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Mapping Disparities in Access to Safe, Timely, and Essential Surgical Care in Zambia

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Abstract

IMPORTANCE—Surgical care is widely unavailable in developing countries; advocates recommend that countries evaluate and report on access to surgical care to improve availability and aid health planners in decision making.

OBJECTIVE—To analyze the infrastructure, capacity, and availability of surgical care in Zambia to inform health policy priorities.

DESIGN, SETTING, AND PARTICIPANTS—In this observational study, all hospitals providing surgical care were identified in cooperation with the Zambian Ministry of Health. On-site data collection was conducted from February 1 through August 30, 2011, with an adapted World Health Organization Global Initiative for Emergency and Essential Surgical Care survey. Data collection at each facility included interviews with hospital personnel and assessment of material resources. Data were geocoded and analyzed in a data visualization platform from March 1 to December 1, 2015. We analyzed time and distance to surgical services, as well as the proportion of the population living within 2 hours from a facility providing surgical care.

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Disclaimer: The content is solely the responsibility of the authors. Drs Makasa, Lishimpi, and Mwaba are members of the Zambian government. These findings reflect the work of all authors and do not necessarily reflect the official position of the Zambian government.

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Author Contributions: Drs Esquivel and Weiser had full access to all the data and take responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Esquivel, Mwaba, Weiser.

Acquisition, analysis, or interpretation of data: Esquivel, Uribe-Leitz, Makasa, Lishimpi, Bowman, Weiser.

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Study supervision: Weiser.

MAIN OUTCOMES AND MEASURES—Surgical capacity, supplies, human resources, and infrastructure at each surgical facility, as well as the population living within 2 hours from a hospital providing surgical care.

RESULTS—Data were collected from all 103 surgical facilities identified as providing surgical care. When including all surgical facilities (regardless of human resources and supplies), 14.9% of the population (2 166 460 of 14 500 000 people) lived more than 2 hours from surgical care. However, only 17 hospitals (16.5%) met the World Health Organization minimum standards of surgical safety; when limiting the analysis to these hospitals, 65.9% of the population (9 552 780 people) lived in an area that was more than 2 hours from a surgical facility. Geographic analysis of emergency and essential surgical care, defined as access to trauma care, obstetric care, and care of common abdominal emergencies, found that 80.7% of the population (11 704 700 people) lived in an area that was more than 2 hours from these surgical facilities.

CONCLUSIONS AND RELEVANCE—A large proportion of the population in Zambia does not have access to safe and timely surgical care; this percentage would change substantially if all surgical hospitals were adequately resourced. Geospatial visualization tools assist in the evaluation of surgical infrastructure in Zambia and can identify key areas for improvement.

Access to safe and timely surgical care has increasingly been included in the global health agenda. Five billion people worldwide lack access to safe and affordable surgical and anesthesia care,¹ and it is estimated that conditions that are treated by surgery account for 18% of the global burden of disease.² In addition, 1.5 million deaths could be averted each year with access to essential surgical procedures such as trauma care, obstetric care, and care of common abdominal emergencies. The significance of emergency and essential surgical care was recognized by global health agencies at the 68th World Health Assembly in 2015, which passed a resolution to prioritize emergency and essential surgical and anesthetic care as a component of universal health coverage.³

Zambia is a sub-Saharan African country with a population of approximately 14.5 million people, most of whom live in rural areas.⁴ The life expectancy at birth is 58 years, reflecting the country's limitations in access to basic health care. Zambia had an estimated surgical rate of 1600 per 100000 people annually in 2012,⁵ well below the recommended surgical rate of 5000 operations per 100 000 people annually as advocated by the Lancet Commission on Global Surgery.⁶ The Zambian Ministry of Health has begun efforts to increase rates of surgery using a universal health coverage model as a means of improving access to surgery for emergency and essential conditions. The Zambian government demonstrated national leadership on the issue of access to essential surgical and anesthetic care through its sponsorship of the World Health Assembly resolution and has now committed to a 5-year surgical improvement plan.

The Lancet Commission on Global Surgery recently proposed 6 key indicators to measure the availability and afford-ability of surgical and anesthesia care for a population: access to timely essential surgery, workforce density of surgical specialists, volume of surgical procedures, perioperative mortality, protection against impoverishing expenditure, and protection against catastrophic expenditure.¹ Their key indicator on timely access to surgical care proposed a maximum 2-hour travel time to a surgical facility. Significant disparities

exist in access to, and outcomes of, surgical care, both across and within countries. There is a large disparity in the rates of surgery occurring in each country, with many countries far below recommended thresholds based on disease burden.^{5,6} In addition, there is also significant variability in surgical mortality rates across countries and regions,⁷ highlighting the importance of not only timely access to surgical care but timely access to safe surgical care. To understand and improve the availability of surgical care, surgical health advocates recommend that countries evaluate and report on surgical services.

