original reports abstract

Toward Equitable Access to Tertiary Cancer Care in Rwanda: A Geospatial Analysis

Temidayo Fadelu, MD, MPH[1]; Pranay Nadella, MPhil[2]; Hari S. Iyer, MPH, ScD[1,3]; Francois Uwikindi, MSc, MD[4]; Cyprien Shyirambere, MD[5]; Achille Manirakiza, MD[6]; Scott A. Triedman, MD[1,7]; Timothy R. Rebbeck, PhD[1,3]; and Lawrence N. Shulman, MD[8]

PURPOSE Geographic access to care is an important measure of health equity. In this study, we describe geographic access to cancer care centers (CCCs) in Rwanda with the current facilities providing care and examine how access could change with expanded care infrastructure.

METHODS Health facilities included are public hospitals administered by the Rwanda Ministry of Health. The WorldPop Project was used to estimate population distribution, and OpenStreetMap was used to determine travel routes. On the basis of geolocations of the facilities, AccessMod 5 was used to estimate the percentage of the population that live within 1 hour, 2 hours, and 4 hours of CCCs under the current (two facilities) and expanded care (seven facilities) scenarios. Variations in access by region, poverty, and level of urbanization were described.

RESULTS Currently, 13%, 41%, and 85% of Rwandans can access CCCs within one, two, and 4 hours of travel, respectively. With expansion of CCCs to seven facilities, access increases to 37%, 84%, and 99%, respectively. There is a substantial variation in current geographic access by province, with 1-hour access in Kigali at 98%, whereas access in the Western Province is 0%; care expansion could increase 2-hour access in the Western Province from 1% to 71%. Variation in access is also seen across the level of urbanization, with current 1-hour access in urban versus rural areas of 45% and 8%, respectively. Expanded care results in improvement of 1-hour access to 67% and 33%, respectively. Similar trends were also noted across poverty levels.

CONCLUSION Geographical access to CCCs varies substantially by province, level of urbanization, and poverty. These disparities can be alleviated by strategic care expansion to other tertiary care facilities across Rwanda.

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INTRODUCTION

The increasing burden of cancer in low- and medium-human development index (HDI) countries is well-recognized. Future projections estimate a doubling of cancer incidence and deaths in low-HDI countries, such as Rwanda, by 2040.[1,2] In response, many countries have enacted cancer control plans to expand access to prevention, early detection, and cancer-directed treatment.[3]

Over the past decade, Rwanda has made great strides in cancer control, which have been previously well-described.[4,5] Rwanda's health care system is organized administratively into five levels with increasing scope of health services and progressively larger catchment areas.[6] The levels include health posts, health centers, district hospitals, provincial hospitals, and national referral and teaching hospitals (Appendix Fig A1). The country also has a unique community-based health insurance (CBHI) scheme with more than 80% of the population enrolled; enrolled participants have incremental premiums on the basis of community assessment of the level of poverty.[6,7] CBHI covers up to 90% of the financial responsibility for approved services.

The Rwanda Ministry of Health (RMOH), in collaboration with several partners, has prioritized cancer prevention and early detection activities such as its national human papilloma virus vaccination program and hepatitis B and C viruses treatment programs.[8] Although these cancer prevention and early detection services are frequently provided at numerous primary health facilities throughout the country, the complexity and multidisciplinary nature of cancer treatment limit its delivery to tertiary and specialized cancer treatment centers.[7] In recent years, although the scope of coverage for the CBHI scheme has expanded from only preventative services and basic health care services to coverage for hospitalizations, surgery, and a variety of tertiary care services available within the public health care system, coverage for some oncology services like chemotherapy remains limited.[6,8]

ASSOCIATED CONTENT

Appendix

Author affiliations and support information (if applicable) appear at the end of this article.

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CONTEXT

Key Objective

How geographically accessible are tertiary cancer care centers (CCCs) in Rwanda today, and how will accessibility change with care expansion to all referral hospitals?

Knowledge Generated

Most Rwandans, more than 87%, currently live over an hour from CCCs, and nearly 60% live over 2 hours. There are significant variations in accessibility on the basis of geography, poverty, and level of urbanization. The Western Province, poorer areas, and rural areas are disproportionately underserved. Geospatial modeling shows that these underserved areas reap the greatest benefit from expansion of CCCs to all public referral hospitals. Care expansion lessens disparities in access, as evidenced by a substantial reduction in median travel time in all the underserved groups.

Relevance

Geospatial modeling can be a valuable tool for describing variation in population cancer care access and for highlighting the magnitude of CCC access inequity in vulnerable populations. The results may influence planning of care expansion nationally and guide rational placement of future CCCs.

