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ORIGINAL ARTICLE

Surgical patients travel longer distances than non-surgical patients to receive care at a rural hospital in Mozambique

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Background: Surgical care is increasingly recognised as an important component of global health delivery. However, there are still major gaps in knowledge related to access to surgical care in low-income countries. In this study, we compare distances travelled by surgical patients with patients seeking other medical services at a first-level hospital in rural Mozambique.

Methods: Data were collected on all inpatients at Hospital Rural de Chókwè in rural Mozambique between 20 June 2012 and 3 August 2012. Euclidean distances travelled by surgical versus non-surgical patients using coordinates of each patient's city of residence were compared. Data were analysed using ArcGIS 10 and STATA.

Results: In total, 500 patients were included. Almost one-half (47.6%) lived in the city where the hospital is based. By hospital ward, the majority (62.0%) of maternity patients came from within the hospital's city compared with only 35.2% of surgical patients. The average distance travelled was longest for surgical patients (42 km) compared with an average of 17 km for patients on all other wards.

Conclusions: Patients seeking surgical care at this first-level hospital travel farther than patients seeking other services. While other patients may have access to at community clinics, surgical patients depend more heavily on the services available at first-level hospitals.

Keywords: Access to surgical care, Global surgery, Mozambique, Sub-Saharan Africa

Introduction

Surgical care is increasingly recognised as an important component to improve global health.[1] Initiatives to integrate surgery into global health policy agendas include the WHO's Emergency and Essential Surgical Care, the Copenhagen Consensus and the Lancet Commission on Global Surgery.[1–3] Surgical care has also been recognised as essential to achieving the Millennium Development Goals through the reduction of maternal and child mortality and treating the rising burden of trauma.[4,5] A recent study also demonstrated the important role that surgical services play in treating the rising burden of non-communicable diseases.[6] In low- and middle-income countries (LMIC), scaling-up surgical services may avert more than 116 million disability-adjusted life-years per year, or 5.2% of the total burden of disease in those countries.[7]

However, surgical care is not equally available across populations. It is estimated that the wealthiest 30% of the world's population receives 74% of the global surgical volume, while the poorest 35% receives <4%.[8] WHO estimates that approximately two billion people lack access to emergency and essential surgical care in resource-poor settings.[9] Within high-income countries (HIC), there are known disparities in the availability of surgical care between urban and rural settings.[10] This is undoubtedly exacerbated in low-income countries (LIC), where surgery is frequently considered specialty care and is disproportionately concentrated in urban centres.[11] Despite the growing integration of surgical services into healthcare packages, there are still major gaps in knowledge related to access to surgical care in LICs.

The concept of access to healthcare can be defined in several different ways. Many researchers equate access with the availability of physical facilities and trained medical care providers. Others

focus on characteristics of the population, such as demographics, culture, education, income and insurance coverage, travel time to healthcare facilities, perceived health and severity of symptoms, and other factors that influence care-seeking behaviours.[12] Together, characteristics of the delivery system and individuals reflect the potential access to medical care. Actual utilisation and satisfaction can be used to measure realised access to services.[12]

Access to healthcare remains an important problem in Mozambique, one of the poorest countries in the world.[13] A 1996/97 survey examining distance to healthcare facilities reported that over one-half of the population lived >30 km away from a physician and, of those who sought care, only 41.0% of respondents lived within 1 h of a hospital.[14] Yet research characterising access to surgical care is lacking. This study compares distances travelled by patients utilising surgical care versus patients seeking other types of medical care at a first-level hospital in rural Mozambique.

Materials and methods

Data for this study were collected from the Hospital Rural de Chókwè (HRC) in the district of Chókwè in Mozambique.

