions of Mali fall far below the national average, such as those in Kayes (49.4%), Tombouctou (48.9%), and Kidal (24.8%) [39].

2.1) Referral System and Free Caesarean Sections

In light of the Mali's undesirable maternal health indicators, measures have been undertaken to increase reproductive healthcare utilisation throughout the country. According to Mali's Health and Social Development Program (PRODESS-II), the country aims to increase the geographic coverage of healthcare infrastructures[7] and to create innovative measures to make services more attractive and increase their rate of usage [35, 37]. National policy espouses measures that improve geographic and financial access to quality health services [27]. Mali has thus embarked on two nationwide initiatives: referral systems throughout the country and free caesarean sections.

Until the early 1990s, EmOC was virtually non-existent outside of the capital city of Bamako, with only 0.2% of deliveries occurring by caesarean section. Decision-makers recognised that maternal mortality could not be reduced if coverage was not increased. Thus, in 1994, several districts tested referral systems and by 1997, referral systems were being promoted as a national strategy to reduce maternal mortality [40].

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[7] In fact, improving the geographic coverage of healthcare infrastructures in Mali was so important to the health ministry, that 80% of the financing in PRODESS was affected by this goal.

Theoretically, in Mali, emergency obstetrical services are organised in the following manner. Basic EmOC is provided at primary facilities, typically CHCs, and includes the provision of antibiotics, oxytocics, and anticonvulsants, as well as manual assistance during delivery and manual removal of the placenta. At secondary and tertiary health centres (RHCs, regional and national hospitals), these same services are provided along with caesarean section and blood transfusion (table II). In reality, very few CHCs have the staff or materials to provide basic EmOC. Thus, the vast majority of obstetrical complications are treated at a secondary or tertiary health facility. Under the referral system, primary centres are furnished with communications equipment- generally a radio- that can alert secondary/tertiary centre of a referral. The secondary/tertiary centre then sends an ambulance to collect the patient. The purpose of this system is to reduce transportation delays that can lead to a mother's death.

Table II: Services provided at EmOC facilities

Basic EmOC (some CHCs)	**Comprehensive EmOC** (hospital in region capital)
Administration of antibiotics, oxytocics, and anticonvulsants	All the services of basic EmOC plus:
Manual extraction of the placenta	Caesarean Sections
Assisted births (forceps, obstetrical vacuum, etc)	Blood transfusions

Development of the referral system was slow, with only 12 of the country's 55 districts running an effective system as of 1999 [40]. By 2004, most districts had a referral system, but insufficient human resources, poor communication between various levels of referral, and an excess of non-referred cases in secondary and tertiary centres plagued the system [35]. Despite these difficulties, the referral system is still considered vital to reducing maternal mortality in Mali, as well as other developing countries [35, 40-42].

In a similar effort to increase EmOC utilisation, the President of the Republic- Amadou Toumani Touré- declared in 2005 that caesarean sections would be provided free of charge [43]. Previously, the direct cost of a caesarean was around 60 000 CFA (approximately 135 Canadian dollars)[8], an exorbitantly high price in a country where over 70 percent of the population lives on less than a dollar a day [43, 44]. Overall, these two initiatives aim to reduce some of the financial and geographic barriers that prevent women with obstetrical complications from accessing lifesaving care and appear, in certain contexts, to have met with success. For instance, the region of Kayes, located in the Western-most part of Mali, has witnessed an increase in the coverage of caesarean section for EmOC from 8 to 19% and a decrease in the number of stillbirths from 55-34% in women with complications [45].

BOX A: Study Context - at a Glance

PROBLEM
- Very high maternal mortality rate: 1200/100 000
- Large rural population- most dispersed, some nomadic
- Harsh climate, poor road infrastructures, insufficient number of rural health providers
- Poor maternal and child health indicators- particularly in rural regions
- Poor access to EmOC

PROPOSED SOLUTION
- Provision of basic EmOC at CHCs
- Implementation of referral system for obstetrical complication
- Free caesarean section

3. LITERATURE REVIEW

In the previous two chapters, the problem of maternal mortality was first introduced in its global context, followed by the particular context of this study. In both chapters, the role of health systems was alluded to, first when describing the amplitude of difference between developed and developing countries' maternal mortality rates and secondly, when describing the specific interventions that Mali has put in place to reduce its maternal mortality ratio. This chapter will provide a thorough literature review on the current state of knowledge on maternal mortality, with a particular focus on the role of health systems.

3.0) THE SEMINAL WORKS

Between 1985 and 1994, three seminal papers on maternal mortality came out of Columbia University:

- In 1985, Rosenfield and Maine wrote ***Maternal mortality- a neglected tragedy: Where is the M in MCH?***
- In 1992, McCarthy and Maine constructed ***A framework for analyzing the determinants of maternal mortality***
- In 1994, Thaddeus and Maine developed ***Too far to walk: Maternal mortality in context***

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[8] This cost represents the procedure itself and does not include costs associated with transportation, lodging, food, or even the procurement of supplies such antibiotics, dressings, and blood for the procedure.

By far, these are three of the most cited works in the literature and for good reason; they forever changed research on maternal and child health in developing countries. In the first of these works, Rosenfield and Maine called attention back to the M (mothers) in MCH (mother and child health) programs. Prior, the assumption was that "whatever is good for the child is good for the mother" [46 p83]. Such programs promoted simple interventions such oral rehydration, growth monitoring, breastfeeding, and immunization, but relegated the maternal aspects of MCH to a secondary priority [46]. While these interventions did (and do) much to prevent many of the common causes of childhood morbidity and mortality such as diarrhoea, infectious diseases, and malnutrition, they were (and continue to be) too focalized to successfully combat the more systematic causes of maternal and neonatal mortality in developing countries, such as inadequate health systems' infrastructures and the exorbitant costs of formal medical care [20, 46-48]. Further, with attention focused exclusively on the child, the prevention of maternal deaths was important only as it adversely impacted children and other family members. It was largely forgotten that pregnant women are intrinsically valuable in their own right [19]. In 1987, because of emerging concerns over the high rates of maternal mortality in developing countries and poignant cries to action (such as that of Rosenfield and Maine), the World Bank in collaboration with WHO and UNFPA, launched the Safe Motherhood Initiative (SMI) in Nairobi, Kenya [49].

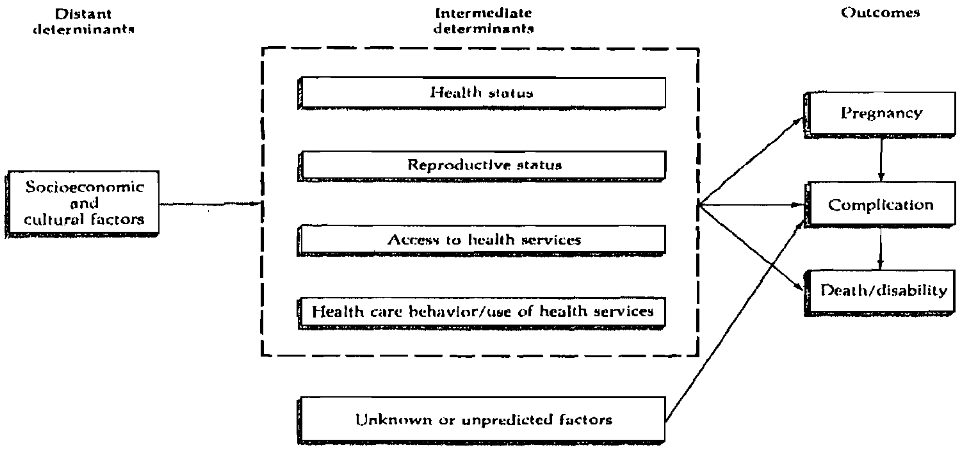
The SMI outlined seven interventions for reducing maternal mortality: 1) provision of family planning services; 2) improvements in the socioeconomic status of women; 3) provision of safe, legal abortion services; 4) provision of prenatal care; 5) improvements in EmOC; 6) training of traditional birth attendants; and 7) education and mobilization of the community (McCarthy and Maine 1992). The interventions outlined in the SMI have been subject to much criticism, largely because they are so wide-reaching. According to McCarthy and Maine (1992) only three interventions from the SMI directly reduce maternal mortality: reducing the number of pregnancies; providing safe, legal abortions; and improving EmOC. Authors such as Weil and Fernandez (1999) blame the SMI for taking responsibility and motivation away from the three main participants in maternal-health programs: decision makers, donors, and obstetricians. They believe that the idealistic vision behind SMI was too diffuse to motivate real change. Authors, such as Ann Starrs (2006), concur by stating that the focus on maternal mortality as a multi-sectoral problem led to complex and expensive national action plans with no clear leadership which in turn, deterred international donors. However, she adds that the SMI never garnered the full support of national and global women's rights movements, as most were never comfortable with the term safe motherhood with its implied focus on women's childbearing role. Overall, it is hard to state that the SMI has been a success, as since its inception, worldwide maternal mortality rates have not changed and may even have increased [22].

Despite the lukewarm success of the SMI, Rosenfield and Maine's work nevertheless transformed the dominant paradigm in mother and child health programs. Ostensibly, the single most important proposition from *Maternal mortality- a neglected tragedy: Where is the M in MCH?* was that access to emergency obstetrical services should be the centerpiece of programs aimed at reducing maternal mortality [46]. This recognition that health services play a vital role in maternal survival was expanded upon in McCarthy and Maine's *A framework for analyzing the determinants of maternal mortality.* In their framework, distal determinants such as socioeconomic and cultural factors influence intermediate determinants such as health and reproductive status, access to health services, and healthcare utilization, which in turn, influence whether a woman will become pregnant, the likelihood of an obstetrical complication, and finally of death or of disability (figure 1).

By conceptualising the pathways in which distal and proximal determinants impact maternal survival, McCarthy and Maine provided health planners with a tool to develop strategic interventions. Following their framework, interventions can target one of three reproductive health outcomes: pregnancy, the development of obstetrical complications, and death due to complication. Interventions aimed at the first target endeavour to reduce the number of pregnancies through the widespread acceptance of family planning practices [2]. The logic is clear, reduce the number of pregnancies and there will be a reduction in the number of obstetrical complications and thus the number of maternal deaths [50]. However, women will become pregnant and these women have a right to a safe pregnancy and a healthy baby [51].

Family planning does not modify a woman's risk of dying once she is pregnant [50]. Thus, the next target is a reduction in the number of complications due to pregnancy. Since the 1987 SMI conference in Nairobi, prenatal care has been trumpeted in developing countries as *the* indispensable tool for reducing maternal mortality. It was

Figure 1: McCarthy and Maine- A framework for analyzing the determinants of maternal mortality (2).



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believed that through prenatal screening, high risk women would be referred to healthcare facilities capable of managing obstetrical complications [50].[9] The problem is that maternal complications are difficult to predict and many do not develop until labour

[9] It should be noted that the 1987 SMI conference came less than 10 years after Alma Ata and its global commitment to primary health care. During this time, the public health community was consumed with prioritizing community-based prevention interventions. Thus, the two major initiatives taken on by donors, UN agencies, and governments after the SMI were antenatal care and the training of traditional birth attendants. Neither was effective and may have even been counter productive. A decade later at the conference marking the 10th anniversary of SMI, two of the key action messages implicitly acknowledged the failure of these approaches [49] Starrs A. Preventing the Tragedy of Maternal Deaths. Nairobi, Kenya: World Bank, WHO, UNFPA; 1987.

begins. Most complications of childbirth occur in low risk women [2, 19] (see box B). Thus, to meaningfully reduce maternal mortality, women must chose to use, be able to reach, and then receive, adequate medical care for obstetrical complications. Implicitly,

Box B- Key studies demonstrating the epidemiological difficulties related to predicting maternal complications through prenatal screening.

- In a prospective population based study of 20 326 pregnant women in West Africa, a series of risk factors were found to be associated with obstructed labour. None, even when used in combination, could provide a good positive prediction value for this obstetrical complication [52]
- Using the same cohort of pregnant women, a series of socio-demographic, gynaecological–obstetrical, and pregnancy-linked risk factors were tested for their associations with direct maternal complications. Only three risk factors had positive predictive values greater than 15 percent: haemorrhage during pregnancy (51.5%), previous caesarean (27.1%), and high diastolic blood pressure (18.9%) [17].
- In a population-based cohort study undertaken in Bangladesh to identify antenatal risk markers, signs, and symptoms associated with severe maternal complications including dystocia, malpresentation, haemorrhage, hypertensive diseases, twin delivery, and death, risk markers were only found for hypertension and twin pregnancy. The authors concluded that screening for specific conditions such as dystocia or haemorrhage, the major causes of death in their cohort, was greatly inefficient, as antenatal risk factors were either too insensitive or too common to be efficient screening tools [18].

this means assuring healthcare utilisation- in the form of EmOC- when complications arise. To reiterate, once a woman becomes pregnant, maternal death due to obstetrical complication can be averted through adequate and timely curative medical care. Thus, it is the interval of time between the onset of an obstetrical complication and its outcome that is crucial to reducing maternal mortality. Consequently, delay emerges as the most pertinent factor contributing to maternal mortality [19].

In the final paper mentioned above, *Too far to walk: Maternal mortality in context,* Thaddeus and Maine constructed the Three Phases of Delay model. This model has helped researchers conceptualize- chronologically- the determinants of delay between the onset of an obstetrical complication and death. In the first phase, delay occurs when deciding to seek care on the part of the individual, the family, or both. The second delay is the time spent reaching a health facility. And finally, the third delay is the time spent waiting to receive appropriate care. In each of these phases, a plethora of facilitators or barriers can increase or decrease delays in the utilization of EmOC and thus influence the probability of a maternal death [19].

3.1) THE EVIDENCE SUPPORTING EMOC

Presently, there is widespread agreement that the two most effective strategies for reducing maternal mortality are access to EmOC and skilled attendance at delivery [16, 20]. These interventions are not mutually exclusive as, "virtually all treatment of obstetric complications is carried out by a provider who would fall squarely within the definition of a 'skilled attendant'" [16 p.182]. Moreover, all countries with low MMR have both a high proportion of births attended by a skilled attendant and near universal access to high-quality EmOC. Nonetheless, in developing countries, where limited resources force leaders to prioritize strategies, the evidence strongly supports access to EmOC as a primary strategy [16]. A review of the evidence by Paxton et al. (2005), employing the US Preventive Services Task Force system of ranking studies, demonstrated that access to high quality EmOC is crucial to reducing maternal mortality, both in settings where home delivery is the norm and in settings where institutional delivery is the norm [16].

This conclusion was further affirmed by a recent ranking of the evidence published by the World Bank [53].

Box C- Key Points from the seminal works above

1) Once a woman becomes pregnant, complications can neither be predicted nor prevented.
2) Timely curative medical care, in the form of EmOC, is highly effective at saving lives once a complication ensues.
3) Most maternal deaths are due to unnecessary delays in reaching EmOC.
4) **ACCESS TO EMOC SHOULD BE THE CENTERPIECE OF ANY PROGRAM AIMING TO REDUCE MATERNAL MORTALITY.**

In the sections above, a description of the literature guiding current research on maternal mortality was given. At the end, four key points summarized the critical lessons learned from the past 20 years of research with an emphasis on the point that *access to EmOC should be the centerpiece of any program aiming to reduce maternal mortality.* In the sections to follow, a review of the literature describing the barriers to EmOC utilisation is presented.