For this study, we defined a cancer care center (CCC) as offering the spectrum of tertiary cancer services, from initial pathologic cancer diagnosis and staging to access to multimodality treatment, including systemic therapy (such as chemotherapy) and oncologic surgery. The Butaro Cancer Center of Excellence (BCCOE) in Northern Rwanda was established in 2012 as Rwanda's first public CCC within the RMOH.[4,9] BCCOE was established through collaboration between RMOH, Partners In Health/Inshuti Mu Buzima—a nonprofit organization, and international academic partners—Dana-Farber Cancer Institute and Brigham and Women's Hospital.[4] At the start, the center used a unique task-shifted model of care delivery in which general practitioners deliver oncology treatment within the bounds of established treatment protocols, supported remotely by oncology specialists. BCCOE provides systemic chemotherapy at no cost to patients, covers referral costs for some services not covered by CHBI, and provides social and financial support for the neediest patients.[4] In 2020, with expansion of the national pool of trained oncology specialists, the Rwanda Cancer Center (RCC) was inaugurated as the second public CCC at the Rwanda Military Hospital (RMH) in the capital city of Kigali. Although elements of cancer treatment are now available at other public provincial and referral hospitals around the country, BCCOE and RCC represent the only two public centers with programs that provide a spectrum of tertiary cancer services, with radiation therapy only available at RCC.[8] Details of currently available services at other referral hospitals are presented in Appendix Table A1.

Similar to Rwanda, many other low-HDI countries also have too few tertiary cancer facilities to adequately serve their populations. Consequently, there is increasing interest in understanding the physical and geographic dimensions of cancer care delivery to inform policy makers and to address these challenges.[10-14] Emerging studies from sub-Saharan Africa (SSA) indicate that longer travel distance is associated with delayed cancer diagnosis, later stages of diagnosis, and inferior survival rates in patients with breast cancer.[12,15] Longer distances can lead to complex and prolonged travel and significantly associated travel cost, whereas individuals in rural areas might have lower awareness of cancer symptoms and need to travel farther distances to health facilities compared with urban dwellers.[12,15,16] These studies are consistent with findings across several other types of communicable and noncommunicable diseases, where both geographic access and transportation barriers have been linked to poor health outcomes.[17-20] Modeling geospatial access to care using geographic information system (GIS) data can provide value to local governments and ministries; this modeling can facilitate planning of health facility locations to maximize coverage and to ensure capacity to adequately cover the surrounding population.[21-23]

The objective of this study is to describe geographic access to CCCs in Rwanda under the current scenario of care being offered at BCCOE and RMH and to model changes in access in a prospective scenario where cancer care is expanded to all of Rwanda's national and regional referral hospitals.[7] Since tertiary health services are frequently concentrated in urban and wealthier regions, we will also examine how access varies by local poverty status and by level of urbanization.[13,24,25]

METHODS

Setting

Rwanda's national referral and teaching hospitals include King Faisal Hospital, RMH, Kigali University Hospital, Butare University Hospital, and Ndera Hospital; three district hospitals, Ruhengeri Hospital, Kibuye Hospital, and Kibungo Hospital, were recently recommended for elevation to national referral status.[6]

As previously described, BCCOE and RMH are the current CCCs that were used for the baseline accessibility analysis.

All the national referral hospitals were included in the modeling analyses for care expansion except King Faisal Hospital, which is considered a private hospital operated by the government, and Ndera Hospital, which is specialized for mental health and psychiatric care. Expansion of tertiary cancer care to national referral hospitals is a stated goal in the Rwanda National Cancer Control Plan 2020-2024.[7]

Data Sources

Data used for this analysis were obtained from multiple electronic public databases. The geospatial coordinates of the health care facilities were obtained using Google Maps.[26] Land cover image files from 2014 were obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) Land Cover Type (MCD12Q1) version 6 satellite data product with a 500-meter resolution.[27] Road network data were obtained from OpenStreetMap.[28] Elevation data were obtained using the Global Multi-Resolution Terrain Elevation Data satellite product in 2010 with a 500-m resolution.[29] Vector polygon data files for water barriers were obtained from Environmental Systems Research Institute (ESRI)'s ArcGIS database files (hydrolines and hydropolys).[30] Population density was obtained from the WorldPop Project, which estimates the number of people living in 100 m^2 areas in different countries around the world and harmonizes these estimates with the most recent census.[31] Population counts were estimated by the WorldPop Project using random forest models with data on environmental, socioeconomic, and built environment covariates as inputs for prediction.[32] All data sources were publicly available, and no individual patient or identifiable data were used in this analysis; hence, ethics review by an institutional review board was not indicated.