Mozambique is a country of approximately 25 million people located in southeastern Africa.[15] The average life expectancy in 2012 was 49.9 years and over one-half (52%) of its population is <18 years old.[15] The 2010 adjusted maternal mortality ratio was 490 deaths per 100 000 live births, slightly lower than the average for sub-Saharan Africa (500 deaths/100 000 live births), but much higher than the worldwide average of 210 deaths/100 000 live births.[15] A little over one-half of women have institutional deliveries (55%) and the Caesarean section rate is <4%.[15] HIV is a significant public health problem, with an estimated prevalence at 11.1% in 2012.[15]

In 2012, Mozambique ranked 185 out of 186 countries on the Human Development Index, a measurement that considers health, education and income.[16] Despite economic growth in recent years, 60% of the population still lives below the international poverty line of US $1.25 per day.[15] The majority of the population (67%) lives in rural areas.[15] Less than one-half of the population (47%) have access to an improved water source, and only 19% have access to an improved sanitation facility.[15]

Access to healthcare is limited by a lack of qualified health workers, with only 1268 physicians in the National Health System of Mozambique in 2011.[17] Including both physicians and nurses, there were 64.5 healthcare workers per 100 000 population in 2011, far below the minimum acceptable health worker density threshold of 230/100 000.[17]

Chókwè district is a predominantly rural, agricultural area. The city of Chókwè, which is the administrative capital of Chókwè District, is located 90 km west of the Gaza Province capital city of Xai-Xai and 230 km northwest of Maputo, Mozambique's capital. HRC serves a catchment area of approximately 200 000 people, of whom approximately 53 000 live in the city of Chókwè. The hospital is divided into four wards: medicine (26 beds); paediatrics (26 beds); maternity (38 beds); and surgery (28 beds). HRC also provides services in emergency care, radiology, physical therapy, dentistry, ophthalmology, orthopaedics and psychiatry. Resources include a laboratory, X-ray machine and pharmacy. Patients requiring a higher level of care are transferred to tertiary hospitals in the provincial capital of Xai-Xai or in the country capital of Maputo.

HRC employs two non-physician surgeons, 'técnicos de cirurgia' (technicians of surgery), who are the only clinicians providing surgery at HRC. Técnicos de cirurgia are mid-level providers who have completed 3 additional years of surgical training and serve as the primary surgical workforce in rural Mozambique.[18]

Data were collected from all inpatients at HRC during the 6-week period between 20 June and 3 August 2012. Data included date of admission and discharge, age, sex, city of residence, hospital ward (medicine, paediatrics, maternity or surgery) and diagnosis. Patients who were admitted to the maternity ward but underwent surgery (Caesarean section, hysterectomy, etc.) were included as surgical patients.

Global positioning system coordinates of cities of residence were found to calculate the Euclidean distance from each patient's city or village to HRC. The Euclidean distance is measured according to the straight line between two points. This was used to maintain consistency since road maps were not always accurate and patients may take paths off marked roads.

Using population data from the August 2007 Mozambique census (the most recent population data available), the proportion of patients from each city was calculated to estimate the percent of the population that was admitted to the hospital. These proportions were compared between wards. Six patients came from cities in which the population was not known; these patients were grouped with nearby cities and included in the analysis. Age, sex, distance travelled and length of stay (LOS) by ward, and between surgical versus non-surgical patients, were compared. Proportions were compared using χ^2 tests while continuous variables were compared using t tests. A p-value of <0.05 was defined as statistically significant.

Data were analysed using ArcGIS 10 (Esri, Redlands, CA, USA) and STATA 64-bit Special Edition v.11.2 (StataCorp LP, College Station, TX, USA). Institutional Review Boards at University of California, San Diego and the National Bioethics Committee of Mozambique approved this project.

Results

A total of 500 patients were admitted to HRC over the course of 6 weeks (Table 1). Figure 1 shows the city of residence of all those admitted. Almost one-half (47.6%; 238/500) of the patients were from the city of Chókwè. Patients who came from outside of Chókwè travelled an average of 48 km. The furthest distance travelled was 288 km by two patients (one surgical and one medicine patient), from the city of Tomaine.

