

Increased Rwandan Access to Obstetrician–Gynecologists Through a U.S.–Rwanda Academic Training Partnership

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OBJECTIVE: To evaluate the first 5 years of the Human Resources for Health Rwanda program from the program onset in the July 2012–2016 academic years, and its effects on access to care through examination of: 1) the number of trained obstetrician–gynecologists (ob-gyns) who graduated from the University of Rwanda and the University of Rwanda–Human Resources for Health program and 2) a geospatial analysis of pregnant women's access to Rwandan public hospitals with trained ob-gyns.

METHODS: We used GPS coordinates in this cross-sectional study to identify public (government) hospitals with ob-gyns in 2011 (before initiation of the program) compared with 2016 (year 5 of the program). We

compared access to care for the years 2011 and 2016 through geocoding the proportion of pregnant women within 10 and 25 km from these hospitals and compared the travel time to these hospitals in the two time periods. We used a World Pop dataset of Rwandan pregnancies from 2015, ArcGIS for spatial operations, R for statistical analysis, zonal statistics for circular distances, and friction surface for travel time analysis.

RESULTS: The number of ob-gyns in public hospitals increased from 14 to 49 nationally. Before the program, 18 residents graduated over a 7-year period (two residents per year); 33 graduated by year 5 (six residents per year). Rwandan faculty increased by 45%. In 2011, most providers were in the capital city. Between 2011 and 2016, the proportion of pregnant women living 10 km from an ob-gyn-staffed public hospital increased from 13.0% to 31.6%; within 25 km increased from 28.4% to 82.9%. Travel time analysis from 2011 to 2016 showed 49.1% of Rwandan women within 1 hour of a hospital and 85.6% within 2 hours. In 2016, this coverage increased to 87.5% and 98.3%, respectively.

CONCLUSION: In 5 years, the Human Resources for Health Rwanda program improved the number of residency graduates in obstetrics and gynecology and nationwide access to these providers. The program reduced rural–urban disparities in access to ob-gyns.

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The World Health Organization (WHO) identifies access to skilled birth attendance and emergency surgical services, including cesarean delivery, as indicators of safe maternal and neonatal outcome.¹ Access to trained health care professionals poses a challenge to Rwanda because of the 1994 genocide against the Tutsis, which created profound structural, social, and

economic destruction. Many health professionals were either killed or forced to flee the country. After these events, the country was left impoverished with a decimated health care structure and medical education system.² After the genocide, medical education was limited with most specialists, including obstetrician–gynecologists (ob-gyns), receiving their training in other countries.²

Rwanda has made considerable efforts to improve overall health, particularly maternal and child health, through policy and economic initiatives targeting women's rights, education, and universal access to health coverage through a community-based health insurance program (Mutuelle de Santé).³ Rwanda met the United Nation's Millennium Development Goals 4 and 5 aimed at the reduction of child and maternal mortality by 75% between 1990 and 2015. The average maternal mortality ratio during the 5 years before 2000 stood at 1,071 per 100,000 live births and steadily decreased to 210 in 2015.⁴ Similarly, infant mortality rates dramatically declined.⁴ Despite meeting these milestones, however, perinatal health care indices remain suboptimal and further improvements require additional investment in the national health care system.

Rwanda is a small, central African land-locked nation approximately the size of the state of Maryland.⁵ With a population of 11 million, Rwanda is one of the most densely inhabited countries in Africa.⁵ The Rwandan public health system is decentralized with health posts and health centers serving as first-line, neighborhood level, outpatient, and preventative care centers. District, military, provincial, and tertiary referral hospitals provide higher levels of care to an established geographic region. The two tertiary care academic centers are in the centrally located capital city of Kigali and the second largest, southern city of Butare. Patients are referred to these higher levels of care by providers in the health posts and health centers. The referral patterns are based on patient proximity to a facility. The health system has 489 health centers and 680 health posts. In 2018, Rwanda had 48 referral and district hospitals. Health centers and health posts provide primary and preventive care including care for uncomplicated pregnancies and are staffed primarily by registered nurses who have a secondary school level education. District and provincial hospitals are primarily staffed by general practitioners and specialty consultants in surgery and obstetrics and gynecology.^{2,3}

General practitioners perform emergency surgical procedures such as cesarean deliveries. Cesarean deliveries account for more than 60% of all operations

performed in rural district hospitals.⁶ Patients must be transferred to a regional, district, or referral hospital for an operative vaginal or cesarean delivery. The most complicated cesarean deliveries (eg, placenta previa, repeat cesareans) are referred to the tertiary care academic centers. The university training hospitals are examples of referral centers where the most complicated obstetric and gynecologic cases are managed. These facilities are staffed with specialists in obstetrics and gynecology. Private sector clinics and hospitals serving pregnant women are primarily located in the capital city, Kigali.