3.2) BARRIERS TO EMOC UTILISATION

Globally, high rates of utilization of healthcare facilities for giving birth and maternal mortality are inversely related. This relationship is generally explained by the fact that women who give birth in healthcare facilities are under the supervision of a health professional who can either treat obstetrical complications or promptly refer a woman should they ensue [20]. Nevertheless, in areas of the world such as West Africa, including Mali, the utilisation of health facilities and services for obstetrical care and delivery are quite low (table III). For example, in nearly every country in West Africa, less than 50% of women have 4 or more antenatal consultation and less than 10% of women give birth under the supervision of a doctor. In countries such as Mali, rates are dramatically lower [54]. Inadequate knowledge, traditional beliefs and practices, lack of female empowerment, high costs, poor quality of care and staff attitudes, and geography and transportation have all been cited for this low utilisation [2, 19, 22, 42, 55-62]. The possible contribution of each of these factors is described in the sections to follow. The relative importance of each is highly debated in the literature, and it seems likely that their importance varies from one context to the next. Nevertheless, certain factors such as cost, distance, and quality of care appear to be resurgent themes dictating a sub-optimal utilisation of EmOC in many countries [19, 63-65].

Table III: Reproductive healthcare utilisation for select West African countries

Country	Source and Year	Antenatal care (≥ 1 visit) (%)	Antenatal care (≥ 4 visits) (%)	Assisted delivery by health professional (%)	Assisted delivery by doctor (%)
Benin	Benin DHS- 2001	88.3	61.6	72.9	4.5
Burkina Faso	Burkina Faso DHS- 2003	72.4	17.6	56.5	1.4
Côte d'ivoire	Côte d'Ivoire DHS-1998/99	84.3	35.4	47.1	2.8
Guinea	Guinea DHS- 2005	78.5	48.8	38	4.7
Mali	**Mali DHS- 2001**[10]	**52.1**	**29.9**	**40.6**	**1.5**
Mauritania	Mauritania DHS- 2000/01	62.9	16.4	56.9	9.8
Nigeria	Nigeria DHS- 2003	61.0	47.4	36.3	6.6
Senegal	Senegal DHS- 2005	92.4	39.8	51.9	3.2

[10] According to the preliminary 2006 Mali DHS, 70.4% of women have 1 antenatal visit and 49.0% of women give birth under the supervision of trained health professional (doctor, nurse, midwife, or health auxiliary); both are meaningful increases from the 2001 survey. No data are given on the number of women having received 4 or more antenatal visit or those having given birth under the supervision of a doctor.

KNOWLEDGE: Some authors have suggested that women are unaware of the signs and symptoms of complications during pregnancy and labour [56] and that this lack of knowledge has led to fatal delays in care seeking. However, focus group discussions with women in several West African countries suggest that the majority of women are knowledgeable about dangerous maternal complications. Instead, these studies point to access barriers, such as cost and distance, as being the most important determinants of care seeking in women [56, 57].

TRADITIONAL BELIEFS AND PRACTICES: Other authors have pointed to traditional beliefs and practices as barriers to healthcare utilisation [56, 57, 66-68]. For example, care units in West Africa do not sufficiently take into account the following traditional practices during pregnancy and birth: discretion during the first trimester, the importance of family presence, traditional care such as massages after pregnancy, access to the placenta and umbilical cord after birth, the view that pregnancy is a woman's affair, and the value of privacy in the care facility [67]. Further, it has been suggested that some beliefs and practices may actually contribute to maternal mortality. Examples include: special herbs being given to women when the umbilical cord is wrapped around foetus' neck or during instances of breech presentation; hot water poured on the abdomen and okra smeared on the vagina to expedite delivery; giving women a bottle to blow in when the placenta is retained; and placing a calabash of hot water on the abdomen of women who experience postpartum haemorrhage. However, it has been indicated that many of these practices are no longer in use and that the hospital is the ultimate source of obstetrical care [57]. Even if many of these practices continue to be used, anthropological studies indicate that culture is adaptable, rational, and framed within specific socioeconomic contexts. As a result, traditional beliefs and practices are not inherently incompatible with biomedical knowledge but rather, dictated by larger issues of accessibility and acceptability [69, 70].

FEMALE EMPOWERMENT: Studies have pointed to the lack of female empowerment as a major determinant of maternal mortality in West Africa. The low priority accorded to women's wellbeing throughout their lifetime contributes to poor nutrition and ill health, which in turn increases health risks to women during pregnancy and childbirth [22, 56-58]. Women in many communities may be aware of serious complications and willing to seek care, but unable to do so because of disempowerment. For example, focus group discussions in Northern Ghana described women as generally unable to make decisions about where to deliver. As a result, the decision was left up to the husband or compound head. Of interest, during the same focus group discussions, some female participants said that "the wise ones (women) will start getting their money ready during the pregnancy and go to the hospital during labour without telling their husbands" [57]. In another study conducted among the Hausa of Northern Nigeria, lack of female empowerment meant that women could not seek care (or even leave the housing compound) without the permission of their husbands. Furthermore, the study showed that many women were being married before their pelvic bones had completely matured, contributing to obstetrical complications and death [58].

COSTS: The prohibitive costs of seeking EmOC have been cited in most research on the determinants of maternal mortality [20, 42, 56, 57, 59, 66]. Costs associated with finding transportation to a care centre, with buying supplies for treatment, with paying user-fees and bribes at hospitals, with paying for food and lodging for the woman, her husband, and/or family while she receives care, and with transporting the dead body back, may all prevent or delay a woman, her husband, or her family from seeking care in the event of an obstetrical complication [56, 57, 59].

QUALITY OF CARE AND STAFF ATTITUDES: Quality of care and the referral practices of primary-level healthcare staff have been suggested as contributing to maternal mortality [19, 57, 59, 66]. Nurses in rural Niger purposefully disregarded referral instructions stating that, "If we were to follow the instructions, we would be referring 50% of our patients" and "the hospitals would be overwhelmed."[11] Additionally, they associated referral with a loss of face and were afraid that they would loose credibility in the eyes of the community (57).

The attitudes of healthcare professionals may strongly influence healthcare utilisation [57, 65]. Women seeking care from nurses and midwives have complained of being shouted at for presenting themselves late, of being sneered at for being poor, of being embarrassed by staff who called them dirty, of being slapped for not pushing hard enough during labour, and of being left unattended. During a series of focus group discussions conducted in Northern Ghana, women suggested that nurses should be counselled on how to be more understanding of women who seek help with delivery, because some do not read or understand clinic or hospital procedures and that nurses should not discriminate against the poor or demand a cash deposit in emergency situations [57].

There may be some truth to the nurses' comment. In a study that assessed whether prenatal screening can identify women at risk of severe labour or delivery complications in rural Bangledesh, the authors found that approximately one-third (34%) of women screen positive one or more antenatal risk markers (18).

GEOGRAPHY AND TRANSPORTATION: Long distances to healthcare centres, poor roads conditions, and lack of transportation have all been implicated as determinants of maternal mortality [19, 55-57, 60, 62, 71, 72]. Many rural communities have no emergency transportation, so women must walk, be carried, or send for a vehicle from another community- all leading to delays. On non-market days, at night, or during the rainy season, additional delays may ensue [19, 57]. In fact, a woman's proximity to a healthcare centre may translate directly into whether she prefers to give birth there or at home. As Mills and Bertrand discovered, women living in communities close to a facility preferred to give birth in it, while those living far away, preferred to give birth at home (55).

3.3) RELATIVE IMPORTANCE OF THE AFOREMENTIONED BARRIERS:

While it is impossible to know the exact contribution of each barrier on EmOC utilisation, the literature does suggest that certain barriers bear more weight than others. For example, the plethora of literature on the diminution of healthcare utilisation in Africa after the implementation of user-fees suggests that cost presents a formidable barrier [20, 64, 73-75]. In situations where costs, such as user-fees, have been removed, spatial access and education become the next most important barriers [63]. In the case of emergencies, spatial access takes precedence [76, 77], as "in true emergencies the location and number of providers assume greater importance than the psychosocial and economic barriers" [76 p64]. Further, evidence from urban areas in some of the poorest countries in the world indicates that when maternal care is spatially accessible, women *will* use it [78].

3.4) Spatial Access and Maternal Mortality

Recent studies have begun to look at the role of health systems' infrastructures on maternal mortality [79-82]. Their findings indicate that improvements in the distribution of healthcare centres, community infrastructures, and road transportation networks are necessary to improving spatial access and, in turn, maternal health outcomes [19, 79]. In particular, the quality and availability of transportation has constituted a continuing preoccupation for those attempting to reduce maternal mortality [19, 61, 83, 84]. While an important barrier, there are many other factors that contribute to inadequate spatial access to healthcare facilities and thus, poor health outcomes. In a study of the geographic distribution of severe malaria in children, those who lived closer to the hospital were most likely to seek care than those who lived further away (Schellenberg, Newell et al 1998). For example, a study that looked at meningitis suggested that road surface quality (paved roads versus gravel roads) plays an important role in access, as children who lived off of gravel roads had worse health outcomes than those who lived off of paved roads [85].

However, similar associations between spatial access and maternal mortality have been inadequately studied. In fact, to the author's knowledge, only two studies have attempted to quantify the relationship between spatial access and maternal mortality. In one study, the sisterhood method (a type of verbal autopsy) was applied to a random population sample of 3123 respondents in two districts of Zambia. This study calculated the maternal mortality ratio for both districts, as well as the population attributable risk and etiological fraction due to poor spatial access. The authors found that resolving the accessibility problem would reduce maternal mortality by 29% in one district and 65% in another [86].

In the other study, risk factors for maternal mortality in Guinea-Bissau were assessed using a longitudinal, population-based study. Risk factors significantly associated with maternal mortality included living more than 25km from the regional hospital, having twins, a stillbirth, and living in the region of Gabu. Of the risk factors identified above, living more than 25km from the hospital carried the greatest odds ratio for maternal death (OR=7.4) [87]. The research above suggests that spatial access contributes meaningfully to maternal mortality. However, important knowledge gaps remain. As both studies were conducted at a population level and employed verbal autopsies, it is unclear whether poor spatial access also increases the chances of maternal mortality in women who obtain obstetrical care. Likewise, as neither study described how measures of spatial access were obtained, considered seasonal differences in spatial access, or controlled for key confounders such as the type of obstetrical complication or medical intervention, further evidence is needed to substantiate the purported relationship.

Box D: Summary of barriers to EmOC

1) Knowledge- most women can recognise obstetrical complications
2) Traditional beliefs and practices- not incompatible with EmOC
3) Female empowerment- difficult to seek care without husband's or family's permission
4) Cost- formidable barrier to seeking and receiving care
5) Quality of care- poor perceptions of care may dissuade utilisation
6) Geography and transportation- geographic obstacles and a lack of transportation may cause life-threatening delays

Nevertheless… "in true emergencies the location and number of providers assume greater importance than the psychosocial and economic barriers"

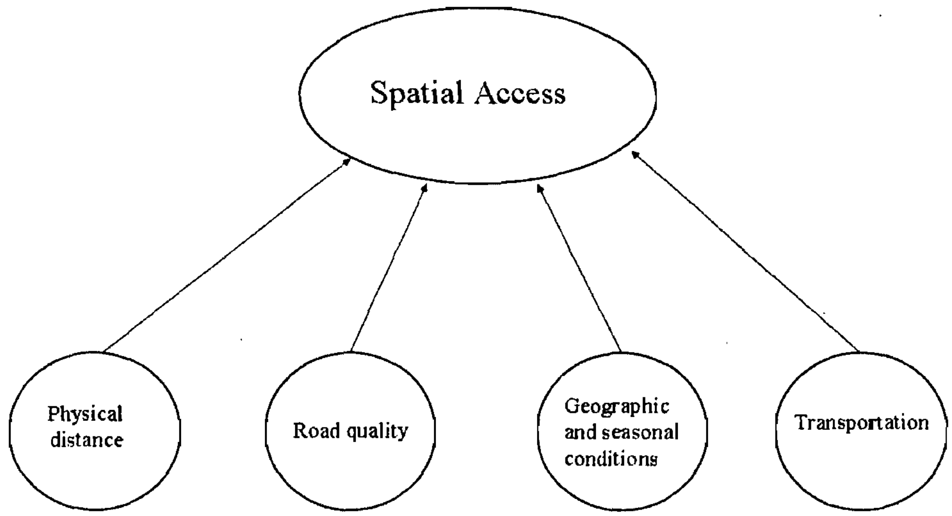
4. CONCEPTUAL FRAMEWORK

4.0) DEFINING SPATIAL ACCESS

The low maternal mortality rates found in the West are largely due to the fact that obstetrical complications are identified and treated promptly in the context of a functioning health system. In countries with high levels of maternal mortality, the reality is, "that many women, especially in rural areas, are not giving birth with a skilled attendant, and that there are often no nearby EmOC facilities available for women with obstetric complications" [16 p183].

Spatial access refers to that which is conditioned by space and is moderated by distance barriers/facilitators. It generates utilisation patterns that are geographically manifested, often in terms of declining utilisation as distance increases [76]. Spatial access is a multidimensional construct that encapsulates a variety of determinants including: physical distance in kilometres, the number and quality of roads (transportation networks), geographic and seasonal barriers such as broken bridges or flooded roads, as well as the type, quality, and availability of transportation. As spatial access is a multidimensional construct, it cannot be measured directly and must therefore, be measured by some proxy (figure 2) [88]. Proxies of spatial access reflect the efforts necessary to bring two separate entities together across space; in the case of this research, it describes the efforts made by a woman with an obstetrical complication to reach EmOC.

Figure 2: Determinants of Spatial Access



4.1) HOW IS SPATIAL ACCESS MEASURED?

Spatial access is not a novel concept and a variety of measures- particularly in the medical geography literature- have been proposed to proxy spatial access to healthcare facilities. In fact, the general question of spatial access has always been a pressing one in rural contexts because the low density and high dispersion of most rural populations means a greater average separation between the potential client and source of treatment when compared to urban areas [89]. The predominant measure of that separation, known as travel-impedance to the nearest provider, is physical distance measured by kilometres [87, 89-95]. Surprisingly, Euclidean straight lines are popular in developing countries, despite being recognised as crude measures of spatial access [89, 94, 95]. This is likely because evidence from industrialised countries has shown Euclidean distance to be an accurate measure of spatial access and that only marginal gains in accuracy occur when calculating access along transportation paths (roads, light rail networks, etc) [96, 97]. However, it is questionable whether such evidence is transferable to contexts with limited road infrastructures, substantial seasonal variations, and important geographic obstacles.

Recent research in developing countries has evoked more sophisticated measures of spatial access which follow actual transportation paths and use geographic information systems [90, 98]. These methods, however, still do not look at seasonal differences and have difficulties accounting for differing transportation methods that are used from one health zone to the next. Irrespective, "The choice of variable to measure spatial separation can be crucial since there may be little relationship between travel time or cost and distance" [95 p563]. Because it is unclear how best to measure spatial access in countries such as Mali, with highly dispersed populations and poor road infrastructures, the following sections provide a quick review of commonly-used proxy measures of spatial access.

POPULATION–TO-PROVIDER RATIOS: These are also known as supply ratios and are computed in bordered areas such as states, counties, or health service areas. The numerator is some indicator of health service capacity (e.g. the number of primary care physicians) and the denominator is the population size in that bordered area. These ratios are then analysed for associations with some indicator of healthcare utilisation or health status [96, 99]. A serious problem with using this type of aggregate proxy based on ecological data is that it only explains a small proportion of the variance in an individual's spatial proximity to services [96]. Population-to-provider ratios do not account for variations in access within bordered areas, nor do they incorporate any measures of distance or travel impedance [99]. Applying population-to-provider ratios to maternal mortality, a comprehensive review of the global patterns in the availability of EmOC facilities showed that, at an aggregate level, developing countries possess a sufficient number of facilities for the population. For example, the national availability of comprehensive EmOC facilities in Mali exceeds the recommended minimum number of facilities for the population (26 facilities versus a recommended 22). The problem, the authors pointed out, is that these facilities are not well distributed throughout the country, as they are often concentrated in urban areas and the capital. Thus, women from rural communities must often travel long distances and overcome significant financial and logistical hurdles to receive EmOC [100]. Consequently, population-to-provider ratios cannot be seen as accurate measures of spatial access in largely rural and geographically diverse areas where significant and possibly deadly delays can ensue when trying to reach EmOC.