Geospatial Methods

Travel time to the nearest facility was estimated using AccessMod 5, a web-based analysis tool for geographic health services research developed by the WHO.[33] GISs databases with facility locations, elevation, road networks, land cover, and lakes and rivers were harmonized using projections in the Universal Transverse Mercator Zone 35S, with a 500-m resolution for rasters. We specified travel speeds for each land cover class and road type and used the Geographic Accessibility tool in AccessMod 5 to implement least cost distance analysis with correction for elevation to estimate the shortest path from each pixel to the closest facility.[23] Travel time assumptions are provided in Appendix Table A2. Travel speeds for vehicles were based on Rwanda's formal speed limits.[34] The analysis produced raster image files of travel time to the hospital facilities with a 1-km resolution. A previous study in Rwanda suggested that self-reported travel times were approximately 1.5 fold higher than AccessMod estimates; to account for this discrepancy, we multiplied the AccessMod 5 time estimates by a 1.5-fold correction factor to arrive at our final travel time estimates.[35]

Estimating Access

Using AccessMod 5, we estimated the percentage of Rwanda's 2020 population that live within 1 hour, 2 hours, and 4 hours of a CCC. Although there are no established thresholds for optimal geographic access to tertiary hospital services, the time thresholds chosen were based on recommendations and commonly used values in other geospatial studies in SSA.[24,25,36,37] The baseline current status accounts for care provided at RCC and BCCOE, whereas a prospective future expansion scenario models access with CCC expansion to all of Rwanda's public referral hospitals.[7]

Using the same time thresholds, we evaluated variation in accessibility on the basis of geography and socioeconomic factors such as home province, poverty level, and urbanization. Home province categorization is the highest administrative population level in the country and comprises five provinces: Kigali, Eastern, Western, Northern, and Southern (Fig 1). A 2012 population and housing census and a 2013-2014 integrated household living conditions survey were used to categorize poverty level and urbanization.[38] Poverty level was defined on the basis of average expenditure per adult and percentage of population in a sector with expenditure below a national threshold. The proportion of the population below the poverty level was classified as very low (under 20%), low (20%-29.9%), average (30%-39.9%), moderately high (40%-49.9%), high (50%-59.9%), and very high (60% or higher). Since only a few sectors had very high poverty, in our analysis, we combined high poverty and very high poverty into one category. Rural versus urban was determined at the level of villages, using a threshold population density.[38]

Data Analysis

Proportions and percentages were used to summarize population accessibility in aggregate and on the basis of predefined categories of interest. The analysis was descriptive, without formal statistical testing.

RESULTS

Overall Population Access

A choropleth map of Rwanda showing baseline accessibility of CCCs is shown in Figure 2A. At baseline, under the current scenario, 12.6% of Rwandans are estimated to have access to a CCC within 1 hour of travel time. The percentage of Rwandans within 2 hours and 4 hours of travel is progressively higher at 41.3% and 85.0%, respectively. With expansion of cancer care to all referral hospitals (Fig 2B), our model shows a marked increase in the percentage of the population with access to 37.0%, 83.8%, and 98.5% within 1-hour, 2-hour, and 4-hour travel thresholds, respectively (Fig 3).

Access Variations by Province

Consistent with the geographic location of the current cancer care facilitates in Kigali and the Northern province,