Recognizing the critical need for highly trained health care professionals, in 2011 the Rwandan government embarked on a novel medical education program to improve their health care system. The World Health Organization designated a baseline health care professional workforce needed to achieve Millennium Development Goals at 23 doctors, nurses, and midwives per 10,000 population.¹ A 2010 Rwandan national survey reported five health care professionals per 10,000 population. Human Resources for Health Rwanda was designed as a 7-year program to produce qualified medical personnel with the aim of increasing quality and access to health care for Rwandans.^{2,7} Human Resources for Health is a partnership between the government of Rwanda and a consortium of 22 U.S. academic institutions to implement training in medical, dental, nursing and health administration. U.S. academic institutions recruited faculty to implement the Human Resources for Health program in Rwanda with the goal of increasing the number of trained Rwandan health care workers.² U.S. generalists contract for a full academic year in Rwanda, and U.S. subspecialists contract for a minimum of 2 months or longer. The core goal of the Human Resources for Health Rwanda program is postgraduate academic training; U.S. faculty supported this goal through clinical and pedagogical support. Many of the academic approaches were innovative and actively incorporated simulations, skills assessments, and oral examinations in addition to traditional didactics and clinical teaching.⁵ Previous works detail the formation of the Human Resources for Health program and comprehensively evaluate its first 5 years.^{2,5} Increasing the number of trained ob-gyns is essential for the provision of comprehensive health services.⁸

Against a backdrop of improvements in preventative and communicable disease management, emergency surgical services, including obstetric services, are recognized as an important unmet need in sub-Saharan Africa.¹ As obstetric emergencies in sub-Saharan Africa comprise a large fraction of all

emergency services, they often serve as indicators of access to emergency services and cesarean deliveries as measures of a system's capacity to offer basic surgical care.⁹

Improving health system capacity to address acute, life-threatening events may decrease resultant mortality by 45% and disability by 36% in low- and middle-income countries.¹

Increased travel distance to hospitals is a known contributor to excess morbidity and mortality for both obstetric and nonobstetric emergent conditions.¹ An analysis of public sector hospitals in sub-Saharan Africa demonstrated only 28% of women of childbearing age living within a minimal 2-hour distance to the nearest hospital. This percentage is well below the international goal of 90% of the population within a two-hour range to provide universal access to health care services.¹ Encouragingly, in a 2017 public hospital database, 88.8% of Rwandan women of childbearing age were within 2 hours of a district hospital.¹ Despite achievement of this 2-hour hospital proximity, studies from Rwanda continue to demonstrate increased maternal morbidity and mortality from cesarean deliveries, particularly after transfers from smaller health centers to district hospitals.^{10,11} Transfers of care during labor are associated with increased maternal and neonatal morbidity and mortality.^{10,11} Travel obstructions often result from poor road conditions or ambulance delays. A 1-hour travel distance threshold to the nearest hospital may provide a better, more conservative measure of access to care.

The aim of this study is to evaluate the first 5 years of the Human Resources for Health program from the program onset in the academic calendar years July 2012 to 2016, which ended in 2017, and its effect on access to care through examination of: 1) the number of trained ob-gyns graduated from the University of Rwanda and the University of Rwanda-Human Resources for Health program and 2) a geospatial analysis of pregnant women's access to Rwandan public hospitals with trained Obstetrics and Gynecology providers. The Human Resources for Health Rwanda model can potentially inform policymakers on the effect of a large-scale national Obstetrics and Gynecology training program, as well as the potential effect on changes in the availability of emergency essential surgical services in public hospitals.