One-Step and Two-Step Floating Catchment Area Methods: In the one-step floating catchment area method (FCA), a threshold distance or time (e.g. 15 miles or 1 hour) is drawn around the centroid of a geographically delimited area (such as census tract or zip code). A circle with the same radius- the catchment area- "floats" from the centroid of one area to another and the population-to-provider ratios are calculated. All areas that contain sub-optimal population-to-provider ratios are considered shortage areas [101]. The problem with this method is that not all health centres are accessible to all residents in a catchment area and health centres on the periphery may serve more than one catchment area [102]. In the two-step FCA, the method is performed twice, once around healthcare centres and once around population centres. This method is supposed to resolve the difficulties described with the one-step FCA [103]. Nevertheless, a threshold distance must already be known before FCA can be applied [101]. Furthermore, as this method uses a single distance measurement circumscribed around a single point, it does not incorporate variations that may be do to physical barriers or seasonality. Such a method is inappropriate in areas where travel times are not uniform around a point and differ significantly according to season.

TRAVEL IMPEDANCE TO NEAREST PROVIDER: This is also referred to as travel cost and is often measured in units of Euclidean distance, travel distance along a road, or estimated travel time via a transportation network. It is generally measured from a residence or population centre to a healthcare facility. Travel impedance to nearest provider is considered a good measure of spatial access in rural areas, as rural residents generally go to the nearest provider, but in urban areas where there can be a lot of overlap in provider choices, it is likely unsuitable [99]. Several different methods for determining travel impedance to nearest provider are described below.

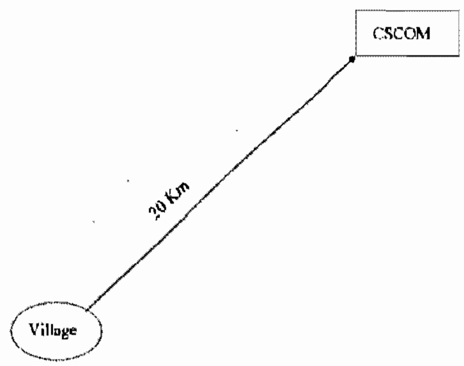
1) Euclidean and/or physical distance is the most commonly-used distance measurement for travel impedance to nearest provider [92-94] (Figure 3A). With this measure, a straight line is drawn between two points and the separation is measured. It neglects to consider the actual distribution of roads, the availability of transportation, or the presence of geographical barriers (Figure 3B-E). This type of measure is simple to use, as a map of the region is the only tool needed and nearly any statistical package can do the computations [96].

2) Physical distance measures according to transportation system: With this measure, the actual paths (such as transportation networks) that users employ are measured. In some cases, the speed at which one can travel along these paths is also considered [90, 104] (figures 3B and 3C). However, even if the number of kilometres separating two points is measured well [see reference 90 for an excellent example], important information on spatial access may still be lost, such as seasonal barriers and transportation delays.

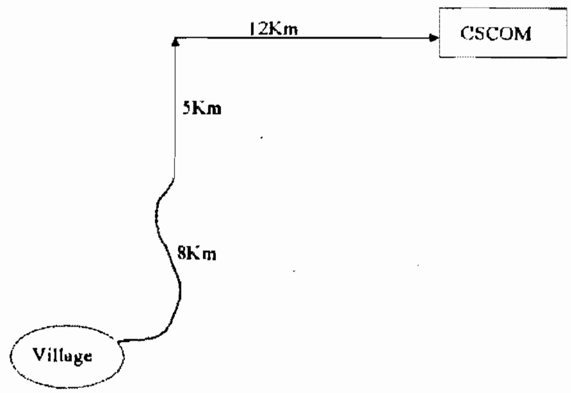
3) Time: Figures 3A through 3C show how physical distance, measured in kilometres, can be used to proxy spatial access. However, by solely measuring the number of kilometres between two points, information on other determinants of spatial access, such as transportation availability, seasonality, or geographic barriers, may be overlooked. Consider figure 3D. This figure is identical to 3C, except that there is a one-hour wait for public transportation at the intersection between the footpath and the paved road. Or, consider figure 3E, which depicts seasonal barriers. Physical distance measurements cannot capture these nuances; however, time-travelled does. Thus, returning to the determinants of spatial access, as shown in figure 2, it becomes clear that time-travelled can encapsulate the various determinants of spatial access in one simple measure, and as such, is probably the most comprehensive measure of travel impedance to the nearest provider.

Figure 3: Five measures of spatial access

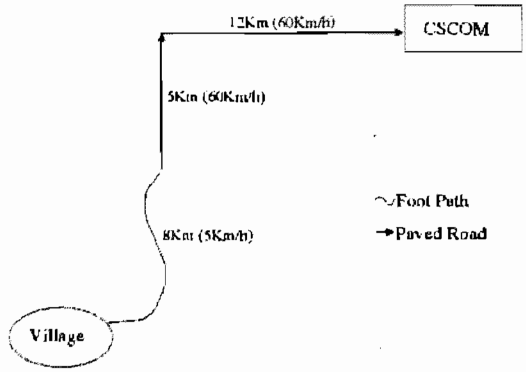
A) Direct Euclidean Measure



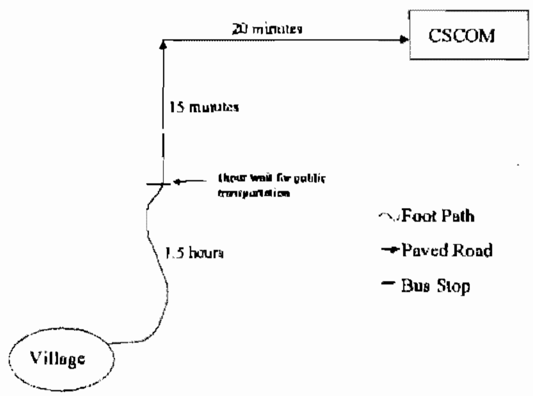
B) Consideration of Road Distribution



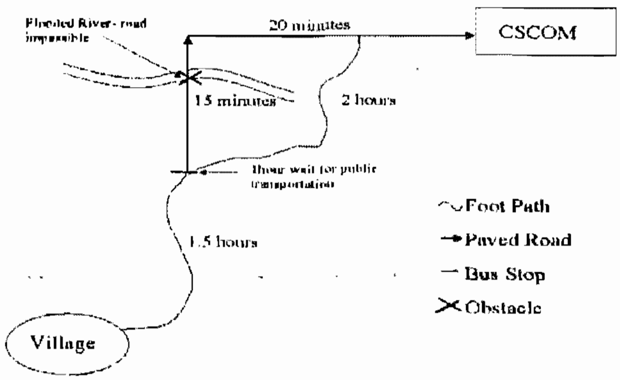
C) Consideration of Road Type



D) Consideration of transportation

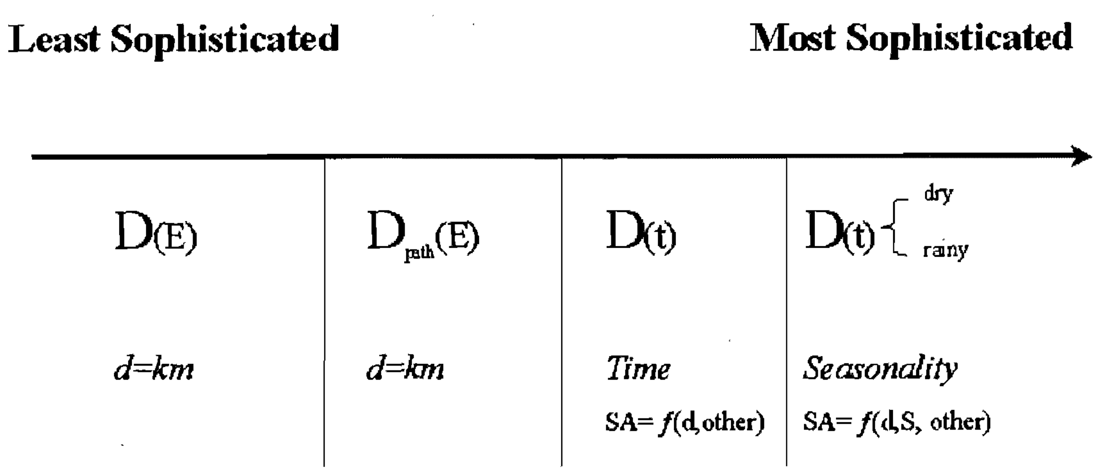


E) Consideration of Seasonality



To reiterate the discussion above, figure 4 demonstrates how the various measures described above can be ordered according to sophistication, or put in another way, according to their abilities to capture the various determinants of spatial access (figure 2). In the first, distance is solely measured by the number of kilometres separating two points. In the second, distance is measured along a transportation route or path. In the third, distance is measured by time, thus encapsulating other determinants of spatial access such as the availability of transportation. Finally, distance in measured by time in both the dry and rainy seasons, capturing barriers to spatial access that may be unique to one season or the other. In the rural regions of many developing countries, where road and communications networks are poorly developed, seasonal barriers can assume a greater importance than even physical distance [24].

Figure 4: Ordering measures of spatial access



Gravity Decay Model: Gravity models attempt to represent the potential interaction between any population point and all service points within a reasonable distance, discounting the potential as distance or travel impedance increases. With this model, spatial access improves as the summed provider capacity (numerator) increases, or the summed travel impedance (denominator) decreases [99]. The advantage of a gravity model is that one can attach weights to different providers representing a greater or lesser "gravitational pull" depending on factors such as patient preference, provider availability, or the provision of speciality services. Despite the increased sophistication of a gravity model, it may not be appropriate in a context where there is only one provider choice, as the model essentially reduces to a travel impedance to nearest provider model. In rural regions of many developing countries, including Mali, health systems are structured in such a fashion that comprehensive health services, such as EmOC, are only provided in one district centre and thus, the provider capacity (the numerator) equals one.

4.2) STUDY OBJECTIVE AND HYPOTHESIS

Spatial access has rarely been related to population health [99]. To the author's knowledge, only two studies in maternal mortality have addressed this topic. As described in the literature review, both provided needed insight into the sizeable role that spatial access plays in maternal mortality, demonstrating that poor spatial access is associated with high rates of maternal mortality [86, 87]. However, associations were found at a population level in which it was likely that many women never accessed care. It is assumed that women who die in hospital from maternal causes are those who had the least spatial access, as patients who arrive at an EmOC facility in an advanced stage of illness probably spent more time travelling than those with a less advanced stage of illness [19].

In the Malian context, where referral systems have been established to improve spatial access, it is important to know whether spatial access continues to be a contributing factor to maternal mortality. Given the little evidence available, this study expands on previous work by testing for an association between spatial access and maternal mortality in women who succeeded at reaching EmOC. It attempts to isolate the hypothesised relationship by controlling for key confounders and while employing a comprehensive measure of spatial access appropriate to the context.

Specifically, the hypothesis of this study is as follows:

- ❖ **Despite the implementation of a functioning referral system, poor spatial access continues to be a considerable problem for women seeking EmOC in Mali and as such, increases the likelihood of in-hospital maternal mortality.**

Thus, the following formula was developed to represent the proposed relationship between spatial access and in-hospital maternal mortality. The variables age, diagnosis, arrival date, and major obstetrical intervention (MOI)[12] are all considered as confounders [17, 107-110].

Figure 5: Formula depicting hypothesized relationship between spatial access and maternal mortality

$$\text{In-hospital maternal mortality} = \int \left(\text{Spatial Access} + \left| \begin{array}{l} \text{Age} \\ \text{Diagnosis} \\ \text{Arrival date} \\ \text{Surgery} \end{array} \right. \right)$$

[12] MOI has been extensively described elsewhere. They include caesarean section, laparotomy for uterine breach, hysterectomy, internal version, symphysiotomy, and craniotomy (105, 106).

5. METHODOLOGY

5.0) CONTEXT AND SETTING

This study was conducted in the administrative district of Kayes, located in the extreme West of Mali, bordering Mauritania to the North and Senegal to the West. It is geographically heterogeneous, with terrain ranging from arid Sahel in the North to semitropical in the South and is one of seven districts in the Kayes region (figure 6). The district of Kayes has a surface area of 22 190 Km^2 and is the most populous district in the region, with 396 398 inhabitants. There are two mains routes of transportation in the region, the Senegal River and the newly paved highway running from Dakar, Senegal to just past the city of Kayes. Both follow approximately the same West-to-East path; there are no paved roads in the northern and southern sections of the district.

The district of Kayes houses the region's capital city, also by the name of 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. The district of Kayes contains 46 health zones, each of which theoretically houses a CHC. In reality, only 29 health zones contain CHCs, another 7 contain private or religious health structures, and 10 are devoid of health centres (6 use an adjacent health zone's CHC and patients from 4 others presumably go directly to the regional hospital). Overall, referrals in the district are conducted from only 36 of the 46 health zones. For most zones, the best a CHC can do for a woman with an obstetrical complication is to stabilise and evacuate her to the regional hospital on time.

Figure 6: Map of study site

In the district of Kayes, the referral system is organised in a manner slightly different from the other districts of Mali. Only the most tertiary centre in the district - the regional hospital in the capital city of Kayes- performs comprehensive EmOC. This contrasts with many other parts of Mali where both secondary and tertiary centres have the capacity to perform comprehensive EmOC. As result, there is only one comprehensive EmOC facility in the entire district and four basic EmOC centres (two in the regional capital and two in the remote northern section of the district). Notably, the region of Kayes has also interpreted the 2005 decree by the president of the Republic to mean that all emergency obstetrical complications are referred and treated free of charge (even if no caesarean section is required). This translates into a large diminution in the cost barriers to EmOC access in Kayes.

5.1) STUDY DESIGN

BACKGROUND: Uniquely, the region of Kayes has put forth efforts to evaluate its referral system. The Regional Health Authority (RHA) benefits from financing and expertise granted by the Canadian International Development Agency and its execution agency the *Unité de Santé Internationale* at the University de Montréal. Additionally, one of the University's researchers, Pierre Fournier, obtained a grant from the International Development Research Centre to undertake an implementation and effects evaluation of Kayes' referral system. This funding and expertise has led to the creation of a regional Obstetrical Emergency Monitoring System (OEMS) which records and monitors all obstetrical complications in the seven districts of Kayes. Data has been registered prospectively since July 2004 and is verified every six months. In the district of Kayes, information is recorded in a series of registers at the hospital and RHA and then transferred to an SPSS database to which the author had access.

DESIGN: This is a matched case-control study on women treated at the regional hospital. The study base[13] was defined geographically (the district of Kayes) and temporally (January 2005 to November 2006). Employing the OEMS, two inclusion criteria were used to create the study base: 1) the woman resided in the district of Kayes

[13] A study base is defined as "the person (or persons-time) in which the outcome of interest is observed. In case-control studies, case and controls should be representative of the same study base experience" (111). Also, see the series by Wacholder et al. (1992), in volume 135 of American Journal of Epidemiology, for an excellent description of the study base principle.

and 2) she was diagnosed with either a direct or indirect obstetrical complication (described below). Women whose trajectory to the hospital was unknown were excluded (N=8), as it was unclear whether they met the first inclusion criterion.[14] Cases were all maternal deaths occurring at the hospital within 42 days of birth, as defined by the WHO [9].