The surgery ward admitted the second largest volume of patients (n=145), including 44 maternity patients who underwent surgery. Patients stayed an average of 9.4 days, the longest of all wards. Only 35.2% (51/145) of surgical patients came from the city of Chókwè, fewer than any other ward. Of the patients admitted to the surgery ward, 81.4% (118/145) received an operation (Table 2). Of those who received an operation, 74.6% (88/118) were performed urgently. Trauma accounted for approximately one-third (35.2%; 51/145) of all surgical patients. The most common traumatic injuries included fractures (n=20), burns (n=11) and wounds (n=9). The most

Table 1. Characteristics of the patient population

	Total (n=500)	Surgery (n=145)[a]	Comparison of surgical patients with others by ward				Comparison of surgical patients with all patients combined	
			Medicine (n=114)	Maternity (n=171)	Paediatrics (n=70)	p-value[b]	All non-surgical patients (n=355)	p-value[c]
No. (%) female	341 (68.2)	83 (57.2)	59 (51.8)	171 (100.0)	28 (40.0)	<0.001	258 (72.7)	0.001
Age (years) [mean (SD)]	27.6 (18.0)	33.5 (20.0)	39.2 (16.3)	24.9 (7.1)	2.7 (2.6)	<0.001	25.1 (16.6)	<0.001
Length of stay (days) [mean (SD)]	6.8 (6.6)	9.4 (9.0)	7.6 (5.2)	3.7 (3.1)	7.9 (5.9)	<0.001	5.8 (4.9)	<0.001
No. (%) of patients living in Chókwè	238 (47.6)	51 (35.2)	52 (45.6)	106 (62.0)	29 (41.4)	<0.001	187 (52.7)	<0.001
Distance travelled (km) [mean (SD)]								
All patients	24 (47)	42 (61)	17 (36)	15 (39)	20 (37)	<0.001	17 (38)	<0.001
Patients outside of Chókwè	48 (57)	65 (65)	33 (45)	42 (56)	36 (44)	0.005	37 (49)	<0.001

[a] Surgery patients include all patients admitted to the surgery department, as well as patients in the maternity department who had an operation.
[b] Pearson's χ^2 for proportions and Bartlett's test for equal variance for means.
[c] Pearson's χ^2 for proportions and *t* test for means.

common non-traumatic surgical diseases were hernias and non-traumatic skin pathology (n=14 each).

The maternity ward admitted the largest volume of patients (n=171), with an average LOS of 3.7 days, the shortest of all wards. More than one-half (62.0%; 106/171) of these patients came from the city of Chókwè. Most patients were admitted for childbirth. Only 44 maternity patients (20.5%; 44/215) underwent a surgical procedure (note that these 44 patients are included in Table 2 as surgical patients). Other medical care included treatment for eclampsia, anaemia and abortions.

The medicine ward admitted 114 patients with an average LOS of 7.6 days. More than 34.2% (39/114) of patients were documented as being HIV-positive. The major presenting illnesses were cardiac insufficiency, bronchopneumonia and/or TB and hypertension.

The fewest number of patients were admitted to the paediatric ward (n=70). Similar to the medicine ward, less than one-half (41.4%; 29/70) of patients were from the city of Chókwè. The major presenting illnesses were malnutrition (34.3%; 24/70) and malaria (27.1%; 19/70). Also common were bronchopneumonia and gastroenteritis.

Overall, almost half (47.6%; 238/500) of all patients live in the city of Chókwè (Figures 1 and 2). When including patients who came from the next three closest cities (Guijá, Lionde and Muzumuia), all <9 km from HRC, the percentage increased to >60% (304/500). The remaining 40% of patients came from over 48 other locations, with 6 patients (1.2%; 6/500) traveling >200 km. The 20 farthest cities (ranging from 39 km to 288 km away) sent five or fewer patients, with an average contribution of just two patients per city.

When comparing patients in the surgery ward versus all other wards, surgical patients were less likely to live in Chókwè (35.2% vs 52.7%), travelled an average of 25 km farther and had a longer mean LOS (9.4 days vs 5.8 days) (Table 1).

While maternity patients made up the highest proportion of patients who lived within the city of Chókwè, surgical patients made up the highest proportion of patients who travelled >100 km (Figure 2).

When evaluating the population representation of each city by hospital ward, linear regression found no difference in distance travelled by the proportion of patients admitted per city population by ward (results not shown). However, while not statistically significant, it appears that while the proportion of patients per population decreases with increasing distance travelled for medicine, paediatric and maternity patients, the proportion of patients per population is more evenly distributed by distance for surgical patients (Figure 3).