Geospatial analysis of the presence of ob-gyns since the beginning of the Human Resources for Health Rwanda program may further highlight ongoing vulnerabilities for populations seeking a higher level surgical and obstetric care in Rwanda. More generally, geospatial analysis of health access dispar-

ities may provide a baseline platform for policy makers to eliminate population disparities as well as form a measurable benchmark for improvement.^{1,9}

METHODS

The University of Rwanda is the only institution providing residency education. Rwanda began its residency programs in 2005. The Rwandan Obstetric Gynecology residency is 4 years in duration and follows an academic calendar similar to the U.S. system. Residents meet metrics for annual promotion based on clinical performance and exam completion. Residents are qualified for graduation after successful completion of an original research thesis as well as final oral and written examinations. Final theses and oral exams are proctored by international, external examiners. The residency program duration and graduation requirements were established at the beginning of the Rwandan residency program, in 2005, and persisted throughout the Human Resources for Health program. All medical practitioners must apply for licenses to practice from the Rwandan Medical Council. The Rwandan Government pays for medical school and provides salary support for all residents. Residents sign contracts obligating them to provide public sector service for at least 5 years after training.^{2,4}

We performed a cross-sectional study using two time points. To determine the number of Rwandan ob-gyns graduated from the University of Rwanda and the University of Rwanda Human Resources for Health program, we used the Rwandan Obstetrics and Gynecology Society database as well as graduation records from the University of Rwanda School of Medicine. The Rwandan Obstetrics and Gynecology Society maintains a current database of practice settings and locations for all ob-gyns in Rwanda.

To map hospitals with at least one ob-gyn, we obtained longitude and latitude coordinate pairs from Rwandan government GPS data. Hospital locations were confirmed using rooftop visualization in Google Earth.

We obtained a WorldPop dataset of pregnancies in Rwanda from 2015.¹² The WorldPop project is a global initiative to "ensure every person is mapped and counted in decision making." WorldPop provides open access, geospatial datasets.¹² The project is particularly focused on low- and middle-income countries where such data may be of low quality or dated. To determine pregnancies per 1-km grid square, WorldPop combines small area data on the distribution of women of childbearing age, age-specific fertility rates, stillbirth, and abortions to map the estimated distribution of pregnancies for each 1-km grid square across all low- and middle-income

countries.¹² Details on these methods and source data have been described previously.¹³ In 2015, approximately 350,000 deliveries occurred in Rwanda.¹⁴

We used ArcGIS 10.5.1 for spatial operations and R 3.4.4 (www.r-project.org) for statistical analysis.¹⁵ To determine the proportion of pregnant women in Rwanda who were within a given distance of hospitals with ob-gyns, we computed circular radii around hospital locations for both academic years, 2011 and 2016. We then selected 10- and 25-km radius zones using the buffer tool in ArcGIS. The zonal statistics tool was used to compute the number of pregnant women falling into each zone. We then used the test of equal or given proportions to calculate 95% CI about the proportion of total pregnant women in Rwanda who fell within the circular radius zones. This test was further used to compute the significance of the observed difference between 2011 and 2016.

The study was approved by the institutional review board from the University Teaching Hospital of Kigali and received institutional review board-exempt status from Duke University School of Medicine.

RESULTS

In 2011, 14 ob-gyns served the public health sector hospitals in Rwanda and at year 5 of Human Resources for Health there were 49, a 3.5-fold

increase. From the beginning of Rwandan Obstetrics and Gynecology residencies in 2005 through 2011, 18 residents graduated (approximately two residents per year), which increased to 33 residents (approximately six per year) from the beginning of the Human Resources for Health (Fig. 1). The annual residents graduated increased 2.6-fold. The number of Rwandan faculty increased by 45%. University of Rwanda-Human Resources for Health graduates now head 75% of referral hospital obstetrics and gynecology departments; others head provincial and district hospitals (Fig. 2).¹⁶ These new leaders from the University of Rwanda-Human Resources for Health program represent recent graduates in the subspecialty of obstetrics and gynecology. As the only trained ob-gyns in many hospitals, they have assumed leadership roles. The 14 district hospitals represented in this analysis now have at least one or two ob-gyns; the two largest tertiary care academic referral centers possess the highest numbers of ob-gyns per institution.