Controls were matched to cases on the basis of age, diagnosis, and date of arrival, using a three-to-one ratio. For a given case, matches had the same diagnosis and were plus or minus five years of age, with an upper-bound set at 18 for those 18 years and younger and a lower-bound at 36 for those 36 years and older. A wide age range was chosen to avoid over-matching and because it has been shown that age is a risk factor for maternal mortality in women of young reproduction age (<19) and of old reproductive age (>35) [17, 109]. For two cases, the age was unknown; the average age of the cases was attributed to these women to obtain matched controls. Diagnosis was chosen as a matching variable because of the differing case-fatality rates between diagnoses [112]. 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) other direct cause, 6) indirect cause. The date of arrival for a matched control had to be within 6 months of the case; when more than three controls could be matched to a case, those selected arrived closest in date to the case. This was done to limit changes that may have occurred in case management and quality of care over the 23 month study period.

[14] These are women who came to the hospital by their own means and for whom the village of origin is uncertain.

5.2) DATA SOURCES AND COLLECTION

DATA SOURCES: Two sources of data were used in this study. The first was the regional OEMS. All women who use the referral system and/or are treated at the hospital for an obstetrical complication 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 outcome and confounder variables (maternal death, MOI, age, diagnosis, and date of arrival).

The second source of data provided information on the exposure variable, spatial access. Spatial access can be proxied by measures of physical distance and time-travelled [99]. Data on spatial access was obtained in the field through key informant interviews performed by the first author. Key informants, identified in a pilot study, included ambulance drivers, vaccinators, and health centre directors [113]. Informants were asked the number of kilometres separating each village from the hospital (following a transportation path). All of the key informants were expected by the RHA to record this information, as the RHA reimburses gas expenditures incurred during vaccination campaigns to the villages. Informants were also asked how long it takes a woman 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, with the last segment spent in an ambulance. Vaccinators and CHC directors provided the travel times between the woman's village and CHC; ambulance drivers provided the times between the CHC and hospital. Supplementary data was obtained on the types of transportation used and on geographic and seasonal barriers around the CHCs. Travel times were applied to all women in the OEMS depending on their home village and season of travel.

5.3) STATISTICS

STATISTICS

Descriptive statistics were computed for all women in the OEMS. Case-fatality rates were determined for each obstetrical diagnosis. They were likewise determined for increasing travel time from the hospital. Specifically, the case-fatality rate was calculated for women whose travel time to the hospital was less than 1 hour, 1-2 hours, 2-3 hours, 3-4 hours, and 4 or more hours.

In the matched case-control study, associations between time travelled and in-hospital maternal mortality were tested using conditional logistic regression in STATA 9.1. Maternal death (outcome), time-travelled (exposure), and MOI (covariate) were coded as dichotomous categorical variables. Two models were compared; the reduced model tested only time-travelled and maternal death, while the full model adjusted for MOI. MOI has been defined elsewhere [25, 26] and was considered as a potential confounder because of its association with maternal survival in women with complications [27-30]. In this study, MOI consisted almost exclusively of caesarean sections, with the exception of one hysterectomy and one hysterraphy (both in cases). The likelihood ratio statistic was used to test the significance of the full model. Multicollinearity between time-travelled and MOI was assessed with a coefficient correlation matrix.

Cases and controls were considered to have poor spatial access, and were thus *exposed*, if they travelled two or more hours to reach the hospital; those who travelled less than two hours were considered to have adequate spatial access and were *non-exposed.* The cut-off of two hours is based on the calculations of case-fatality rate with increasing travel time from the hospital (see results) and is consistent with the literature [12, 31]. However, sensitivity analyses were also conducted using different cut-off points for poor spatial access (from one to four hours from the hospital).

5.4) CHOOSING THE SPATIAL ACCESS PROXY

In addition to the article presented in chapter 6, a supplementary results chapter is provided in chapter 7 to demonstrate why spatial access was measured by time rather than kilometres. The methods for this chapter are presented below.

Descriptive statistics for physical distance measured in kilometres (dKm) and for distance measured by time during the dry and rainy seasons (dTD, dTR respectively) were calculated. To assess (dis)proportionality, Lorenz curves were plotted. The coefficient of variation, the Gini coefficient, and the Atkinson measure were likewise calculated for each measure. As the three indexes are weighted differently, calculating each allowed the author to explore whether (dis)proportionality was consistent across functions. Finally, kilometre and time measurements (dry and rainy season) were converted to z-scores for direct comparison between measures.

DEMANDE D'AUTORISATION DE RÉDIGER PAR ARTICLE

1) Identification de l'étudiante

Nom de l'étudiante : Catherine Pirkle
Code Permanant : PIRC 11608202

2) Nom de l'unité académique

Département de médecine sociale et préventive, Faculté de médecine

3) Nom du programme

MSc. Santé communautaire

4) Liste des articles proposés

1) Liste des auteurs : Catherine Pirkle, Pierre Fournier, Caroline Tourigny, et Slim Haddad
Titre: *Emergency Obstetrical Complications in Kayes, Mali: the link between spatial access and mortality*
La revue prévue: American Journal of Public Health
Date de soumission: Septembre 2007
L'état actuel de l'article : terminé

5) Signature et déclaration de l'étudiante concernant les articles

Par rapport à l'articles mentionné ci-dessus, Catherine Pirkle est la première auteur. Globalement, elle était responsable pour la recension de la littérature, la création du cadre conceptuel et le devis de recherche, ainsi que l'analyse des données et finalement, l'écriture complet de l'articles. Les co-auteurs étaient responsables pour la conception globale du projet, la mise-en-œuvre logistique et financière, les avis experts, et la rédaction finale.

Catherine Pirkle	[information retirée / information withdrawn] [redacted]	24 août 2007
Nom	Signature	Date

6. Avis et signature du directeur de recherche

L'étude que Catherine a réalisée sur l'accès spatial et la mortalité maternelle dans la région de Kayes au Mali fait partie d'une recherche plus large sur la mise en place d'un système de référence-évacuation dans cette région. Pour son étude, elle s'est rendue sur le terrain pour la collecte des données : cette collecte incluait des entrevues avec les informateurs-clés (chefs de poste de santé, vaccinateurs, ambulanciers). À Montréal, Catherine a fait la revue de la littérature, l'élaboration du cadre conceptuel et des méthodes, l'analyse des données, ainsi que l'écriture de l'article. Son étude apporte un nouvel angle sur l'influence de l'accès spatial sur la mortalité maternelle., car elle est la seule à avoir quantifiée la relation entre l'accès spatial et la mortalité maternelle dans un système de référence-évacuation. De plus, l'utilisation d'un devis de type cas-témoin a permis de contrôler pour des facteurs importants dans le domaine de mortalité maternelle, là où d'autres études semblables n'étaient pas en mesure de le faire. En rédigeant son mémoire par article, Catherine sera capable de partager ses résultats rapidement avec un large auditoire. Elle soumettra son article dans un numéro spécial de la revue *American Journal of Public Health* qui cible les études sur la mortalité maternelle; les éditeurs ont déjà exprimé un intérêt pour sa recherche. Une publication dans cette revue permettrait que les résultats de l'étude rejoignent un large auditoire de personnes œuvrant dans le domaine de la mortalité maternelle.

Pierre Fournier

Nom du directeur de recherche

[information retirée / information withdrawn]

[redacted]

Signature

24 août 2007

Date

ACCORD DES COAUTEURS

1) Identification de l'étudiante et du programme

Nom de l'étudiante : Catherine Pirkle
Sigle et titre du programme : MSc. santé communautaire

2) Description de l'article

Liste des auteurs : Catherine Pirkle, Pierre Fournier, Caroline Tourigny, et Slim Haddad
Titre: *Emergency Obstetrical Complications in Kayes, Mali: the link between spatial access and mortality*
La revue prévue: American Journal of Public Health
Date de soumission: Septembre 2007

3) Déclaration de tous les coauteurs autres que l'étudiante

À titre de coauteur de l'article identifié ci-dessus, je suis d'accord pour que Catherine Pirkle inclue cet article dans son mémoire de maîtrise qui a pour titre *Emergency Obstetrical Complications in Kayes, Mali: the link between spatial access and mortality.*

Coauteur	Signature	Date
[information retirée / information withdrawn]	[information retirée / information withdrawn]	09/08/07
[information retirée / information withdrawn]	[information retirée / information withdrawn]	09/08/07
[information retirée / information withdrawn]	[information retirée / information withdrawn]	16/08/07.

6. RESULTS (ARTICLE)

The next two chapters contain the results from this study. The article can be found in this chapter (chapter six), while the supplementary results can be found in chapter seven.

6.0) ORIGINAL CONTRIBUTION OF ARTICLE

To this author's knowledge, this is the first article to look at the relationship between spatial access and maternal mortality in women who have accessed EmOC and to do so while controlling for key confounders. The findings of this article have important programmatic and policy implications that benefit from the rapid diffusion that is possible with publication of a scientific article.

6.1) CONTRIBUTION OF AUTHOR AND CO-AUTHORS

A) **Catherine Pirkle**- responsible for the literature review, creation of the conceptual framework and study design, as well as the data analysis and finally, the writing and editing of the article.

B) **Pierre Fournier and Slim Haddad**- provided technical assistance with developing the conceptual framework and conducting the data analysis. Assisted with the editing of the article.

C) **Caroline Tourigny**- provided direction and assisted with the literature review, facilitated data collection in the field, and provided feedback on the study context.

Emergency obstetrical complications in a rural African setting (Kayes, Mali): The link between spatial access and mortality

Authors: Catherine Pirkle, Pierre Fournier, Caroline Tourigny, Slim Haddad

Affiliation : Unité de Santé Internationale, Centre de Recherche du CHUM/Université de Montréal

Objectives: We test the hypothesis that spatial access- proxied by travel time during the rainy and dry seasons- is associated with in-hospital maternal mortality in Kayes, Mali.

Methods: We conducted a matched case-control study on women who were treated at the regional hospital for obstetrical complications in 2005 and 2006. Key informant interviews provided exposure data on spatial access. A medical registry provided clinical and demographic details for matching.

Results: Poor spatial access (2 or more hours from the hospital) was significantly associated with mortality (OR: 2.97; CI: 1.16-7.57). Spatial access was no longer significant once major obstetric intervention (e.g. caesarean section) was added to the model; intervention had a significant protective effect against mortality (OR: 0.19; CI: 0.05-0.75).

Conclusions: This study supports previous evidence demonstrating that poor spatial access leads to increased maternal mortality and shows that spatial access contributes to maternal mortality even in women who reached a health facility; however, protective interventions, such as caesarean section, militated against the deleterious effects of limited spatial access. Nevertheless, improving spatial access will help to assure that women arrive at the hospital in time to be treated.

Each year, an estimated 8 million women worldwide suffer complications related to pregnancy and birth; of these, 529 000 die [1]. With the sole exception of Afghanistan, the highest rates of maternal mortality in the world (≥1000 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 [2]. Thus, 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 2800 [2].

The differences in maternal mortality rates between developed and developing countries (20/100 000 versus 440/ 100 000 respectively) reflect disparate levels of access to and use of obstetrical care [2, 3]. While past lessons have shown that most fatal complications cannot be predicted or prevented [4-6], 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 [7]; however, a plethora of infrastructural, socio-cultural, economic, and political factors prevent the widespread implementation and utilisation of EmOC in many developing countries [8, 9]. These factors present significant barriers to women trying to reach EmOC and can conceptually be divided into spatial access and aspatial access. Major determinants of spatial access include distance, type and availability of transportation, and geographic barriers that pose significant obstacles to individuals seeking care in a timely manner. Aspatial access describes the non-geographic expression of access as it is influenced by economic, social, cultural, or political determinants [10]. In the case of obstetrical complications, spatial access may be the most important determinant of EmOC utilisation [9-12] as *"in true emergencies the location and number of providers assume greater importance than the psychosocial and economic barriers"* [10 p64].

In Thaddeus and Maine's seminal article, three phases of delay were outlined in their framework describing the determinants of maternal mortality: 1) delay in deciding to seek care, 2) delay in identifying and reaching care, and 3) delay in receiving appropriate care. Accordingly, delay *"emerges as the pertinent factor contributing to maternal deaths,"* as the majority of maternal deaths can be prevented with timely medical treatment [9 p1092]. Since their article, numerous authors have stated that barriers to spatial access must be reduced in order to lower maternal mortality rates, as such barriers contribute to at least two if not all three delays [12-19]. However, with the exception of Le Bacq and Rietsema's (1997) work in Zambia and Hoj et al.'s (2002) work in Guinea Bissau, few efforts have been made to quantify the relationship between spatial access and maternal mortality. The first of these works showed that, depending on the region, maternal mortality could be reduced by 29 to 65% with improvements in spatial access [12]. In the second work, an odds ratio for maternal mortality of 7.4 was found in women living more than 25km from a hospital [20]. Despite the exceptional nature of these works, little is known as to how spatial access influences maternal mortality in women who have actually received treatment. Given that both studies were population-based and employed verbal autopsies, many women included likely never received medical care. 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 put in place to improve spatial access. These systems include three components: transportation, communication, and a community financing scheme. A woman will first visit her community health centre (CHC) and if necessary, will be referred to a higher-up facility- generally the district or regional hospital. Transfers are conducted with 4*4 ambulances sent from the hospital. Since

2005, the government of Mali has made caesarean sections free. In the region of this study- Kayes- the regional health authority has made referral and treatment of all obstetrical complications free (irrespective of caesarean section), thus eliminating much of the cost barriers to EmOC utilisation. Despite the referral system, there is still concern that spatial barriers to care have not been sufficiently reduced in the region. In other words, among women who receive EmOC, do spatial barriers increase their likelihood of death?

METHODS

STUDY SITE AND CONTEXT

This study was conducted in the administrative district of Kayes, located in the extreme West of Mali, bordering Mauritania to the North and Senegal to the West. It is geographically heterogeneous, with terrain ranging from arid Sahel in the North to semitropical in the South and is one of seven districts in the Kayes region. The district of Kayes has a surface area of 22 190 Km^2 and is the most populous district in the region, with 396 398 inhabitants. It houses the region's capital city, also by the name of 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 section and blood transfusion occur. The district of Kayes contains 46 health zones, each of which theoretically houses a CHC. In reality, only 29 health zones contain CHCs, another 7 contain private or religious health structures, and 10 are devoid of health centres. Overall, referrals in the district are conducted from 36 of the 46 health zones and for most, the best a CHC can do for a woman with an obstetrical complication is to stabilize and evacuate her to the regional hospital on time.

Data Sources and Collection

Two sources of data were used in this study. The first was the regional Obstetrical Emergency Monitoring System (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 an obstetrical complication 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 and confounder variables (maternal death, major obstetrical intervention (MOI), age, diagnosis, and date of arrival). 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 [21]. Data on time-travelled were obtained in the field through key informant interviews performed by the first author. Key informants were identified in a pilot study and included ambulance drivers, vaccinators, and health centre directors [22]. Informants were asked how long it takes a woman 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 transport her. For most women, the travel trajectory was village to CHC and CHC to hospital, with the last segment 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. Supplementary data were obtained on the types of transportation used and on geographic and seasonal barriers around the CHCs. Travel times were applied to all women in the OEMS depending on their home village and season of travel (694 possibilities).

STUDY DESIGN

This is a matched case-control study on women treated at the regional hospital. The study base was defined geographically (the district of Kayes) and temporally (January 2005 to November 2006). Employing the OEMS, two inclusion criteria were used to create the study base: 1) the woman resided in the district of Kayes and 2) she was diagnosed with either a direct or indirect obstetrical complication (described below). Women whose trajectory to the hospital was unknown were excluded (N=8), as it was unclear whether they met the first inclusion criterion. Cases were all maternal deaths occurring at the hospital within 42 days of birth, as defined by the WHO [2].