Discussion

This study demonstrates that surgical patients travelled farther to utilise care at a first-level hospital compared with patients on other wards. On average, surgical patients travelled more than twice the distance, or 25 km farther, to seek care than their non-surgical counterparts. These results reinforce previous reports that surgical patients travel long distances to receive care: 25 km in Bangladesh; 30 km in Uganda, Liberia and Rwanda; 56 km in Haiti; 85 km in Bolivia; and 144 km in Ethiopia.[19–25] A previous

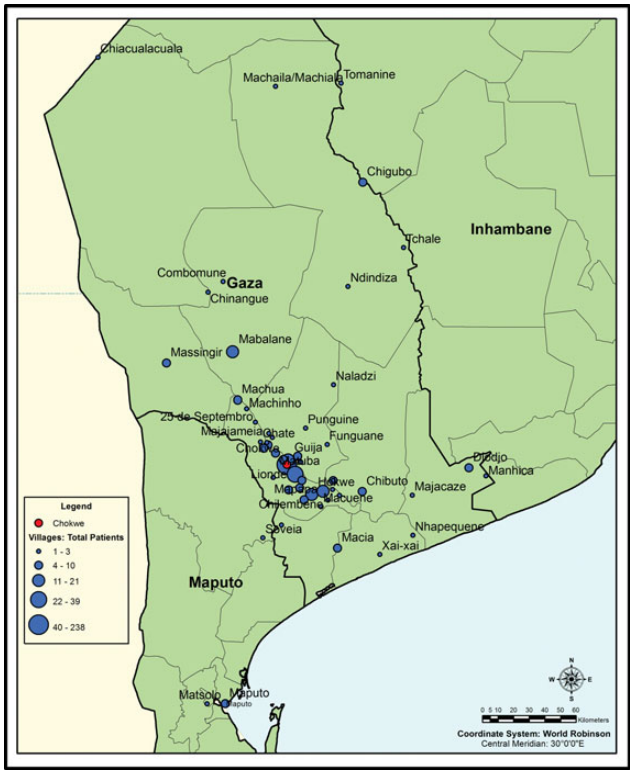

Figure 1. Map of residence of patients admitted to Hospital Rural de Chókwè, Mozambique. This figure is available in black and white in print and in colour at International Health online.

Table 2. Diagnoses of surgical patients

	Total	Required surgery	Urgent surgery
Non-trauma			
Abscess, cellulitis, other non-traumatic skin pathology	14	14	11
Hernia	14	14	3
Appendicitis	4	4	4
Other musculoskeletal	4	2	2
Urinary retention or haematuria	4	0	0
Hydrocoele	3	3	0
Intestinal obstruction	3	3	3
Anorectal pathology	2	2	0
Peritonitis, other	2	2	2
Obstetrics/gynaecology			
Caesarean section	37	37	28
Ectopic pregnancy	3	3	3
Obstetrics/gynaecology other	4	4	2
Trauma			
Fracture, lower extremity	13	4	4
Burn	11	11	11
Wound	9	8	8
Fracture, other	7	1	1
Head trauma	4	0	0
Trauma, other	4	3	3
Snake bite	3	3	3
Total	145	118	88

study in Mozambique also found that surgical conditions were the most common reason for admission at three first-level hospitals (including HRC).[26] Together, these findings highlight the central role of first-level hospitals in providing surgical care in rural areas of LICs.

Effect of distance on access to surgical care

The effect of travel distance on access to surgical care, specifically, is not well studied. In a review of barriers to surgical care in LICs conducted in 2011, Grimes et al. found a total of 52 articles discussing access to surgical care, 51 of which used qualitative methods.[27] The three primary categories were cultural (acceptability), financial (affordability) and structural (accessibility). The most common barrier to care discussed was direct cost (42 studies), followed by distance to nearest treatment facility (27 studies).[27] By type of treatment, the highest number of papers discussed access to ophthalmologic care (28 studies) and obstetric-gynaecological care (16 studies), with only a few papers dedicated to trauma or other types of general surgery.[27] Where available, the literature shows an inverse relationship between distance and access. For example, Gabrysch et al. reported lower usage rates of health facilities for obstetric care for women living farther away in multiple LICs.[28] Similarly, in Rwanda, the lowest Caesarean section rates were found in remote areas, which correlated with the highest peripartum mortality rates, suggesting that increased distance to surgical care is associated with worse outcomes.[29]