Geospatial analysis from 2011 demonstrated the majority of hospitals with obstetrics and gynecology providers were located in Kigali, the area of highest population density and Butare, the second largest city (Figs. 2 and 3). In 2011, the majority of hospitals with ob-gyn providers were in the university teaching hospitals in either Kigali or in the southern city of Butare, leaving most of the rural areas of the country without

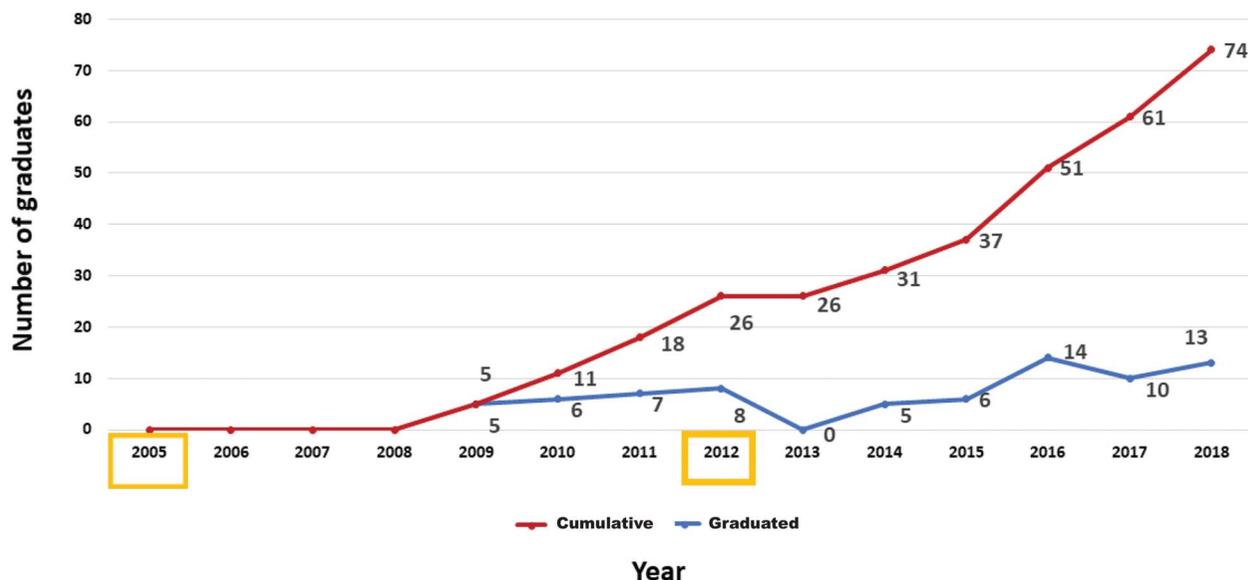


Fig. 1. Cumulative and graduated obstetrics and gynecology graduates from 4-year residency program. Human Resources for Health program onset was in the 2011–2012 academic year. Cumulative (*red*) and annual (*blue*) numbers of obstetrics and gynecology graduates. Rwanda began obstetrics and gynecology residency programs in 2005. The Human Resources for Health program began in 2012. The *yellow boxes* indicate the years that Rwanda began residency programs (2005) and the beginning of the Human Resources for Health program (2012).

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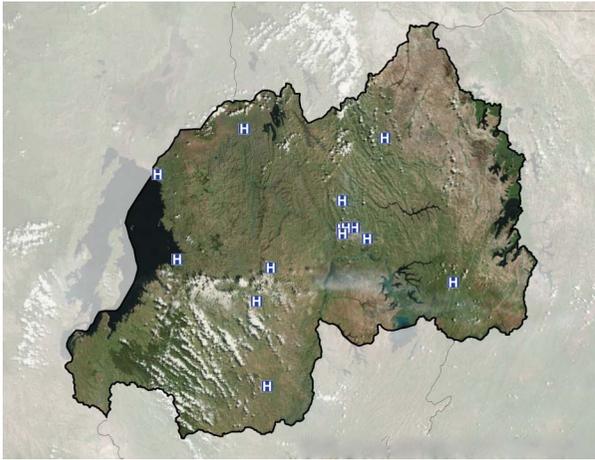
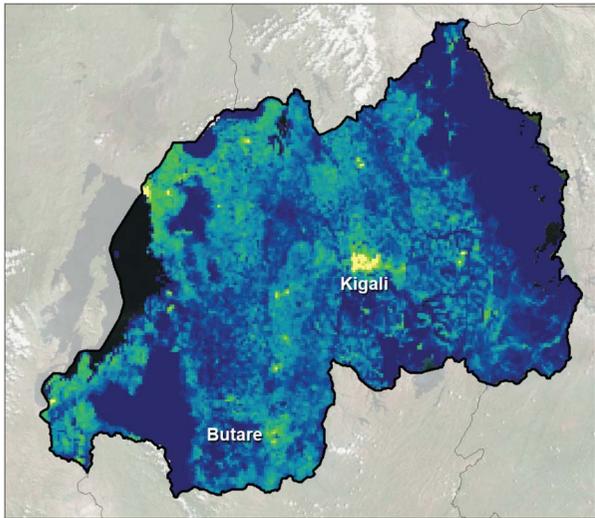