Controls were matched to cases on the basis of age, diagnosis, and date of arrival, using a three-to-one ratio. For a given case, matches had the same diagnosis and were plus or minus five years of age, with an upper-bound set at 18 for those 18 years and younger and a lower-bound at 36 for those 36 years and older. A wide age range was chosen to avoid over-matching and because it has been shown that age is a risk factor for maternal mortality in women of young reproduction age (<19) and of old reproductive age (>35) [4, 23, 24]. For two cases, the age was unknown; the average age of the cases was attributed to these women to obtain matched controls. Diagnosis was chosen as a matching variable because of the 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) other direct cause, 6) indirect cause (anaemia, HIV/AIDS, other indirect cause). The date of arrival for a matched control had to be within 6 months of the case (in either direction of the date of arrival); when more than three controls could be matched to a case, those selected arrived closest in date to the case. This was done to limit changes that may have occurred in case management and quality of care over the 23 month study period.

STATISTICS

Descriptive statistics were computed for all women in the OEMS. Case-fatality rates were determined for each obstetrical diagnosis. They were likewise 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 hour, 1-2 hours, 2-3 hours, 3-4 hours, and 4 or more hours.

In the matched case-control study, associations between time-travelled and in-hospital maternal mortality were tested using conditional logistic regression in STATA 9.1. Maternal death (outcome), time-travelled (exposure), and MOI (covariate) were coded as dichotomous categorical variables. Two models were compared; the reduced model tested only time-travelled and maternal death, while the full model adjusted for MOI. MOI has been defined elsewhere [26, 27] and was considered as a potential confounder because of its association with maternal survival in women with complications [28-31]. In this study, MOI consisted almost exclusively of caesarean sections, with the exception of one hysterectomy and one hysterraphy (both in cases). The likelihood ratio statistic was used to test the significance of the full model. Multicollinearity between time-travelled and MOI was assessed with a coefficient correlation matrix.

Cases and controls were considered to have poor spatial access, and were thus *exposed*, if their time-travelled was two or more hours to the hospital; those who travelled less than two hours were considered to have adequate spatial access and were *non-exposed*. The cut-off of two hours is based on the calculations of case-fatality rate with increasing time-travelled to the hospital (see results) and is consistent with the literature [12, 32]. However, sensitivity analyses were also conducted using different cut-off points for poor spatial access (from one to four hours from the hospital).

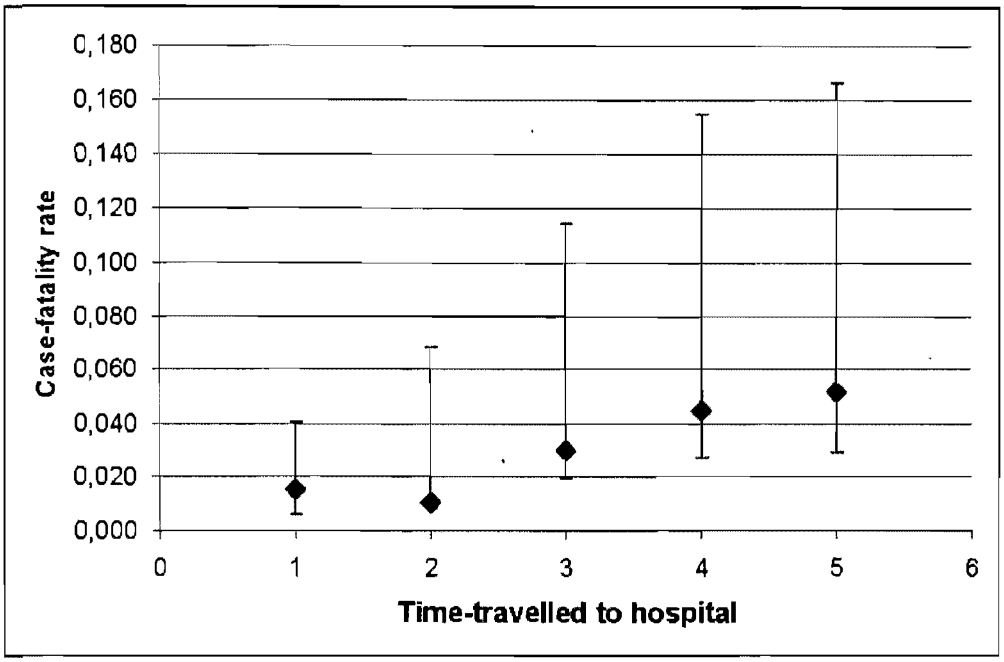
RESULTS:

DESCRIPTIVE DATA

Between January 2005 and November 2006, 1533 women from the district of Kayes were treated for obstetrical complications at the regional hospital. 28 resulted in maternal deaths, yielding a case-fatality rate of 1.8%. The primary diagnoses of the maternal deaths were: haemorrhage (9), uterine rupture (5), (pre-) eclampsia (5), obstructed labour (2), other direct cause (3), and indirect cause (4). The case-fatality rate for each was: 27.8% for uterine rupture, 6.7% for indirect cause, 4.3% for haemorrhage, 3.4% for (pre) eclampsia, 1.1% for other direct cause, and 0.4% for obstructed labour. The case-fatality rate for indirect cause was likely inflated by incomplete denominator data; patients treated for indirect causes do not always report their pregnancies. There were no in-hospital deaths due to infection, miscarriage, or ectopic pregnancy. The average age of a woman was 25 years old (min 12, max 48), the median time-travelled was 15 minutes (mean 1 hour 7 minutes, min 15 minutes, max 25 hours), 30.9% came from outside the city of Kayes, and 51.2% had an MOI.

Case-fatality rates increased with increasing time-travelled to the hospital. There was a jump in case-fatality for women living two or more hours from the hospital (Figure 1); the rate nearly tripled in these women compared to those living less than 2 hours from the hospital (4.2% vs 1.5%).

FIGURE 1: Case-fatality rate with increasing time-travelled to the hospital.



CASE CONTROL

All maternal deaths in the study base were classified as cases. The average age of a case was 28 years old (min 16, max 45) and the average time-travelled was 2 hours and 21 minutes (min 15 minutes; max 10 hours). The majority of cases (N=16; 57.1%) came from outside of the city of Kayes; a little less than half had an MOI (N=11; 40.7%). We matched 81 controls to 28 cases. On average, controls arrived at the hospital within one month of the case (mean 31 days; range 0-161 days). The mean age and time-travelled for the controls were 27 years old (min 15, max 43) and 1 hour and 11 minutes (min 15 minutes, max 8 hours). 27 controls, or 33.3%, lived outside of the city of Kayes and 54, or 64.2%, had an MOI (table 1).

Table 1- Descriptive Data for Cases and Controls:

	Case (N=28)	Control (N=81)
Age, years, mean (SD)	28 (9)	27 (8)
Time-travelled, minutes, mean (SD)	141 (180)	71 (99)
Live in Regional Capital (%)	12 (42.9%)	54 (66.7%)
Time-travelled ≥2 hours (%)	10 (35.7%)	13 (16.0%)
MOI (%)	11 (40.7%)	52 (64.2%)

Conditional logistic regression of the matched cases and controls showed that in model one, time-travelled was significantly associated with being a case. With the addition of MOI to model two, time-travelled was no longer significant; MOI was significantly associated with being a control (table 2). Both models were statistically significant and the likelihood-ratio test indicated that model one was nested in model teo ($p = 0.005$).

Table 2: Conditional logistic regression- association between time-travelled and in-hospital maternal mortality.

	Model I		Model II	
	OR	CI	OR	CI
≥2 hours	2.97	1.16-7.57	2.11	0.75-5.93
MOI			0.19	0.05-0.75

The test of multicollinearity showed little intercorrelation between time-travelled and MOI (R^2=0.12), suggesting that the two variables are not strongly related. Sensitivity analyses revealed that time-travelled of ≥2 hours to the hospital was the best cut-off for poor spatial access.

DISCUSSION

Spatial access has rarely been related to population health [21]. The primary objective of this study was to test the hypothesis that inadequate spatial access, proxied by time-travelled, increases the likelihood of maternal mortality. To our knowledge, only two studies have addressed this question. As explained in the introduction, both studies provided needed insight into the sizable role that spatial access plays in maternal mortality; however, associations were found at a population level in which it was likely that many women never accessed care. Given the little evidence available, this study expands upon previous work by testing for an association between time-travelled and maternal mortality in women who succeeded at reaching EmOC. It attempts to isolate the hypothesised relationship while controlling for key confounders unaddressed in previous studies [12, 20].

EVIDENCE FOR THE ROLE OF SPATIAL ACCESS

This study supports the hypothesis that among women who reach EmOC, inadequate spatial access increases the chances of maternal mortality. First, descriptive data computed for all women recorded in the OEMS showed that the case-fatality rate increased as the number of hours from the hospital increased. Consistent with the literature [12, 32], two hours appears to be a meaningful cut-off point for poor spatial access, as the case-fatality rate nearly tripled in women living 2 hours or more from the hospital.

Further evidence supporting the hypothesised relationship between spatial access and in-hospital mortality came from the matched case-control study. In our first model, which *ex ante* controlled for age, diagnosis, and date of arrival, we found a significant association between time-travelled and in-hospital maternal mortality (OR: 2.96, CI: 1.07-8.15). This suggested that women who lived 2 or more hours from the hospital were three times more likely to die from a complication. However, in our second model, which adjusted for MOI, time-travelled was no longer significantly associated with being a case. The odds ratio remained fairly similar in both models.

The non-significant result found in model two may be due to: 1) no real association between spatial access and maternal mortality, 2) a lack of power in the study, and/or 2) measurement of the exposure variable. We feel the available evidence supports an association between spatial access and in-hospital maternal mortality, but insufficient power accounted for the non-significant finding in model two. Even in areas with high rates of maternal mortality, maternal deaths are fortunately rare events. This is particularly true for hospital based studies, especially as most births in Mali occur in the absence of a healthcare professional [33]. Adequate sample sizes are thus difficult (if not impossible) to obtain [7]. Even in the best studies, the numbers of recorded maternal deaths rarely surpass double digits and/or have wide confidence intervals around study estimators [3, 15, 16, 20, 34]. The choice of a matched case-control study design partially addresses this limitation, as it allows for the study of rare events. Nonetheless, the matching process itself may have affected the study's power, as the diagnosis, uterine rupture, may result from the study exposure [25]. By controlling for uterine rupture (matched for 5 cases of which, 4 were exposed), we may have attenuated the association with spatial access [35, 36].

Errors in the measurement of the exposure variable may also account for the non-significant association; however, this is unlikely. Measurement of spatial access in this study was more comprehensive than that of previous works. By measuring spatial access in terms of time-travelled, we were able to capture important differences in access due to season, transportation method, and geographic barriers that Euclidean measures of distance cannot. Likewise, our exposure cut-off point of two hours was supported both empirically (figure 1) and theoretically [32]. Sensitivity analyses, testing different cut-off points, further supported our choice of two hours. Finally, as data on the exposure variable were obtained independently of cases and controls, we greatly reduced the possibility of differential misclassification due to recall or interview bias.

Overall, the available evidence supports the hypothesized relationship between inadequate spatial access and in-hospital maternal mortality. This evidence includes previous research demonstrating an association at a population level [12, 20]; increasing case-fatality rates for women in the OEMS as time-travelled to the hospital increased; and results from the case-control study suggesting that women who lived 2 or more hours from the hospital were 2-3 times more likely to be a case than a control. Finally, previous research has shown that since the inception of the referral system in Kayes, use of EmOC has increased dramatically while in-hospital maternal mortality has dropped significantly [37]. The most likely explanation for this drop is that spatial barriers to EmOC have been reduced and that many women are receiving EmOC in time to save their lives.

THE PROTECTIVE ROLE OF MOI

It is unsurprising to find that major obstetrical interventions, such as caesarean section, protect against maternal mortality in women with complications. Ecological evidence shows that, in low-income countries such as Mali, as caesarean section rates increase, maternal and neonatal mortality rates decrease [38]. When medically justified, such interventions are effective at reducing maternal mortality when compared to vaginal delivery [29, 38] This is particularly true in settings with low rates of caesarean section, as they likely reflect access to life saving care [31].

Access to appropriate care moderates the influence of spatial access on in-hospital maternal mortality. Nevertheless, it was surprising that cases were less likely to receive

MOI (40.7% of cases had an MOI while only 64.2% of controls did). It is unlikely that controls were treated differently from cases, as at the moment of treatment, their outcome was unknown. Also unlikely, is that temporal patterns in case management had an influence on the selection of controls, as cases and controls were matched by date of arrival.

More likely, cases arrived at the hospital too late for treatment. We therefore calculated the case-fatality rates in women who received a surgical intervention. Employing all women in the OEMS, we found that among women who received a surgical intervention *and* who lived less than 2 hours from the hospital, the case-fatality rate was 0.8% (5/591). However, for women who received a surgical intervention, but lived 2 or more hours from the hospital, the case-fatality rate was 4.8% (6/126). This suggests that the protective effect of MOI was not equal for everyone, as the benefit of MOI was less pronounced in those living further away. In other words, if utilisation of MOI was the driving determinant behind in-hospital maternal mortality in Kayes, one would expect that the case-fatality rate in those who *did* receive an intervention to be similar, no matter what their travel time. This further supports the hypothesized relationship between spatial access and in-hospital maternal mortality.

While delays due to spatial access were controlled for, we could not control for delays in the decision to seek care, nor could we control for delays at the CHC or hospital. Because of these delays, certain cases may have arrived in such bad condition that they died before MOI was possible or, even more likely, were so ill that MOI was impossible. Future studies should look at the reasons for such delays (perhaps the result of aspatial factors such as socio-economic status, ethnicity, etc.) and then assess impact of these delays in conjunction with spatial access.

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. In order for such efforts to be effective, or on a more basic level- justifiable, we must first know the relationship between spatial access and maternal mortality. This study takes a further step towards evaluating this relationship and provides evidence upon which programmatic and policy interventions can be built. In all, our study provides evidence that spatial access is related to in-hospital maternal mortality. Nonetheless, protective obstetrical interventions, such as caesarean section, help to mitigate the deleterious effects of limited spatial access. Overall, for EmOC to be truly effective, women must arrive in a treatable condition. Major obstetrical interventions should certainly be made more accessible in rural regions, such as Kayes; the best way to do that is to assure that women are capable of receiving quality care with a minimum of delay. 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 and evacuation.

ACKNOWLEDGEMENTS

We would like to thank the Regional Health Authority of Kayes for opening their doors and assisting us with this study. We would also like to thank D[r] Alexandre Dumont for his useful insight and feedback.

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7. SUPPLEMENTARY RESULTS

In the conceptual framework, a literature review detailing various measures of spatial access was provided. From this review, it was shown that the most comprehensive measure of spatial access, in the Malian context, is travel impedance to the nearest provider, as measured by physical distance along a transportation path or time-travelled.[15] As described in the methodology, data was collected for both of these measures. In this chapter, supplementary results are presented demonstrating the rational behind measuring spatial access by time-travelled rather than physical distance.

7.0) DESCRIPTIVE DATA

Of the 347 villages in the district of Kayes, key informants were able to provide the number of kilometres separating the village from the hospital for 345 villages, the times travelled during the dry season for 337 villages, and the times travelled during the rainy season for 336 villages. The mean number of kilometres (dKm) separating a village from the hospital was 73.8 km (min 2, max 180). The average time travelled during the dry season (dTD) was 279.1 minutes (min 15, max 1080). The average time travelled during the rainy season (dTR) was 529.1 minutes (min 15, max 2880). There were 35 villages reported to be more than 24 hours from the hospital during the rainy season. None were more than 24 hours from the hospital during the dry season.

[15] In a context with more than one comprehensive EmOC facility in a district, a gravity model may be more appropriate. In Kayes, however, there is only one comprehensive facility.