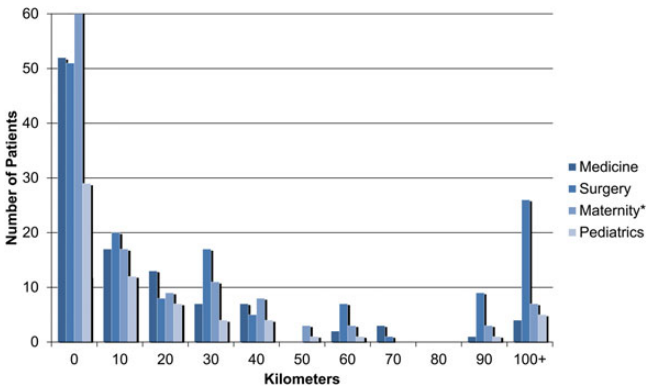

Figure 2. Distance travelled by patients by department (distances calculated by Euclidean km). *There were 106 maternity patients who lived in Chókwè and thus travelled 0 km. This figure is available in black and white in print and in colour at International Health online.

Physical access to health care in LICs has been better studied in other medical disciplines. Studies on malaria treatment and childhood vaccination in LICs found that patients living closer to health facilities were more likely to utilise these services.[30–32] In

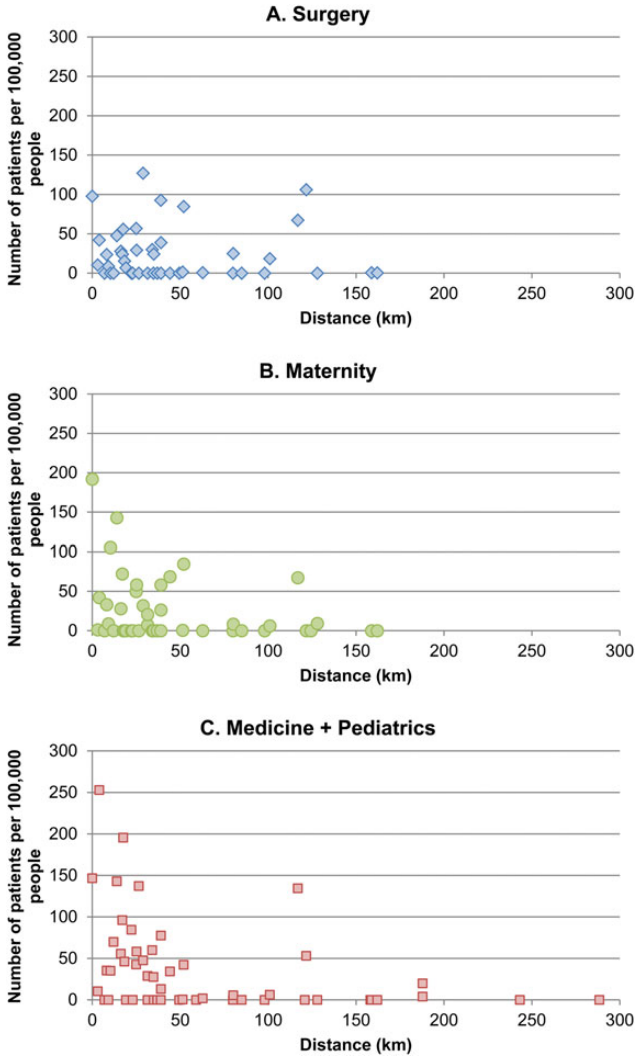

Figure 3. Relationship between distance and number of patients admitted per population of each city, comparing patients by ward. This figure is available in black and white in print and in colour at International Health online.

Mozambique, distance to clinics has also been found to be correlated with utilisation of HIV testing.[33] Several studies report increased paediatric mortality with decreased physical access to a health centre in sub-Saharan Africa, except in the case of Kenya where there is a higher density of health posts.[34–38]

This study suggests that the relationship between distance and healthcare utilisation differs by the type of healthcare sought at this first-level hospital. Furthermore, this study suggests an inverse relationship between travel distance and hospital admission for patients admitted to non-surgical wards but not to the surgical ward (Figure 3). Theoretically, if distance were not a barrier to accessing first-level hospital care, then the number of patients per population from each location should be similar. This is especially relevant in Mozambique. Since there are very few alternative hospitals, obtaining care at a higher-level hospital requires a referral and there are very few private hospitals, especially in rural areas. Understanding the relationship of hospital admission to distance travelled for healthcare can more accurately identify variations in healthcare utilisation due to differences in distance than simply calculating average distance travelled by surgical patients.