Fig. 2. Rwandan map (2016) showing district and referral hospitals with at least one obstetrician–gynecologist. H, hospital.

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local ob-gyn services. Before Human Resources for Health, only six Rwandan hospitals had at least one ob-gyn. In 2016, 16 hospitals had ob-gyn coverage (Fig. 4). Between 2011 and 2016 the proportion of pregnant women living within 10 km of a hospital with ob-



Pregnancies per km²

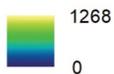


Fig. 3. Population density map of pregnant women in Rwanda (numbers per km²). The *lighter* areas of the map are the areas of highest population density and the *darker blue* areas represent sparsely populated regions.

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gyn services increased from 13.0% to 31.6%. From 2011 to 2016 the proportion of pregnant women within 25 km of a hospital with an ob-gyn increased from 28.4% to 82.9% (Fig. 5). Similarly, travel time analysis demonstrated a substantial increase in access to hospitals. In 2011 49.1% of Rwandan women were within 1 hour of a hospital with ob-gyn physicians and 85.6% were within 2 hours. In 2016, this coverage increased to 87.5% and 98.3%, respectively (Fig. 5).

DISCUSSION

Human Resources for Health Rwanda is an innovative, large-scale collaboration between a sub-Saharan African government and a consortium of 22 U.S. academic institutions to address the critical shortage of health care professionals. This work demonstrates the widespread national effect of the Human Resources for Health Rwanda Obstetrics and Gynecology program on improved access to care. Training efforts generated by U.S. and Rwandan academicians resulted in a nearly fourfold increase in the number of ob-gyns in a 5-year period. In addition, qualified ob-gyns have formed a new cadre of academic faculty, increasing the sustainability of obstetrics and gynecology training opportunities in Rwanda. The Dean of the University of Rwanda School of Medicine’s vision was to increase the number of ob-gyns to 100 by 2020, have two ob-gyns per district hospital and eight in each teaching hospital. Since 2005, the University of Rwanda and University of Rwanda Human Resources for Health program graduated 74 residents in obstetrics and gynecology. The district and teaching hospitals are close to these metrics.

After 5 years of the Human Resources for Health program, Rwandan women’s proximity and travel time to hospitals with ob-gyns increased. By 2016, nearly 100% of Rwandan women were within a 2-hour travel time to a hospital with an ob-gyn. The nationwide increase in ob-gyn coverage enables access to potential life-saving surgical and emergency services. The WHO global surgical workforce database highlights the scarcity of available anesthesiologists, surgeons, and obstetricians in low-income countries.¹⁷ Globally, low- and middle-income countries possess 48% of the world’s population but only 20% of these specialists. The WHO surgical workforce analysis demonstrated 0.7 providers per 100,000 population in low-income countries compared with 56.7 providers per 100,000 population in high-income countries.¹⁷ The WHO database, however, does not address the rural–urban distribution of providers and does not, therefore, address a key component of universal access to surgical care.¹⁷