We hypothesize that people in Zambia have highly variable access to safe surgical care. In particular, we hypothesize that a large proportion of the population lives more than 2 hours away from a safe surgical facility that is capable of providing essential surgery. The aim of this study is to use geographic information systems to evaluate surgical infrastructure and capacity in Zambia, analyze timely access to safe and essential surgical care, and provide guidance on improving allocation of surgical resources.

Key Points

Question

What proportion of Zambia's population has access to timely, safe, and essential surgical care?

Findings

This observational study of 103 surgical facilities in Zambia found that 14.9% of the population did not live within 2 hours from a surgical facility. However, when access to safe surgical facilities and access to facilities providing essential surgical care was assessed, 65.9% and 80.7%, respectively, did not live within 2 hours from such surgical facilities.

Meaning

Large disparities in access to safe, essential, and timely surgical care exist in Zambia; this study provides insight into improved allocation of resources.

Methods

All hospitals providing surgical care in 2010 were identified in cooperation with the Zambian Ministry of Health. On-site data collection was completed between February 1 and August 30, 2011, by one of us (K.B.). A validated and adapted World Health Organization (WHO) Global Initiative for Emergency and Essential Surgical Care survey⁸ was completed at each facility through on-site audit of facilities and through 495 interviews with hospital personnel. Data collected included information on location and type of hospital, availability of different types of surgical procedures, human resources (eg, type and number of surgical and hospital personnel), supplies (eg, intraoperative supplies, such as sterile gloves and availability of oxygen, laboratory facilities, and imaging procedures), and infrastructure (eg, availability of electricity and water). Details of this data collection have been described.⁹

This study was approved by the institutional review board at the Zambian Ministry of Health, as described by Bowman and colleagues.⁹ Verbal consent was obtained prior to all participant interviews.

Data analysis was conducted from March 1 to December 1, 2015. Data were geocoded using ArcGIS, version 10.3 (Esri), and analyzed in Redivis (Redivis Inc), an online data visualization platform, with additional statistical analysis completed in SAS statistical software, version 9.4 (SAS Institute Inc). We combined multiple geospatial layers of data for Zambia with our geocoded data from the surgical facilities; we used road infrastructure with road speed data from OpenStreetMap (OpenStreetMap Foundation)¹⁰ and the WorldPop database (GeoData Institute)¹¹ that maps the world's population density per square meter to complete our analyses.

We analyzed time and distance to all surgical facilities, as well as the proportion of the population living within 2 hours of a surgical facility, as recommended by the Lancet Commission on Global Surgery.¹ To calculate the distance and time, we used Manhattan distance (the distance based on road infrastructure), not Euclidean distance (straight-line distance). The use of Manhattan distance allowed evaluation of actual travel times via real travel routes in Zambia. The *WHO Guidelines for Safe Surgery*¹² include the minimum complement for resuscitation, airway management, and sterility that could be sustained in settings with limited resources. These guidelines were adapted and we applied a list of 8 minimal safety criteria from the WHO guidelines that include continual availability of a pulse oximeter, adult bag mask, oxygen, suction, intravenous fluids, sterile gloves, skin preparation solution, and a functioning sterilizer.⁹ We completed the analysis on these facilities, which were considered safe surgical facilities if they met all 8 criteria. In addition, we completed a similar analysis of facilities that provide essential surgery—trauma care, obstetric care, and care of common abdominal emergencies—as outlined in the third edition of *Disease Control Priorities*.² To meet these criteria, facilities were required to have a general surgeon, orthopedic surgeon, obstetrician, and anesthesiologist available at the facility. We performed a χ^2 test to examine the association between the population living within a 2-hour travel time for all surgical facilities compared with those living within a 2-hour travel time for safe surgical facilities and for essential surgical facilities, as defined above.

Results

Data were collected using direct observations and 495 interviews with personnel at all 103 surgical facilities in Zambia identified as providing surgical care. When including all 103 surgical facilities (regardless of human resources and supplies), 2 166 460 people (14.9% of the population) lived in a location that was more than 2 hours from surgical care (Figure 1A). When our abbreviated *WHO Guidelines for Safe Surgery*¹² criteria for minimal safety standards were included in the analysis, access to safe surgical facilities declined: only 17 hospitals (16.5%) met these minimum standards of surgical safety, and geospatial analysis indicated that 9 552 780 people (65.9% of the population) lived more than 2 hours from these safe surgical facilities (Figure 1B). Assessment of essential surgical facilities showed the lowest access, with 11 704 700 people (80.7% of the population) living more than 2

hours from facilities that provide trauma care, obstetric care, and care of common abdominal emergencies (Figure 1C). There was a statistically significant difference in access between WHO safe surgical facilities and essential surgical facilities and all surgical facilities, as summarized in the Table. Figure 2 depicts the differences in access to each type of facility based on travel time.