Implications for policy-making

Recognising distances patients travel to receive care can inform new strategies for efficient referral systems and emergency transportation for surgical diseases. While many community clinics in Mozambique offer basic medical and maternal health care, these providers must also be trained to recognise surgical conditions in order to decrease referral time. In this study, 74.6% of patients admitted to the surgical ward required urgent surgical intervention. In emergency situations, these providers can also provide important acute care to stabilise patients prior to transfer. Identifying strategies to improve community health worker training and the availability and efficiency of emergency transportation can help reduce mortality and morbidity.

Limitations

This research is not without limitations. As a hospital-based study, we are unable to evaluate the fate of patients who do not arrive at the hospital. We also do not have estimates of the burden of surgical diseases in the community, including surgically related mortality or the number of individuals who live with untreated surgical conditions. As such, hospital data do not conclusively resolve the question of access.

We also assume that Euclidean (or straight-line) distances are the best estimate of actual travel time to the clinic, since actual travel times were unavailable. Previous studies have argued that the Euclidean distance is an acceptable proxy for actual distance as it correlates to travel time.[39–41] Information on the exact location of patients' residences within each city was not available, but cities were generally small enough that these did not significantly impact the results.

There are also likely seasonal differences in both disease epidemiology and travel conditions, which are not represented during this 6-week data collection period conducted during the dry winter season. This time period was chosen because it typically has the highest hospital admissions and likely represents the greatest variability in travel distance during the year since patients can more easily travel during the dry season. However, the incidence of burns may be over-represented in this study, since it was conducted in the winter. In contrast, during the rainy season malaria becomes more prevalent and many roads may become impassable, altering both the burden of disease and the proportion of patients presenting to the hospital.

Population admission rates were also calculated using data from the 2007 census, whereas the study data are from 2012. Unfortunately this was the most recent population data available. Mozambique has experienced a 2.5–2.7% population growth over this time period and the population-based admission rates thus likely overestimate true rates.[42]

Limiting this discussion to physical distance to the hospital also excludes consideration of overlapping coverage by other healthcare facilities and variable availability of physical, technical and human resources. Deficits in surgical expertise at HRC may also preclude timely treatment of patients with more complex

surgical diseases or patients who present late in their disease course. Treatment options may also vary throughout the year, since staff or medication availability can fluctuate. Thus, proximity to a first-level hospital does not always translate into access to adequate surgical care required for a particular patient at a particular time.

Furthermore, we assume that patients with equal physical access will utilise health services equally. The finding that only 51 patients from Chókwè, a city with a population of around 53 000, received inpatient surgical services during a 6-week period suggests that other variables influenced healthcare seeking. While we do not know the exact burden of surgical disease in this region, this is likely an under-representation of the surgical need of this city. Although physical proximity has long been recognised as an essential component of healthcare utilisation, it is not the sole factor.[43] Thus, there are undoubtedly non-spatial barriers impacting the utilisation of surgical care, such as socio-economic or cultural factors.[26]

Conclusions

This research suggests that patients utilising surgical care at a first-level hospital travel much farther than patients seeking other services. While other patients may have access to health care at community clinics, surgical patients depend more heavily on the expertise and services available at first-level hospitals. Much of the current literature on access to surgical care in LMICs focuses on the physical capacity of first-level hospitals to provide surgical care. However, more attention should be paid to the ability of hospitals to meet the surgical needs of their communities.[44] Mapping access to health services by department can help identify geographic discrepancies, particularly by the type of care needed. This information can help inform new strategies to improve access to surgical care and resource allocation at first-level hospitals in LICs.