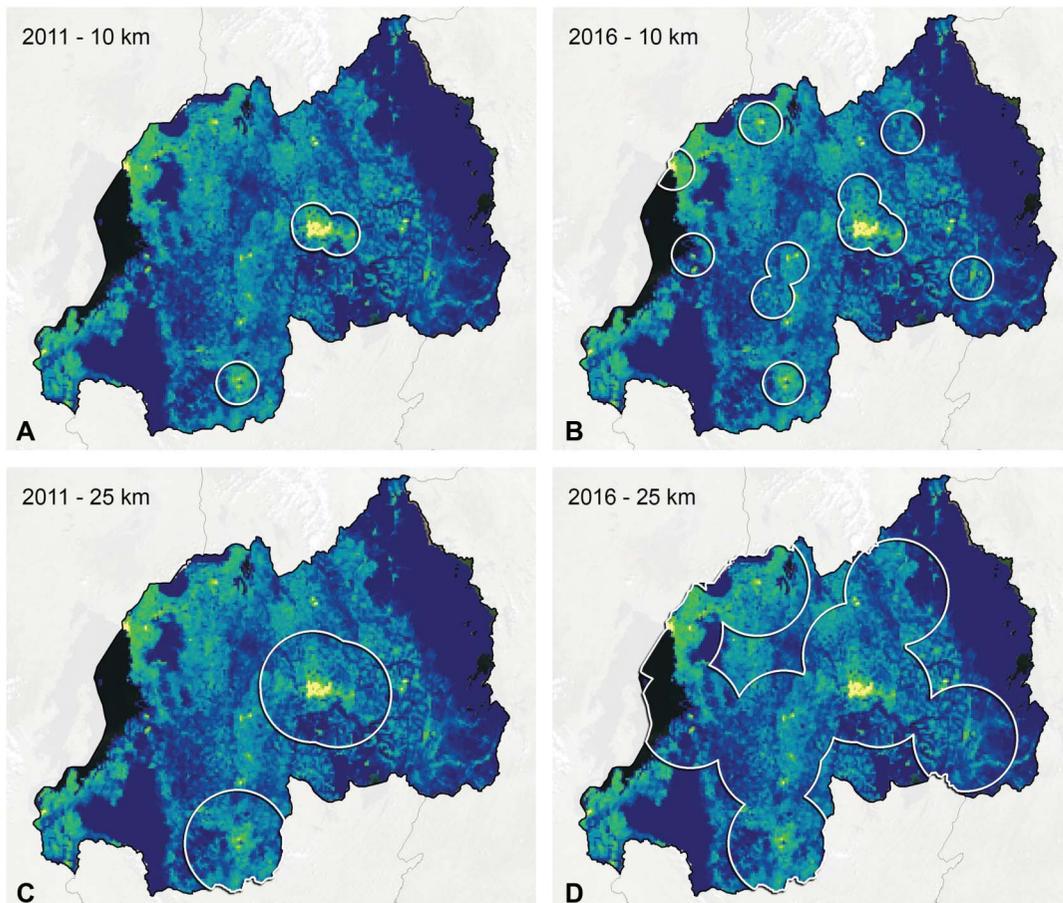


Fig. 4. Ten- and 25-kilometer radius to hospitals with an obstetrician–gynecologist (ob-gyn) in 2011 compared with 2016. Area in Rwanda within 10 and 25 km of hospitals with obstetrics and gynecology services. In 2011, hospitals with an ob-gyn were in Kigali or Butare, the site of the medical school campus. Substantially more of the population was within short distances of an ob-gyn hospital by 2016. Ten-kilometer radius to hospitals with an ob-gyn in 2011 (**A**) compared with 2016 (**B**). Twenty-five-kilometer radius to hospitals with an ob-gyn in years 2011 (**C**) compared with 2016 (**D**).

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Studies from similar settings demonstrate a concentration of specialists in urban areas.¹⁸ At the onset of the Human Resources for Health Rwanda program, all ob-gyns were located in the two largest cities, the capital city, Kigali, and the southern city of Butare. Butare is the second largest city in Rwanda and the site of the University of Rwanda medical school campus. The Human Resources for Health program reduced the rural–urban disparity in the geographic distribution of ob-gyns. A national challenge will be to maintain and expand this coverage to areas still lacking access. Many low-income countries struggle with an ongoing, critical shortage of health care providers in rural settings.

Universal access to health care is a priority for Rwanda and loss of domestically trained physicians to higher income countries is a challenge to the health system of many sub-Saharan African countries.¹⁹ The

Rwandan government’s strategy to minimize these departures is through mandatory 5-year contracts to the public health sector and allowing physicians some choice in city of placement after graduation. Many choose to return to their home communities. The effectiveness of this approach will need to be evaluated over time.