The most common form of transportation between village and CHC was a donkey-drawn carriage, followed by vehicle for those located near a paved road[16], and canoe or boat for those living close to the Senegal River. Commonly encountered geographic obstacles included arroyos[17], swamps, and sticky mud during the rainy season, as well as dry sand[18] and rarely, hills. Transportation from CHC to the hospital was almost exclusively conducted in 4*4 ambulances.

Table IV: Descriptive statistics according to the measure of spatial access

	Distance in kilometres N=345	**Distance in minutes during the dry season** N=337	**Distance in minutes during the rainy season** N=336
Min	2	15	15
Max	180	1080	2880
Average	73.8	279.1	529.1
Median	76.5	240	360

7.1) (DIS)PROPORTIONALITY OF MEASURES

In medical geography, a Lorenz curve it is a graphical representation of spatial inequality [115], in this case, cumulative spatial access (dKm, dTD, dTR) versus cumulative population (villages). This graph demonstrates increasing inequality between measures as one goes from dKm to dTR. If one uses the measure dKm, 50% of villages have 25-35%

[16] There is a paved road running from Dakar in Senegal to slightly past the city of Kayes. The road largely follows the Senegal River.
[17] Temporary body of water that occurs after heavy rain, known locally as "marigots."
[18] Dry sand causes carriage wheels to spin and slip.

of the spatial access, where as if one uses dTR, 50% of villages have 15-20% of the access (figure 7).

Figure 7: Lorenz curve of dKm, dTD, dTR

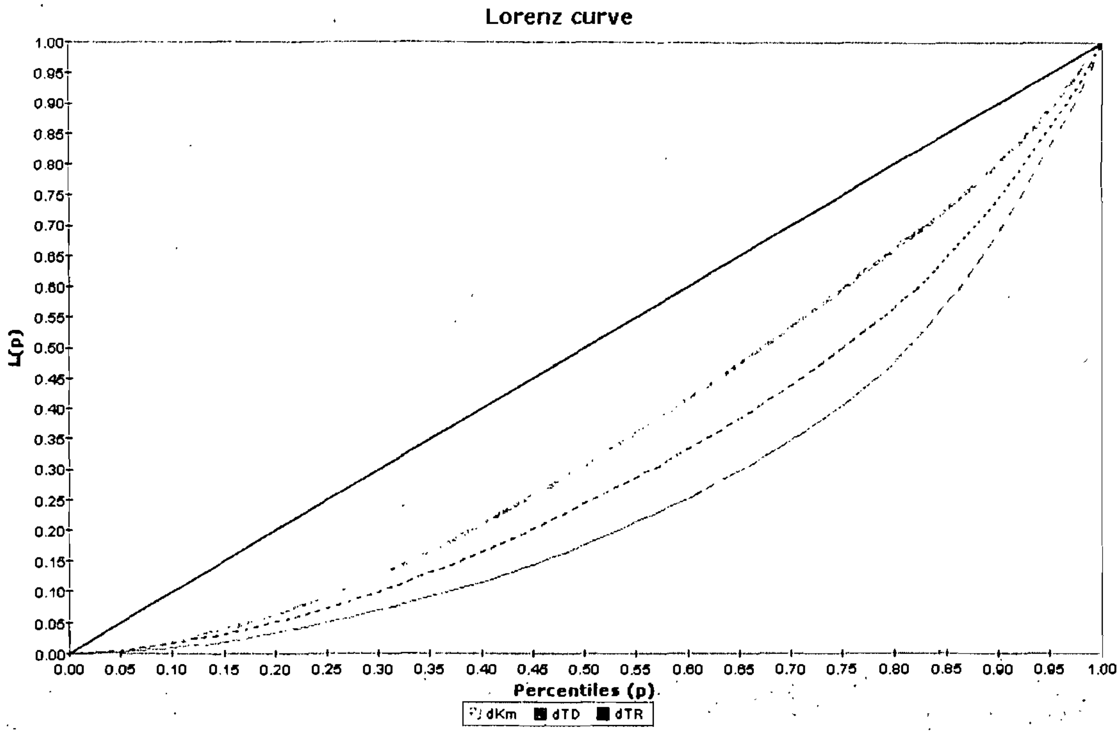


Table V, provides the values of three different disproportionality functions. In each case, we see increasing disparities between measures as we go from dKm to dTR, suggesting a large incongruence in which dKm may over-summarize women's true spatial access to the regional hospital.

Table V: Measures of spatial access according to disproportionality function

	Coefficient of Variation	**Gini Index**	**Atkinson's Measure**
D(km)	0.500 (0.021)	0.277 (0.013)	0.080 (0.007)
D(TD)	0.702 (0.026)	0.374 (0.013)	0.120 (0.008)
D(TR)	0.928 (0.035)	0.473 (0.013)	0.180 (0.010)

7.2) Differences in Z-scores between measures

Figure 8 shows the differences in z-scores between dKm and dTD. Black diamonds represent villages. If the two measures were identical, then there would be no difference in z-scores and the black diamonds would be situated on or near the x-axis. For most villages less than 75 km from the hospital, dKm and dTD are within one z-score of each other. However, after 75 km, large differences in z-scores appear (0-3.5).

Figure 9 shows the difference in z-scores between dKm and dTR as the number of kilometres increases. Similar to the dry season, most dKm and dTR measures are within one z-score of each other for villages 75 km or less from the hospital. In contrast with the dry season, there are a notable number of villages within this kilometre range that are 2-3 z-scores different. After 75 km, an increasing number of villages fall out of the single z-score range and only a handful are in this range after 100 km.

Figure 9: Difference in z-scores between dKm and dTD as the number of kilometres from the hospital increases

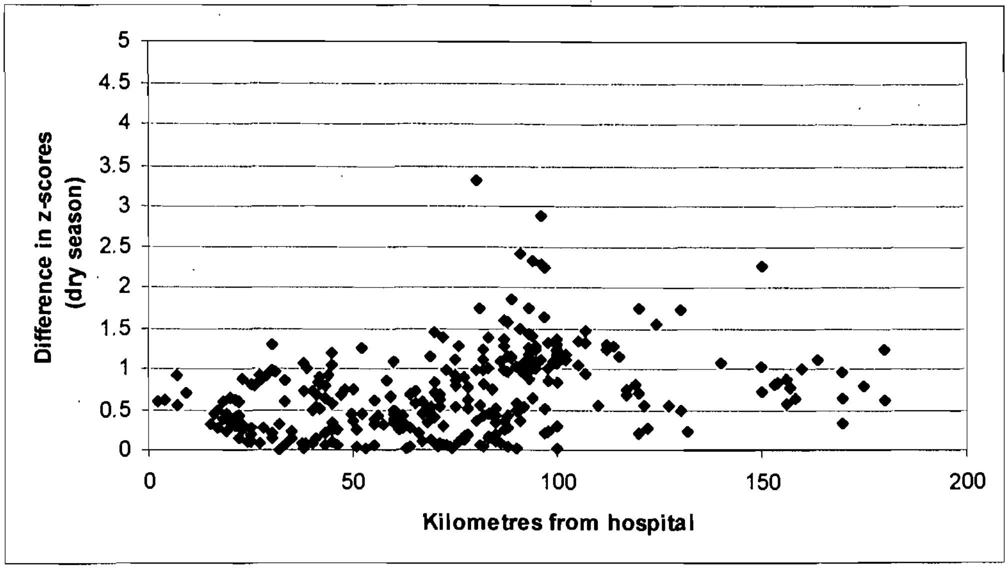


Figure 9: Difference in z-scores between dKm and dTD as the number of kilometres from the hospital increases

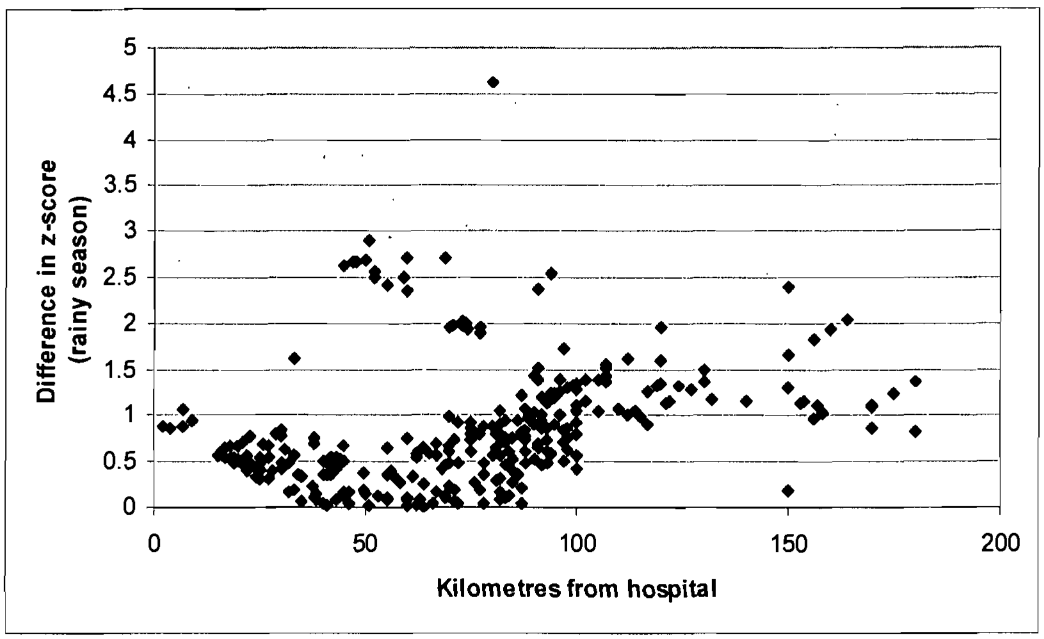
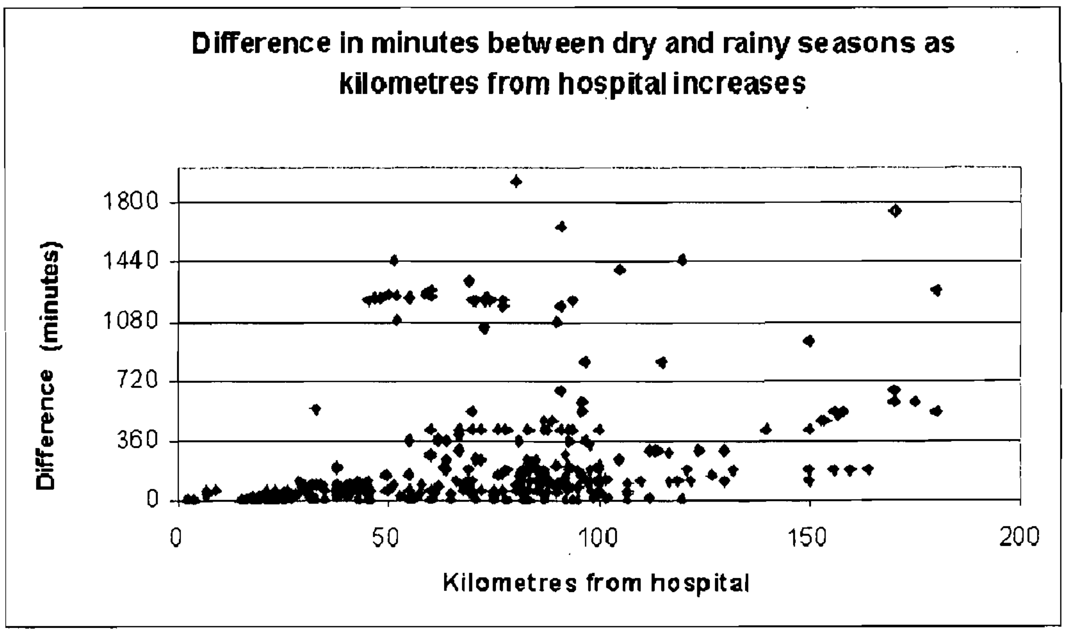


Figure 10 shows the differences in time-travelled during the dry and rainy seasons as the number of kilometres from the hospital increases. Between 0 and 50 kilometres from the hospital, the time travelled between seasons does not differ dramatically and for most villages, it ranges from 0 to 3 hours. After 50 kilometres, the differences in time-travelled between seasons increase substantially, ranging from 0 to over 24 hours. There appears to be a slightly increasing trend, as the number of kilometres from the hospital increases, so do the differences in travel times between seasons.

Figure 10: Difference in minutes between dTD and dTR as the number of kilometres from the hospital increases



8. DISCUSSION

The discussion is divided into three large sections. The first section discusses the supplementary results (chapter 7), while the second discusses those presented in the article (chapter 6). A final section discusses future implications and directions for the research.

I. TIME-TRAVELLED AS A MEASURE OF SPATIAL ACCESS

8.0) SPATIAL ACCESS MEASURES ARE NOT EQUAL

The author compared two measures of travel impedance, physical distance measured in kilometres (dKm) along a transportation path, and time-travelled measured in minutes during the dry and rainy seasons (dTD, dTR), in order to determine the most comprehensive measure to be applied to the case-control study design presented in chapter 6. The results show important differences between measures and suggest that physical distance measures are inadequate proxies of spatial access in the context of Kayes. First, the Lorenz curves and the three disproportionality functions demonstrated large disparities between the measures dKm, dTD, and dTR. The physical distance measure showed proportionately more spatial access than when compared to time-travelled (particularly during the rainy season). As a result, these measures were further analysed to see if the disparities were consistent as the number of kilometres from the hospital increased. In other words, were the measures consistently unequal for all villages in Kayes?

The results show that the measures are not consistently unequal. Comparing the measures directly, results show that for villages less than 75 km from the hospital, most dKm, dTD, and dTR are within one z-score of each other. This may justify the use of a kilometre measure over a time-travelled measure for women living close to the hospital.

After 75 km, large differences in z-scores appear for both seasons suggesting important divergences between the measures in villages more than 75km from the hospital (about half of villages in the district). During the rainy season, this difference is most evident in villages more than 100 km from the hospital, as almost none have dKm or dTR measures within one z-score of each other. Finally, differences in time-travelled during the dry and rainy seasons were compared. For villages under 50 kilometres from the hospital, the difference between seasons is generally less than 180 minutes. While this seems small, it should be noted that for certain obstetrical complications, travel times exceeding 2 hours can mean the difference between life and death [116]. This was further demonstrated in the present research, as case-fatality rates in women nearly tripled after the 2 hour cut-off. For villages more than 50 kilometres from the hospital, the differences between seasons become dramatic and can be upwards of 24 hours. In addition, there appears to be a slight trend wherein travel time differences between seasons increase with increasing kilometres. This may reflect an accumulation of spatial barriers as distance from the hospital increases.

8.1) RELIABILITY

While time-travelled appears to be a more comprehensive measure of spatial access than physical distance, especially for villages more than 75 kilometres from the hospital, the reliability of the method for obtaining the measure has not been tested empirically. It is possible that key informants over-estimated travel times, thus explaining the large differences between measures. However, one would expect this form of information bias to be uniform. Figures 8, 9, 10 demonstrate that this is not the case. Further, the OEMS contains a variable that records when the ambulance departed and returned from various villages in the district. Values for the variable are poorly filled out, but among those that are, the times recorded correlate almost perfectly with those obtained through the interviews. In fact, of the measures of spatial access given, it may be the measures of physical distance that are over-estimated. The RHA reimburses gas expenditures and it is not unusual for health centre directors to overstate the number of kilometres in order to get greater reimbursements.