Discussion

Large disparities in access to safe, essential, and timely surgical care exist in Zambia. Surgical facilities are spread broadly across Zambia, but the infrastructure available for surgical care is lacking. Less than 20% of the population lives within 2 hours of facilities providing essential and emergency surgical care that meets standards of equipment and availability of health care professionals. However, if infrastructural resources could be appropriately allocated to all existing surgical facilities, coverage would improve to 85.1% of the population. Allocating critical equipment and resources to boost clinical capacity could mirror work done in essential drug lists, whereby ministries and governments identify key medicines that must be available to treat conditions within the country. Creating such lists allows for bulk purchasing, sets supply expectations of facilities, and have been shown to dramatically improve access to medications and could be replicated for essential surgical supplies.¹³

The use of geospatial visualization tools assisted in the evaluation of surgical infrastructure in Zambia and can identify key areas for improvement. Our work highlights how improving specific facilities or regions could affect the ability of a population in a particular catchment area to access surgical care. For example, using our data techniques, we were able to identify areas of high population density in which people live beyond a 2-hour travel time to a surgical facility (regardless of resources), indicating an area that might benefit from a new facility. In addition, there may be areas of high population density that have a surgical facility nearby, but the facility lacks safe surgical supplies or human resources, in which case improved resource allocation, and not a new facility, would best serve that population. This finding is demonstrated in Figure 3.

There are several limitations to our study. A primary limitation is low access to transportation. As shown in the Demographic Health Survey in Zambia for 2013–2014, most of the population that lived beyond a 2-hour travel time to a surgical facility do not own personal transportation and have a low wealth index (a measure of a household's overall standard of living), and may not be able to readily afford transportation to surgical facilities.¹⁴ In addition, we used recommended road speeds based on type of road (primary, secondary, or tertiary) and road condition (as documented in OpenStreetMaps), although road conditions vary throughout the year, and owing to flooding for significant portions of the year, road access is likely intermittently decreased. These 2 limitations caused our analysis to overestimate access to surgical care, as these barriers would increase travel times to surgical facilities. In addition, we did not assess acceptability (a patient recognizing the need to seek care) and affordability of surgical care, as assessment of these factors is beyond the scope of this study. Finally, of the 8 resources considered crucial to a safe surgical facility, pulse oximetry, sterilization, and suction all require a power source. While

interruptions of power could affect these resources, we found that most facilities had power and most operating theaters had a back-up generator, but we did not specifically assess the reliability of electricity. Bag masks and sterile gloves are typically disposable but could potentially be reused, and we did not assess whether this was the case.

Although limitations exist, to our knowledge, our geospatial analyses are the most detailed and complex currently available in the literature. First, we used the actual road infrastructure in Zambia to calculate travel times, including analysis of type of road, recommended maximum road speeds, and road condition. We applied the Manhattan distance, which uses the actual roads to calculate distance, and then applied road speeds and conditions to calculate actual travel times. Two recent studies have assessed geographic access to health care facilities through the use of the Euclidean distance (straight-line distance between 2 points), which does not account for road infrastructure or terrain (presence of lakes, mountains, rivers), and are thus limited in their real-life application and assessment of access.^{15,16} Second, as mentioned above, we assessed population densities that live within or outside of coverage areas that are defined as the population that lives in each square meter. This method allows us to not only better understand how many people live in areas beyond a 2-hour travel time to a surgical facility and do not have timely access to surgical care but it also helps in informing where to prioritize future efforts. As shown in Figure 3, we can relate population densities to facility location and determine whether a new facility is needed to cover a large population density, or, if a facility exists in a large population density, we can improve resource allocation at that facility.

Our next steps are to focus on the assessment of health outcomes in association with access to surgical care. With the use of these data, we will be able to better define timely access to surgical care, as a 2-hour travel time may actually be too long for specific conditions. Assessment of surgical infrastructure and outcomes will also allow us to better understand key components of human resources, supplies, and infrastructure that are related to improved outcomes.

Conclusions

Geographic information systems are an excellent tool for evaluating a range of facility-based health services. As a modeling and decision support tool, we have used geographic information systems to help determine the geographic distribution of surgical facilities and resources and identified populations in Zambia who do not have access to safe, essential, and timely surgical care. By identifying these populations at risk, this work can inform policy makers and those within the Zambia Ministry of Health to make informed decisions on resource allocation, and plan and target interventions. We hope this study will show the importance of standardized collection of surgical data and its application to the development of core geographic data sets that include visualization of key surgical information for every country. In addition, this type of geospatial analysis could help with health system planning across many countries and types of health services.