There are limitations to the current work. We did not focus on the private sector, although they provide access primarily in urban centers. The vast majority of the Rwanda population resides in rural areas. Even within cities, the private sector primarily refers obstetric emergencies and the most challenging gynecologic cases to the tertiary, academic hospitals for specialized services. The public sector is the foundation of the Rwandan Health System. In 2012, a baseline assessment using a WHO survey tool demonstrated severe resource shortages in Rwandan

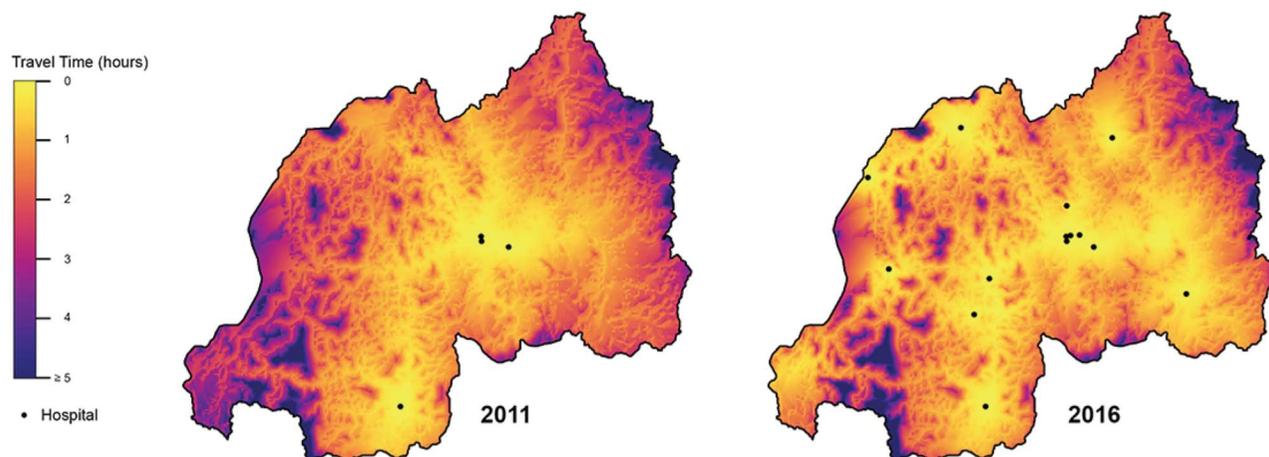


Fig. 5. Change in travel time to an obstetrician–gynecologist in Rwanda 2011 compared with 2016. Travel time analysis shows that, compared with 2011, virtually all of the Rwandan population had a less than 120-minute travel time to hospitals with obstetrics and gynecology services in 2016.

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hospitals.²⁰ These factors may contribute to life-threatening treatment delays despite a patient’s prompt arrival to the appropriate level care facility.

There are limitations to our evaluation of the physical environment. Physical access is an established barrier to care. Longer travel times are known to worsen both maternal and neonatal outcomes.¹⁰ Our analyses are dependent on the quality of our underlying data sources, most notably the completeness and spatial accuracy of the population data used. It is possible that harder-to-access populations are relatively underrepresented in this dataset. Our travel time analysis incorporates assumptions about travel conditions, including the effect of road quality and land cover type on travel time. These assumptions may be generally sound at a very large geographic scale but cannot incorporate local impediments to travel. Moreover, the quality of many roads in Africa is poor and made worse by rains.

This geospatial approach forms an important scaffold for understanding the physical health care environment and the effect of a large obstetrics and gynecology training program on the Rwandan population. This approach can allow us to visually demonstrate areas where additional innovative, creative, resourceful measures are still needed to reach universal health care access. Geospatial mapping not only highlights these improvements, but also exposes ongoing vulnerabilities in areas of the country that remain distant from newly established ob-gyns.

With this study, we address two aspects of barriers to health care access—human resources and the physical landscape. The Human Resources for Health Rwanda Obstetrics and Gynecology program

enhanced both the human workforce capacity in obstetrics and gynecology, as well as the nationwide physical proximity to hospitals with ob-gyns, reducing the national rural–urban disparity in access to care.