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Authors' contributions: MLF acquired the data and drafted the manuscript; JEA performed the statistical analysis and helped draft and revise the manuscript; JAR and PB assisted with study design and made critical revisions to the manuscript; AA, FV and CF helped acquire the data; EVN and SWB conceived the study, participated in its design and co-ordination, and made critical revisions to the manuscript. All authors read and approved the final manuscript. SWB and JEA are guarantors of the paper.

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References

1 Third Copenhagen Consensus Outcome Document. Copenhagen Consensus Center; 2012. http://www.copenhagenconsensus.com/sites/default/files/Outcome_Document_Updated_1105.pdf [accessed 19 June 2014].

2 Meara J, Hagander L, Leather AJM. Surgery and global health: a Lancet Commission. Lancet 2013;383:12–3.

3 WHO Global Initiative for Emergency and Essential Surgical Care. World Health Organization. http://www.who.int/surgery/globalinitiative/en/ [accessed 19 June 2014].

4 Kushner AL, Cherian MN, Noel L et al. Addressing the Millennium Development Goals from a surgical perspective: essential surgery and anesthesia in 8 low- and middle-income countries. Arch Surg 2010;145:154–60.

5 Mock C, Joshipura M, Arreola-Risa C et al. An estimate of the number of lives that could be saved through improvements in trauma care globally. World J Surg 2012;36:959–63.

6 Rose J, Chang DC, Weiser TG et al. The role of surgery in global health: analysis of United States inpatient procedure frequency by condition using the global burden of disease 2010 framework. PLoS One 2014;9:e89693.

7 Bickler SW, Weiser TG, Kassebaum N et al. Global burden of surgical conditions. In: Debas H, Mock C, Kruk M, Gwande A, editors. Disease Control Priorities for Developing Countries, Vol. 9. 3rd ed. World Bank; 2014 [Forthcoming].

8 Weiser TG, Regenbogen SE, Thompson KD et al. An estimation of the global volume of surgery: a modeling strategy based on available data. Lancet 2008;372:139–44.

9 WHO. Surgery: the Neglected Component of Primary Care. World Health Organization. http://www.who.int/surgery/esc_component/en/index.html [accessed 19 June 2014].

10 Finlayson SR. Assessing and improving the quality of surgical care in rural America. Surg Clin North Am 2009;89:1373–81.

11 Farmer PE, Kim JY. Surgery and global health: a view from beyond the OR. World J Surg 2008;32:533–6.

12 Andersen RM, McCutcheon A, Aday LA et al. Exploring dimensions of access to medical care. Health Serv Res 1983;18:49–72.

13 The World Bank. World DataBank: Mozambique. http://databank.worldbank.org/ [accessed 19 June 2014].

14 Lindelow M. Health Care Demand in Rural Mozambique: Evidence from the 1996/97 Household Survey. http://www.ifpri.org/publication/health-care-demand-rural-mozambique-0 [accessed 19 June 2014].

15 UNICEF. Mozambique: Statistics. http://www.unicef.org/infobycountry/mozambique_statistics.html [accessed 19 June 2014].

16 UNDP. Human Development Report 2013. The Rise of the South: Human Progress in a Diverse World. New York, NY: United Nations Development Programme; 2013. http://hdr.undp.org/sites/default/files/reports/14/hdr2013_en_complete.pdf [accessed 19 June 2014].

17 WHO Regional Office for Africa. Mozambique: Health Workforce. http://www.afro.who.int/en/mozambique/country-programmes/health-systems/human-resources-for-health.html [accessed 19 June 2014].

18 Kruk ME, Pereira C, Vaz F et al. Economic evaluation of surgically trained assistant medical officers in performing major obstetric surgery in Mozambique. BJOG 2007;114:1253–60.

19 LeBrun DG, Saavedra-Pozo I, Agreda-Flores F et al. Surgical and anesthesia capacity in Bolivian public hospitals: results from a national hospital survey. World J Surg 2012;36:2559–66.

20 LeBrun DG, Dhar D, Sarkar MIH et al. Measuring global surgical disparities: a survey of surgical and anesthesia infrastructure in Bangladesh. World J Surg 2013;37:24–31.

21 Linden AF, Sekidde FS, Galukande M et al. Challenges of surgery in developing countries: a survey of surgical and anesthesia capacity in Uganda's public hospitals. World J Surg 2012;36:1056–65.