II. THE RELATIONSHIP BETWEEN INADEQUATE SPATIAL ACCESS AND MATERNAL MORTALITY

Spatial access has rarely been related to population health [99]. The primary objective of this study was, therefore, to test the hypothesis that inadequate spatial access increases the likelihood of maternal mortality. To the author's knowledge, only two studies have addressed this question. Both studies provided needed insight into the sizable role that spatial access plays in maternal mortality. In the first of these works, it was shown that, depending on the region, maternal mortality could be reduced by 29 to 65% percent if improvements in spatial access were made in Zambia (84). In the second work, an odds ratio for maternal mortality of 7.4 was found for women living more than 25km from a hospital in Guinea-Bissau [86, 87]. However, these associations were found at a population level in which it was likely that many women never accessed care. Further, neither study controlled for key confounders, such as diagnosis, nor described how the spatial access measure was obtained. Given the little evidence presently available, this study expands upon previous work by testing for an association between time-travelled (our proxy of spatial access) and maternal mortality in women who succeeded at reaching EmOC, while also controlling for key confounders unaddressed in previous studies [86, 87].

8.2) THE EVIDENCE FOR SPATIAL ACCESS IN MATERNAL MORTALITY

This study supports the hypothesis that among women who reach EmOC, inadequate spatial access increases the chances of maternal mortality. First, descriptive data computed for all women recorded in the OEMS showed that the case-fatality rate increased as time-travelled to the hospital increased. Consistent with the literature [86, 114], two hours appears to be a meaningful cut-off point for poor spatial access, as the case-fatality rate nearly tripled in women living 2 hours or more from the hospital.

Further evidence supporting the hypothesised relationship between inadequate spatial access and in-hospital mortality came from the matched case-control study. In the first model, which *ex ante* controlled for age, diagnosis, and date of arrival, we found a significant association between time-travelled and in-hospital maternal mortality (OR: 2.96, CI: 1.07-8.15). This suggested that women who lived 2 hours or more from the hospital were three times more likely to die of an obstetrical complication. However, in the second model, which adjusted for MOI, time-travelled was no longer significantly associated with being a case. Nevertheless, the odds ratio remained fairly similar in both models.

The non-significant result found in model two may be due to: 1) no real association between spatial access and maternal mortality, 2) a lack of power in the study, and/or 2) measurement of the exposure variable. We feel the available evidence supports an association between time-travelled and in-hospital maternal mortality, but insufficient power accounted for the non-significant finding in model two. Even in areas with high rates of maternal mortality, maternal deaths are fortunately rare events. This is particularly true for hospital based studies, especially as most births in Mali occur in the absence of a healthcare professional [39]. Adequate sample sizes are thus difficult (if not impossible) to obtain [16]. Even in the best studies, the numbers of recorded maternal deaths rarely surpass double digits and/or have wide confidence intervals around study estimators [68, 83, 87, 117, 118]. The choice of a matched case-control study design partially addresses this limitation, as it allows for the study of rare events. Nonetheless, the matching process itself may have affected the study's power, as the diagnosis, uterine rupture, may result from the study exposure [112]. By controlling for uterine rupture (matched for 5 cases of which, 4 were exposed), we may have attenuated the association with time-travelled [119, 120].

Similar to the example of uterine rupture, it is also possible that MOI is on the line of causality between spatial access and in-hospital maternal mortality. If that is the case, then adjusting for MOI in model two would be over-controlling, possibly explaining the non-significant result. However, the author does not believe this to be the case.

Theoretically, it is unclear how spatial access would be associated MOI except, perhaps, through an intermediate variable, such as the physiological condition of the woman upon arrival at the hospital. Statistically, the test of multicollinearity indicated that there was little intercorrelation between time-travelled and MOI in cases and controls.

Errors in the measurement of the exposure variable may also account for the non-significant association; however, this is unlikely. Measurement of spatial access in this study was more comprehensive than that of previous work. By measuring spatial access with time-travelled, we were able to capture important differences in access due to season, transportation method, and geographic barriers that physical distance measures cannot. This was demonstrated in the supplementary results section, where kilometre measures along a transportation path greatly over-summarised women's spatial access to care, particularly among those living more than 75km from the hospital. Likewise, the exposure cut-off point of two hours is supported by the literature [86, 114], and through our results (see figure 1) and sensitivity analyses.

In conjunction, one important concern in case-control studies is differential misclassification of the exposure variable, often attributable to recall bias. It is common for case-control studies to obtain data on the exposure variable through retrospective self-report. The resulting "recall bias" is thought arise through a greater effort on the part of cases to find the exposure that "caused" their ailment [119]. It is unlikely that this study is subject to such as bias, as data on the exposure variable were obtained independently of cases and controls. Even if key informants exaggerated exposure data, they were unaware of the individuals included in the study base and thus misclassification would have been non-differential. It this was the case, then the effect estimate may have been biased towards the null, possibly explaining the non-significant finding with time-travelled [119].

Overall, the available evidence supports the hypothesized relationship between spatial access and in-hospital maternal mortality. This evidence includes previous research demonstrating an association at a population level [86, 87]; increasing case-fatality rates for women in the OEMS as time-travelled increased; and results from the case-control study suggesting that women who lived 2 or more hours from the hospital were 2-3 times more likely to be a case than a control. Finally, previous research has shown that since the inception of the referral system in Kayes, use of EmOC has increased dramatically while in-hospital maternal mortality has dropped significantly [45]. The most likely explanation for this drop is that spatial barriers to EmOC have been reduced and that many women are receiving EmOC in time to save their lives.

8.3) THE PROTECTIVE ROLE OF MOI

It is unsurprising to find that major obstetrical interventions, such as caesarean sections, protect against maternal mortality in women with complications. Ecological evidence shows that, in low-income countries such as Mali, as caesarean section rates increase, maternal and neonatal mortality rates decrease [121]. When medically justified, such interventions are effective at reducing maternal mortality when compared to vaginal delivery [107, 121]. This is particularly true in settings with low rates of caesarean section, as they likely reflect access to life saving care [122].

Access to appropriate care moderates the influence of spatial access on in-hospital maternal mortality. Nevertheless, it is unclear why cases were less likely to receive interventions (40.7% of cases had an MOI while only 64.2% of controls did). It is unlikely that controls were treated differently from cases, as at the moment of treatment, their outcome was unknown. Also unlikely, is that temporal patterns in case management had an influence on the selection of controls, as cases and controls were matched by date of arrival and on average, arrived within a month of one another. Lastly, as described above, the author does not feel spatial access influenced the utilisation of MOI in a causal manner (e.g. that MOI is on the line of causality between spatial access and maternal mortality).

Instead, the author feels that many cases arrived at the hospital too late for MOI and that this was largely due to limited spatial access. Because some women may have arrived at the hospital in a condition too poor to treat (or died before treatment was possible)[19]; we calculated the case fatality rates in women who received an MOI. Employing all women in the OEMS, we found that among women who received a surgical intervention *and* who lived less than 2 hours from the hospital, the case fatality rate was 0.8% (5/591). However, for women who had an MOI, but lived 2 or more hours from the hospital, the case fatality rate was 4.8% (6/126). This suggests that the protective effect of MOI was not equal for everyone, as the benefit of MOI was much less pronounced in those living further away. In other words, if utilisation of MOI was the driving determinant behind in-hospital maternal mortality in Kayes, one would expect that the case-fatality rate in those who *did* receive an intervention to be similar, no matter how far from the hospital they

[19] According to the database, at least one woman died *en route* of post-partum haemorrhage.

were. This further supports the hypothesized relationship between poor spatial access and in-hospital maternal mortality.

Nevertheless, the question of why a smaller proportion of cases received MOI than controls remains undecided. Unexplored by this study is whether unmeasured factors, specifically those contributing to the first and third delays, may have influenced in-hospital maternal mortality, spatial access, MOI, or a combination of all three. For example, aside from diagnosis, we were unable to control for other physiological characteristics (e.g. blood pressure or nutritional status) related to the condition of the woman upon treatment. It is imaginable that a factor such as ethnicity influenced spatial access (through geographic settlement), as well as nutritional status (through dietary norms), and both influenced the physiological condition of the woman upon arrival at the hospital. This in turn, influenced the recourse to MOI and finally, the likelihood of maternal death. Thus, while this model expands upon previous work on spatial access and maternal mortality by considering key confounders (age, diagnosis, date of arrival, MOI), future research could look at factors contributing to delays in the decision to seek care and related delays at the CHC or hospital. Examples of important variables to consider include socio-economic status, ethnicity, educational attainment, and key physiological indicators such as blood pressure. Further work should consider the mechanisms by which such factors influence mortality outcome.

III. IMPLICATIONS AND FUTURE DIRECTIONS

This research provides tools for programmic and policy interventions in Kayes, Mali as well as for comparable rural settings in other developing countries. First, it demonstrates that in a region characterized by highly dispersed populations, poor road infrastructures, considerable geographic variability, and striking seasonal fluctuations, physical distance as a proxy measure of spatial access to EmOC is likely an inadequate. Time-travelled is a more valid measure of spatial access. Second, this study provides evidence to suggest that even with a functioning referral system, spatial access continues to contribute to maternal mortality. Therefore, in order to maximize the impact of such interventions, future efforts need to be geared towards improving spatial access within the system. Such interventions require important investments into district infrastructures including expanding and improving transportation systems, particularly roads and bridges, as well as increasing the number of basic and comprehensive EmOC centres in the district. Further interventions include encouraging women, particularly in remoter parts of the district, to give birth in the CHCs in order to reduce transportation delays between villages and CHCs and to increase the chances of rapid recognition and referral of women with complications.

Future research should also look at the non-utilisation of EmOC. Qualitative data gathered by the author indicated that limited spatial access prevents utilisation. Key informants stated that certain parts of Kayes are completely inaccessible during the rainy season, meaning that women from these areas would never reach the hospital. In support of the informants' assertions, only 7% of obstetrical cases recorded in the OEMS resided more than 3 hours from the hospital, substantially less would be expected based on the population. Future studies should map the coverage of the referral system based on expected and actual utilisation rates. Spatial access should continue to be measured by time.

9. CONCLUSION

There is general consensus that poor spatial access to EmOC must be reduced in order to decrease the high maternal mortality rates found in many developing countries. In order for such efforts to be effective, or on a more basic level- justifiable, we must know the relationship between spatial access and maternal mortality. A first step to doing so is employing a measure of spatial access appropriate to the context. By demonstrating the rationale behind using time-travelled as a proxy of spatial access, this study provides practical tools for programmatic and policy interventions. Further, the research provides evidence that spatial access is related to in-hospital maternal mortality, but that protective interventions, such as caesarean sections, can help mitigate the effect of spatial access. Overall, for EmOC to be truly effective, women must arrive in a treatable condition. Surgical interventions such as caesarean sections should certainly be made more accessible in rural regions such as Kayes; the best way to do that is to assure that women are capable of receiving quality care with a minimum of delay. 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 and evacuation.

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ANNEX 1- LIST OF CASES AND CONTROLS

Case: age, diagnosis, date of arrival, intervention, exposure (at 2 hours).	Control 1:	Control 2:	Control 3 :	Max number of days apart
Kayes2828: 45; uterine rupture; 26/02/2006; surgical intervention; unexposed *Exact time: 50 minutes*	1) **Kayes2879:** 40; uterine rupture; 08/06/06; surgical intervention; unexposed *Exact time: 50 minutes*	2) **Kayes3128:** 40; uterine rupture; 20/03/06; surgical intervention; unexposed *Exact time: 30 minutes*		102
Kayes2932: 20; uterine rupture; 07/04/06; surgical intervention; exposed *Exact time: 3 hours*	1) **Kayes1960:** 20; obstructed labour with pre-uterine rupture syndrome; 17/07/06; surgical intervention; unexposed *Exact time: 2 hours*	2) **Kayes3165:** 20; obstructed labour with pre-uterine rupture syndrome; 17/06/06; surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes2865:** 20; obstructed labour with pre-uterine rupture syndrome; 11/03/06; surgical intervention; unexposed. *Exact time: 15 minutes*	101
Kayes1869: 17; (pre)eclampsia; 25/06/2005; surgical intervention; exposed *Exact time: 6 hours*	1) **Kayes346:** 17; (pre)eclampsia; 03/07/05; surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes688:** 16; (pre) eclampsia; 11/07/05; surgical intervention; exposed *Exact time: 3 hours*	3) **Kayes1879:** age 17; (pre) eclampsia; 27/06/05; surgical intervention; exposed *Exact time: 6 hours*	16
Kayes2931: 40; obstructed labour; 07/04/2006; surgical intervention; exposed *Exact time: 8 hours*	1) **Kayes2852:** 42; obstructed labour; 07/03/06; surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes2866:** 38; obstructed labour; 11/03/06; surgical intervention; unexposed *Exact time: 1 hour 45 minutes*	3) **Kayes3001:** 38; obstructed labour; 26/04/06; surgical intervention; unexposed *Exact time: 15 minutes*	31
Kayes968: ??; 10/11/05; other direct obstetrical cause; no surgical intervention; exposed *Age=28 (average for cases)* *Exact time: 8 hours*	1) **Kayes514:** 30; other direct cause; 26/10/05; surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes966:** 30; other direct cause; 17/11/05; surgical intervention; unexposed *Exact time: 1 hour 20 minutes*	3) **Kayes433:** 23; other direct cause; 22/11/05; surgical intervention; unexposed *Exact time: 15 minutes*	15

Kayes3046: 16; uterine rupture; 13/05/06; surgical intervention; exposed *Exact time: 9 hours*	1) **Kayes3123:** 16; obstructed labour with pre-uterine rupture syndrome; 07/06/06; surgical intervention; unexposed *Exact time: 45 minutes*	2) **Kayes2945:** 18; obstructed labour with pre-uterine rupture syndrome; 10/04/06; surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes3069:** 18; obstructed labour with pre-uterine rupture syndrome; 20/05/06; surgical intervention; unexposed *Exact time: 15 minutes*	33
Kayes2060: 33; uterine rupture; 18/08/06; surgical intervention; exposed *Exact time: 3 hours*	1) **Kayes3173:** 28; uterine rupture; 20/06/06; surgical intervention; unexposed *Exact time: 1 hour 45 minutes*	*2)* **Kayes2383:** 30; obstructed labour with pre-uterine rupture syndrome; 16/10/06; surgical intervention; exposed *Exact time: 8 hours*	3) **Kayes2364:** 28; obstructed labour with pre-uterine rupture syndrome; 11/10/06; surgical intervention; unexposed *Exact time: 1 hour 40 minutes*	59
Kayes2318: 29; indirect cause; 12/09/06; no surgical intervention; exposed *Exact time: 10 hours*	1) **Kayes2317**: 28; indirect cause; 29/09/06; no surgical intervention; exposed *Exact time: 2 hours 30 minutes*	2) **Kayes2572**: 30; indirect cause; 25/08/06; no surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes2570**: 27; indirect cause; 26/08/06; no surgical intervention; exposed *Exact time: 8 hours*	18
Kayes1856: 30; haemorrhage; 15/06/05; no surgical intervention; exposed *Exact time: 2 hours*	1) **Kayes1886:** 28; haemorrhage; 06/07/05; surgical intervention; unexposed *Exact time: 15 minutes*	**Kayes1838:** 26; haemorrhage; 03/06/05; no surgical intervention; exposed *Exact time: 6 hours*	2) **Kayes642:** 28; haemorrhage; 06/06/05; surgical intervention; unexposed *Exact time: 15 minutes*	21
Kayes904 : 30; haemorrhage; 12/08/05; ?? ; exposed *Exact time: 3 hours*	**Kayes18:** 26; haemorrhage; 07/08/05; no surgical intervention; unexposed *Exact time: 1 hour 15 minutes*	1) **Kayes353:** 25; haemorrhage; 05/08/05; surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes417:** 25; haemorrhage; 15/08/05; surgical intervention; unexposed *Exact time: 15 minutes*	7
Kayes896 : 40; other direct cause; 13/07/05; surgical intervention; unexposed *Exact time: 45 minutes*	1) **Kayes1785:** 40; other direct cause; 12/05/05; surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes1862:** 42; other direct cause; 20/06/05; no surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes1805:** 43; other direct cause; 19/05/05; surgical intervention; unexposed *Exact time: 15 minutes*	62
Kayes1770: 18; (pre) eclampsia; 07/05/2005; surgical intervention; unexposed *Exact time: 45 minutes*	1) **Kayes1678:** 18; (pre) eclampsia; 28/03/05; surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes341:** age 18; (pre) eclampsia; 10/06/05; surgical intervention; unexposed *Exact time: 1 hour 15 minutes*	3) **Kayes1680:** 15; (pre) eclampsia; 31/03/05; no surgical intervention; exposed *Exact time: 2 hours*	40