REFERENCES

1. Ouma PO, Maina J, Thurairira PN, Macharia PM, Alegana VA, English M, et al. Access to emergency hospital care provided by the public sector in sub-Saharan Africa in 2015: a geocoded inventory and spatial analysis. *Lancet Glob Health* 2018;6:e342–50.
2. Binagwaho A, Farmer PE. The human resources for health program in Rwanda. *N Engl J Med* 2014;370:981–2.
3. Bucagu M, Kagubare JM, Basinga P, Ngabo F, Timmons BK, Lee AC. Impact of health systems strengthening on coverage of maternal health services in Rwanda, 2000–2010: a systematic review. *Reprod Health Matters* 2012;20:50–61.
4. National Institute of Statistics of Rwanda (NISR) [Rwanda], Ministry of Health MOH [Rwanda], ICF International. Rwanda demographic and health survey 2014–15. Rockville (MD): NISR, MOH, ICF International; 2015.
5. Cancedda C, Cotton P, Shema J, Rulisa S, Riviello R, Adams LV, et al. Health professional training and capacity strengthening through international academic partnerships: the first five years of the human resources for health program in Rwanda. *Int J Health Policy Manag* 2018;7:1024–39.
6. Petroze RT, Joharifard S, Groen RS, Niyonkuru F, Ntaganda E, Kushner AL, et al. Injury, disability and access to care in Rwanda: results of a nationwide cross-sectional population study. *World J Surg* 2015;39:62–9.
7. Cancedda C, Farmer PE, Kyamanywa P, Riviello R, Rhatigan J, Wagner CM, et al. Enhancing formal educational and in-service training programs in rural Rwanda: a partnership among the public sector, a nongovernmental organization, and academia. *Acad Med* 2014;89:1117–24.
8. Victora CG, Requejo JH, Barros AJ, Berman P, Bhutta Z, Boerma T, et al. Countdown to 2015: a decade of tracking progress for maternal, newborn, and child survival. *Lancet* 2016;387:2049–59.

9. Stewart BT, Tansley G, Gyedu A, Ofosu A, Donkor P, Appiah-Denkyira E, et al. Mapping population-level spatial access to essential surgical care in Ghana using availability of bellwether procedures. *JAMA Surg* 2016;151:e161239.
10. Niyitegeka J, Nshimirimana G, Silverstein A, Odhiambo J, Lin Y, Nkurunziza T, et al. Longer travel time to district hospital worsens neonatal outcomes: a retrospective cross-sectional study of the effect of delays in receiving emergency cesarean section in Rwanda. *BMC Pregnancy Childbirth* 2017;17:242.
11. Nyirahabimana N, Ufashingabire CM, Lin Y, Hedt-Gauthier B, Riviello R, Odhiambo J, et al. Maternal predictors of neonatal outcomes after emergency cesarean section: a retrospective study in three rural district hospitals in Rwanda. *Matern Health Neonatol Perinatol* 2017;3:11.
12. WorldPop. Available at: www.worldpop.org. Retrieved May 16, 2019.
13. Tatem AJ, Campbell J, Guerra-Arias M, de Bernis L, Moran A, Matthews Z. Mapping for maternal and newborn health: the distributions of women of childbearing age, pregnancies and births. *Int J Health Geogr* 2014;13:2.
14. National Institute of Statistics of Rwanda. Rwanda data at-a-glance. Available at: <http://Rwanda.opendataforafrica.org>. Retrieved May 16, 2019.
15. The R project for statistical computing. Available at: www.r-project.org. Retrieved July 6, 2018.
16. Esri. Redlands CWIS, 349,091. Available at: <http://www.arcgis.com>. Retrieved May 16, 2019.
17. Holmer H, Lantz A, Kunjumen T, Finlayson S, Hoyler M, Siyam A, et al. Global distribution of surgeons, anaesthesiologists, and obstetricians. *Lancet Glob Health* 2015;3(suppl 2):S9–11.
18. Dare AJ, Ng-Kamstra JS, Patra J, Fu SH, Rodriguez PS, Hsiao M, et al. Deaths from acute abdominal conditions and geographical access to surgical care in India: a nationally representative spatial analysis. *Lancet Glob Health* 2015;3:e646–53.
19. Mullan F. The metrics of the physician brain drain. *N Engl J Med* 2005;353:1810–8.
20. Petroze RT, Nzayisenga A, Rusanganwa V, Ntakiyiruta G, Calland JF. Comprehensive national analysis of emergency and essential surgical capacity in Rwanda. *Br J Surg* 2012;99:436–43.

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