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References

1. Meara JG, Leather AJ, Hagander L, et al. Global surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet*. 2015; 386(9993):569–624. [PubMed: 25924834]
2. Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME, Debas HT. Essential surgery: key messages from Disease Control Priorities, 3rd edition. *Lancet*. 2015; 385(9983):2209–2219. [PubMed: 25662414]
3. World Health Organization. [Accessed June 1, 2015] Sixty-eighth World Health Assembly. http://apps.who.int/gb/ebwha/pdf_files/WHA68/A68_R15-en.pdf. Published May 26, 2015
4. The World Bank. [Accessed December 1, 2015] Zambia. <http://data.worldbank.org/country/zambia>
5. Weiser TG, Haynes AB, Molina G, et al. Size and distribution of the global volume of surgery in 2012. *Bull World Health Organ*. 2016; 94(3):201–209F. [PubMed: 26966331]
6. Esquivel MM, Molina G, Uribe-Leitz T, et al. Proposed minimum rates of surgery to support desirable health outcomes: an observational study based on three strategies. *World J Surg*. 2015; 39(9):2126–2131. [PubMed: 25968342]
7. Uribe-Leitz T, Jaramillo J, Maurer L, et al. Variability in mortality following caesarean delivery, appendectomy, and groin hernia repair in low-income and middle-income countries: a systematic review and analysis of published data. *Lancet Glob Health*. 2016; 4(3):e165–e174. [PubMed: 26916818]
8. World Health Organization. [Accessed December 1, 2015] Emergency and essential surgical care. <http://www.who.int/surgery>
9. Bowman KG, Jovic G, Rangel S, Berry WR, Gawande AA. Pediatric emergency and essential surgical care in Zambian hospitals: a nationwide study. *J Pediatr Surg*. 2013; 48(6):1363–1370. [PubMed: 23845631]
10. OpenStreetMap. [Accessed October 1, 2015] Zambia. <https://www.openstreetmap.org/relation/195271>
11. WorldPop. [Accessed October 1, 2015] Summary: Zambia. <http://www.worldpop.org.uk/data/summary/?contselect=Africa&countselect=Zambia&typeselect=Population>
12. World Health Organization. WHO Guidelines for Safe Surgery. Geneva, Switzerland: World Health Organization; 2009.
13. Laing R, Waning B, Gray A, Ford N, 't Hoen E. 25 years of the WHO essential medicines lists: progress and challenges. *Lancet*. 2003; 361(9370):1723–1729. [PubMed: 12767751]
14. Central Statistical Office (Zambia), Ministry of Health (Zambia), ICF International. Zambia Demographic and Health Survey 2013–14. Rockville, MD: Central Statistical Office, Ministry of Health, Zambia; Fairfax, VA: ICF International; 2014.
15. Dare AJ, Ng-Kamstra JS, Patra J, et al. Million Death Study Collaborators. Deaths from acute abdominal conditions and geographical access to surgical care in India: a nationally representative spatial analysis. *Lancet Glob Health*. 2015; 3(10):e646–e653. [PubMed: 26278186]
16. Hanson C, Cox J, Mbaruku G, et al. Maternal mortality and distance to facility-based obstetric care in rural southern Tanzania: a secondary analysis of cross-sectional census data in 226000 households. *Lancet Glob Health*. 2015; 3(7):e387–e395. [PubMed: 26004775]

Figure 1. Population of Zambia Within a 2-Hour Travel Time of Surgical Facilities

A, Population (85.1%) within 2-hour travel time for all surgical facilities (gray dots) in Zambia. B, Population (34.1%) within 2-hour travel time for surgical facilities (gray dots) that meet the World Health Organization (WHO) minimum surgical safety standards. C, Population (19.3%) within 2-hour travel time for surgical facilities (gray dots) that provide essential surgery—trauma care, obstetric care, and care of common abdominal emergencies.

Figure 2. Travel Time to Types of Surgical Facilities

Differences in access to each type of facility based on travel time. Ess-Surg indicates essential surgical facilities; WHO-SS, World Health Organization safe surgical facilities.

Figure 3. Population Densities and Travel Time to Surgical Facilities

Partial map of Zambia depicting higher population densities (>300 people/m²) with colored dots: if they are outside of the 2-hour travel time to safe surgical facilities, the population densities are red; if they are within this travel time, the population densities are blue. The circles with a black outline indicate locations of all surgical facilities.

Table

Population Not Within 2 Hours of Surgical Facilities

Facility Type	Population Not Within 2-h Travel Time, % (95% CI)	No. of People Not Within 2-h Travel Time (95% CI)	P Value
All facilities	14.9 (13.9–16.0)	2 166 460 (2 021 060–2 326 400)	NA
WHO safe surgical facilities	65.9 (64.5–66.8)	9 552 780 (9 378 300–9 712 720)	<.001
Essential surgical facilities	80.7 (80.0–81.2)	11 704 700 (11 632 000–11 806 480)	<.001

Abbreviations: NA, not applicable; WHO, World Health Organization.