22 Notrica MR, Evans FM, Knowlton LM et al. Rwandan surgical and anesthesia infrastructure: a survey of district hospitals. World J Surg 2011;5:1770–80.

23 Chao TE, Burdic M, Ganjawalla K et al. Survey of surgery and anesthesia infrastructure in Ethiopia. World J Surg 2012;36:2545–53.

24 Knowlton LM, Chackungal S, Dahn B et al. Liberian surgical and anesthesia infrastructure: a survey of county hospitals. World J Surg 2013;37:721–9.

25 Friedman JM, Hagander L, Hughes CD et al. Distance to hospital and utilization of surgical services in Haiti: do children, delivery mothers, and patients with emergent surgical conditions experience greater geographical barriers to surgical care? Int J Health Plann Manage 2013;28:248–56.

26 Anderson JE, Erickson A, Funzamo C et al. Surgical conditions account for the majority of admissions to three primary referral hospitals in rural Mozambique. World J Surg 2014;38:823–9.

27 Grimes C, Bowman KG, Dodgion CM et al. Systematic review of barriers to surgical care in low-income and middle-income countries. World J Surg 2011;35:941–50.

28 Gabrysch S, Campbell OMR. Still too far to walk: literature review of the determinants of delivery service use. BMC Pregnancy Childbirth 2009;9:34.

29 Sudhof L, Amorosco C, Barebwanuwe P et al. Local use of geographic information systems to improve data utilisation and health services: mapping Caesarean section coverage in rural Rwanda. Trop Med Int Health 2013;18:18–26.

30 Okwaraji YB, Mulholland K, Atrmstrong Schellenberg JRM et al. The association between travel time and health facilities and childhood vaccination coverage in rural Ethiopia: a community-based cross-sectional study. BMC Public Health 2012;12:476.

31 Noor AM, Zurovac D, Hay SI et al. Defining equity in physical access to clinical services using geographical information systems as part of malaria planning and monitoring in Kenya. Trop Med Int Health 2003;8:917–26.

32 Alegana VA, Wright JA, Pentrina U et al. Spatial modeling of healthcare utilization of fever in Namibia. Int J Health Geogr 2012;11:6.

33 Yao J, Murray AT, Agadjanian V et al. Geographic influences on sexual and reproductive health service utilization in rural Mozambique. Appl Geogr 2012;32:601–7.

34 Armstrong Schellenberg JR, Mrisho M, Manzi F et al. Health and survival of young children in southern Tanzania. BMC Public Health 2008;8:194.

35 Rutherford ME, Dockerty JD, Jasseh M et al. Access to healthcare and mortality of children under 5 years of age in the Gambia: a case–control study. Bull World Health Organ 2009;87:216–24.

36 Broeck Van den J, Eeckels R, Massa G. Maternal determinants of child survival in a rural African community. Int J Epidemiol 1996;25:998–1004.

37 Becher H, Muller O, Jahn A et al. Risk factors of infant and child mortality in rural Burkina Faso. Bull World Health Organ 2004;82:265–73.

38 Moisi JC, Gatakaa H, Noor AM et al. Geographic access to care is not a determinant of child mortality in a rural Kenyan setting with high health facility density. BMC Public Health 2010;10:142.

39 Cudnik M, Yao J, Zive D et al. Surrogate markers of transport distance for out-of-hospital cardiac arrest patients. Prehosp Emerg Care 2012;16:266–72.

40 McLafferty SL. GIS and health care. Annu Rev Public Health 2003;24:25–42.

41 Haynes R, Jones AP, Sauerzapf V et al. Validation of travel times to hospital estimated by GIS. Int J Health Geogr 2006;5:40.

42 The World Bank. Data, Mozambique, Population Growth (% Annual). http://data.worldbank.org/indicator/SP.POP.GROW/countries/MZ?display=graph [accessed 19 June 2014].

43 Higgs G. The role of GIS for health utilization studies: literature review. Health Serv Outcomes Res Method 2009;9:84–99.

44 Grimes CE, Law RSL, Borgstein ES et al. Systematic review of met and unmet need of surgical disease in rural sub-Saharan Africa. World J Surg 2012;36:8–23.