Kayes2832: 34; 28/02/06; indirect cause; no surgical intervention; exposed *Exact time: 2 hours*	1) **Kayes2642:** 35; indirect cause; 02/07/06; no surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes2578:** 35; indirect cause; 08/08/06; no surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes667**: 29; indirect cause; 31/10/05; no surgical intervention; unexposed *Exact time: 15 minutes*	161
Kayes1983: 19; haemorrhage; 24/07/06; no surgical intervention; unexposed *Exact time: 1 hour*	1) **Kayes2270:** 20; haemorrhage; 28/07/06; no surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes1977**: 21; haemorrhage; 23/07/06; no surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes2648:** 21; haemorrhage; 13/07/06; no surgical intervention; exposed *Exact time: 3 hours*	11
Kayes2353: 38, haemorrhage, 7/10/06; surgical intervention; exposed *Exact time: 2 hours 30 minutes*	1) **Kayes2486:** 38; haemorrhage; 14/11/06; surgical intervention; unexposed *Exact time: 1 hour 45 minutes*	2) **Kayes2210:** 36; haemorrhage; 26/09/06; no surgical intervention; exposed *Exact time: 3 hours*	3) **Kayes2535:** 38; haemorrhage; 29/11/06; surgical intervention; unexposed *Exact time: 1 hour 45 minutes*	53
***Kayes785**, ??; indirect cause; 23/05/05; no surgical intervention; exposed* Age 28 (average for cases) *Exact time: 3 hours*	1) **Kayes425:** 34; indirect cause; 27/10/05; no surgical intervention; unexposed *Exact time: 15 minutes*			157
Kayes2973: 35; uterine rupture; 19/04/06; surgical intervention; unexposed *Exact time: 30 minutes*	1) **Kayes3087:** 33; obstructed labour with pre-uterine rupture syndrome; 26/05/06; surgical intervention; exposed *Exact time: 3 hours*	2) **Kayes1984:** 33; obstructed labour with pre-uterine rupture syndrome; 25/07/06; surgical intervention; unexposed *Exact time: 1 hour 30 minutes*	3) **Kayes2757:** 30; obstructed labour with pre-uterine rupture syndrome; 04/02/06; surgical intervention; unexposed *Exact time: 1 hour 45 minutes*	97
Kayes490: 16; haemorrhage; 03/07/05; no surgical intervention; unexposed *Exact time: 15 minutes*	1) **Kayes350:** 16; haemorrhage; 31/07/05; no surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes983:** 18; haemorrhage; 03/08/05; surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes344:** 18; haemorrhage; 26/06/05; surgical intervention; unexposed *Exact time: 30 minutes*	31
Kayes989: 38; haemorrhage; 06/07/05; surgical intervention; unexposed *Exact time: 15 minutes*	1) **Kayes1841:** 37; haemorrhage; 05/06/05; surgical intervention; unexposed *Exact time: 1 hour 30 minutes*	2) **Kayes342:** 39; haemorrhage; 17/06/05; surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes340:** 40; haemorrhage; 07/06/05; surgical intervention; unexposed *Exact time: 15 minutes*	31

Kayes982: 23; haemorrhage; 01/07/05; no surgical intervention; unexposed *Exact time: 15 minutes*	1) **Kayes647:** 23; haemorrhage; 13/07/05; surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes491:** 21; haemorrhage; 03/07/05; surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes646:** 26; haemorrhage; 11/07/05; surgical intervention; unexposed *Exact time: 15 minutes*	12
Kayes2023: 30; haemorrhage; 08/08/06; no surgical intervention; unexposed *Exact time:15 minutes*	1) **Kayes2027:** 30; haemorrhage; 08/08/06; surgical intervention; exposed *Exact time: 4 hours*	2) **Kayes1993:** 27; haemorrhage; 27/07/06; surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes2018:** 33; haemorrhage; 05/08/06; surgical intervention; unexposed *Exact time: 15 minutes*	12
Kayes2409: 26; haemorrhage; 26/10/06; no surgical intervention; unexposed *Exact time: 15 minutes*	*1)* **Kayes2394:** 28; haemorrhage; 20/10/06; surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes2397:** 22; haemorrhage; 22/10/06; surgical intervention; unexposed *Exact time: 15 minutes*	3) Kayes2456: 22; haemorrhage; 06/11/06; no surgical intervention; unexposed *Exact time: 15 mins*	11
Kayes1942: 35; (pre)eclampsia; 09/07/06; no surgical intervention; unexposed *Exact time: 15 minutes*	1) **Kayes2235:** 35; (pre)eclampsia; 03/07/06; no surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes1953:** 30; (pre)eclampsia; 14/07/06; no surgical intervention; unexposed *Exact time: 30 minutes*	3) **Kayes2245:** 33; (pre) eclampsia; 11/07/06; no surgical intervention; exposed *Exact time: 2 hours 15 minutes*	6
Kayes2438: 18; (pre)eclampsia; 10/10/06; no surgical intervention; unexposed *Exact time: 15 minutes*	1) **Kayes2368:** 18; (pre)eclampsia; 11/10/06; no surgical intervention; exposed *Exact time: 3 hours 30 minutes*	2) **Kayes2366:** 17; (pre)eclampsia; 11/10/06; surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes2371:** 17; (pre)eclampsia; 12/10/06; surgical intervention; unexposed *Exact time: 15 minutes*	2
Kayes429: 32; (pre)eclampsia; 07/11/05; no surgical intervention; unexposed *Exact time: 15 minutes*	1) **Kayes1905:** 28; (pre) eclampsia; 22/07/05; surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes363:** 35; (pre) eclampsia; 02/10/05; no surgical intervention; unexposed *Exact time: 15 minutes*	3) Kayes2830: 32; (pre) eclampsia; 27.02.06; surgical intervention; unexposed Exact time: 15 minutes	112
Kayes3140: 23; obstructed labour; 12/06/06; no surgical intervention; unexposed *Exact time: 15 minutes*	1) **Kayes3135:** 23; obstructed labour; 09/06/06; surgical intervention; unexposed *Exact time: 15 minutes*	2) **Kayes3169:** 21; obstructed labour; 19/06/06; no surgical intervention; unexposed *Exact time: 15 minutes*	3) **Kayes3150:** 28; obstructed labour; 14/06/06; surgical intervention; exposed *Exact time: 3 hours*	7

Kayes2452: 16; other direct cause; 03/11/06; no surgical intervention; unexposed *Exact time: 15 minutes*	**1) Kayes2457:** 16; other direct cause; 05/11/06; no surgical intervention; unexposed *Exact time: 15 minutes*	**2) Kayes2406:** 18; other direct cause; 26/10/06; no surgical intervention; unexposed *Exact time: 15 minutes*	**3) Kayes2485:** 15; other direct cause; 13/11/06; no surgical intervention; unexposed *Exact time: 15 minutes*	10
Kayes2446: 18; indirect cause; 23/10/06; no surgical intervention unexposed *Exact time: 15 minutes*	**1) Kayes2436:** 18; indirect cause; 08/10/06; no surgical intervention; unexposed *Exact time: 15 minutes*	**2) Kayes2440:** 17; indirect cause; 13/10/06; no surgical intervention; exposed *Exact time: 2 hours*	**3) Kayes2544:** 15; indirect cause; 11/11/06; no surgical intervention; unexposed *Exact time: 1 hour 40 minutes*	19

ANNEX 2- ABSTRACT FOR CSEB

The abstract below was accepted for an oral presentation at Canadian Society for Epidemiology and Biostatistics (CSEB) 2007 Student Conference, on May 28th, 2007 in Calgary, Alberta. The presentation won second prize.

Emergency Obstetrical Complications in Kayes, Mali : the link between spatial accessibility and death

Authors: **Catherine Pirkle**, Pierre Fournier, Caroline Tourigny, and Slim Haddad

Affiliation: Unité de Santé Internationale, Centre de Recherche du CHUM/Université de Montréal

Background : Study is part of a larger implementation-evaluation project aimed at reducing the high levels of maternal mortality (estimated at 1200 deaths/ 100 000 live births) in the Kayes region of Mali. This project has developed a reference-evacuation system that allows women with emergency obstetrical complications to be transported from community health centres to the hospital. Evacuation for and treatment of emergency obstetrical complications is free in the Kayes region. The clinical details of all women treated at the hospital for obstetrical complications are recorded for project evaluation.

Purpose : Improve our understanding of the influence of spatial accessibility on the health outcomes of women experiencing emergency obstetrical complications. Spatial accessibility is measured by time and represents the efforts of women to overcome barriers of a geographic and seasonal nature. Study also evaluates time as novel measure of spatial accessibility.

Study Design : Retrospective and transversal study designs.

Methods : Field interviews coupled with a retrospective database. Statistical analyses done with logistic regression.

Results : Time is shown to be an improved measure of spatial accessibility when compared to other measures (e.g. Euclidean distance). Reduced temporal access to the hospital is associated with maternal mortality and stillbirths; distance measured in kilometres is not.

Conclusions : Improvements in health infrastructures that facilitate spatial access- by reducing the *time* it takes to reach a health centre- are likely to reduce the number of maternal deaths and stillbirths in West Africa.

CATHERINE PIRKLE

Curriculum vitae

Last revised: February 18, 2008

A. EDUCATION

Undergraduate

BACHELOR OF SCIENCE (*ECOLOGICAL DETERMINANTS IN THE HEALTH OF SOCIETY-CELLULAR STREAM*) FROM MCGILL UNIVERSITY, MONTREAL (2004)

- Grade point average of 3.7 out of a possible 4.0.
- Completed a four-year undergraduate program in three and half years due to advanced placement credits from the United States

Certificate

French Language Proficiency from McGill University, Montreal (2005)

Graduate

Presently a student in The University of Montreal's Master's of Community Health Program.
Thesis title: *Emergency obstetrical complications in Kayes, Mali: The link between spatial access and mortality*
Thesis directors: Dr. Pierre Fournier and Dr. Slim Haddad (co-director).

B. WORK EXPERIENCE

(Feb. 2007 to present) Research assistant to Dr. Vinh-Kim Nguyen M.D., PhD (Université de Montréal). Assist in the coordination of the multi-country ATARAO project which studies antiretroviral adherence in the resource-poor countries of Burkina Faso and Mali. Duties include organizing and heading weekly project meetings and writing weekly minutes; assuring communication between the African and Montreal teams; tracking team member publications and conference presentations; facilitating the dissemination of research results by keeping team members aware of important conference dates, publication opportunities, and translating abstracts from French to English; searching out supplementary grants and assisting in the grant application process; ethics requests preparation; maintaining and updating collaborators CVs; editing; and general administration. Other work includes a systematic review of the clinical trials for the drug Nevirapine and the history of the randomised controlled trial.

(Aug.-Oct. 2007) Consultant for IDRC. Responsible for coordinating the organisation of the CII2 knowledge translation workshop. This workshop brought together researchers from across Canada, as well as Canadian funders and researcher-users from UNICEF, WHO, and PAHO and addressed the methods and results of IDRC-funded research projects on immunisation in developing countries.

C. AWARDS AND DISTINCTIONS

- Poster presentation prize ($500)- 10^{e} congrès du Centre de recherche du CHUM

- Second Prize winner ($250)- 2007 Canadian Society of Epidemiology and Biostatistics student conference
- Awarded the «bourse de maitrise» from CR-CHUM, University of Montreal, for the amount of $2000 CND.
- Awarded a «bourse d'excellence» from the «Faculté des études supérieures» at the University of Montreal, for the amount of $500 CND.
- Awarded the « bourse pour la favorisation de la diplomation » from the « département de médecine sociale et preventive» at the University of Montreal for the amount of $4285 CND.
- Awarded the « bourse d'exemption des frais de scolarité supplémentaire pour les étudiant(e)s international(e)s » for $9000 CND.
- Awarded Annual Brock scholarship of $3000 CND during undergraduate studies at McGill University from 2000-2003.
- Achieved Dean's List for academic excellence (2002 and 2003) at McGill University

D. PUBLICATIONS/CONFERENCES

Publications:

1) **Pirkle, Catherine**, Soundardjee, Riswana, Artuso, Stella (2007) *Female Sex Workers in China, vectors of disease?* **Sexually Transmitted Diseases** 34 (9): 695-703.
2) Nguyen, Vinh-Kim; Klot, Jennifer; Phillips, Alton; **Pirkle, Catherine** (2006) *Culture, HIV & AIDS: an annotated bibliography*, prepared by the Social Science Research Council for UNESCO: http://unesdoc.unesco.org/images/0014/001472/147244M.pdf.

Conferences:

1) Phillips, Alton & **Pirkle, Catherine.** *The Social History of Nevirapine: A Magic Bullet for Global Health*; oral presentation for : Anthropologie des cultures globalisées : Terrains complexes et enjeux disciplinaires, Quebec City, Canada, November 2007.
2) **Pirkle, Catherine**. Epidemiogical fallacies: Beyond methodological individualism. Oral presentation for the expert group meeting, "Fourth Wave" Website for The SSRC-UNSECO Volume on "The Fourth Wave: An assault on women - Gender, Culture and HIV/AIDS in the 21st Century," Paris, France, October 2007.
3) Phillips, Alton & **Pirkle, Catherine.** *From everyday cultures to cultures of response: Developing the sociology of the global HIV/AIDS pandemic*; roundtable presentation for: The Annual American Sociological Association Conference, New York, USA, August 2007.
4) **Pirkle, Catherine.** *Emergency obstetrical complications in Kayes, Mali: The link between spatial access and death*; oral presentation for: Canadian Society of Epidemiology and Biostatistics student conference, Calgary, Canada, May 2007.
5) Soundardjee Riswana, Artuso Stella, **Pirkle Catherine.** *Significance of structural factors in the spread of HIV in the context of a strong state;* oral presentation for: Colloque étudiant sur la rencontre de l'anthropologie et de la santé, Montréal, Canada, March 2007.
6) Phillips, Alton & **Pirkle, Catherine.** *The Culture of Response to the Global HIV and AIDS Pandemic;* oral presentation for: 77th Annual Meeting of the Eastern Sociological Society, Phillidephia, USA, March 2007.
7) **Pirkle, Catherine.** *Spatial Accessibility and Maternal Health Outcomes*; oral presentation for: Women's Health in West Africa: Issues and Challenges at Concordia University. Montréal, Canada, March 2007.
8) Artuso, Stella ; **Pirkle, Catherine** ; Soundardjee, Riswana. Female Sex Workers: *A Growing Concern for the Proliferation of HIV/AIDS*; poster presentation for: CHUM Research Centre's 9th Annual Congress of students, Montréal, Canada, December, 2006.
9) Artuso, Stella ; **Pirkle, Catherine** ; Soundardjee, Riswana. Female Sex Workers: *A Growing Concern for the Proliferation of HIV/AIDS*; poster presentation for: Premier

Colloque en Santé Publique à L'Université de Montréal, Montréal, Canada, January, 2006.

10) Artuso, Stella ; Pirkle, Catherine ; Soundardjee, Riswana. *Female Sex Workers: A Growing Concern for the Proliferation of HIV/AIDS*; poster presentation for: 2e Colloque du Réseau de recherche en santé mondiale du Québec à la Direction de santé publique de Montréal, Montréal, Canada, May, 2006.