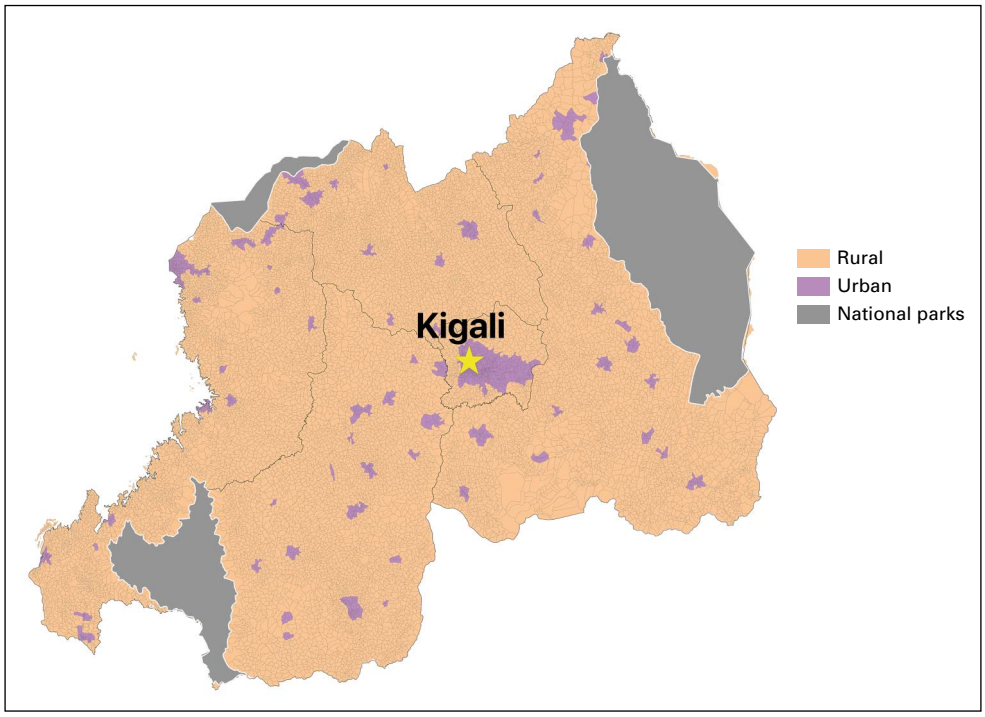

FIG 1. Map of Rwanda. The star represents the location of capital city, Kigali.

we show marked variation in population access by province (Table 1). Within 1 hour of travel under the current scenario, Kigali City has the greatest population access at 97.8%, whereas all other regions are below 15%. In the Northern Province, 14.8% of the population have 1-hour access, followed by the Eastern province at 7.1% and the Southern province at 2.2%; but none of the population in the Western province (0%) is within 1-hour access of a CCC. There was a progressive increase in population access at 2 hours and 4 hours. Four-hour access in the Northern and Eastern provinces exceeded 95%, whereas the Southern and Western provinces were 79.8% and 64.7%, respectively.

As anticipated, the modeling showed that expanded care increases population accessibility, especially in the Southern and Western provinces that were previously most underserved. With expansion of CCCs, the median travel time to a CCC markedly reduced for individuals in the

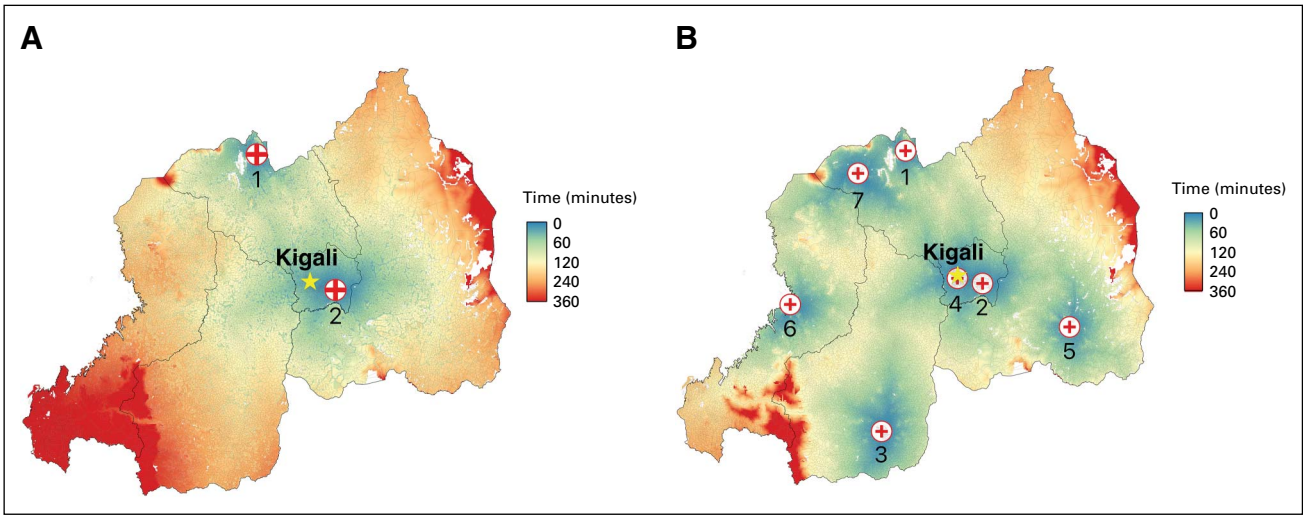

FIG 2. (A) Accessibility of current facilities. (B) Changes in accessibility of cancer care centers with expansion of services. This panel depicts time to a cancer care center under two scenarios: (1) current facilities and (2) all prospective facilities. The facilities numbered on the map are 1—Butaro Hospital, 2—Rwanda Military Hospital, 3—Butare University Hospital (CHUB), 4—Kigali University Hospital (CHUK), 5—Kibungo Hospital, 6—Kibuye Hospital, and 7—Ruhengeri Hospital. The star represents the location of capital city, Kigali, while the red crosses represent the locations of the hospitals.

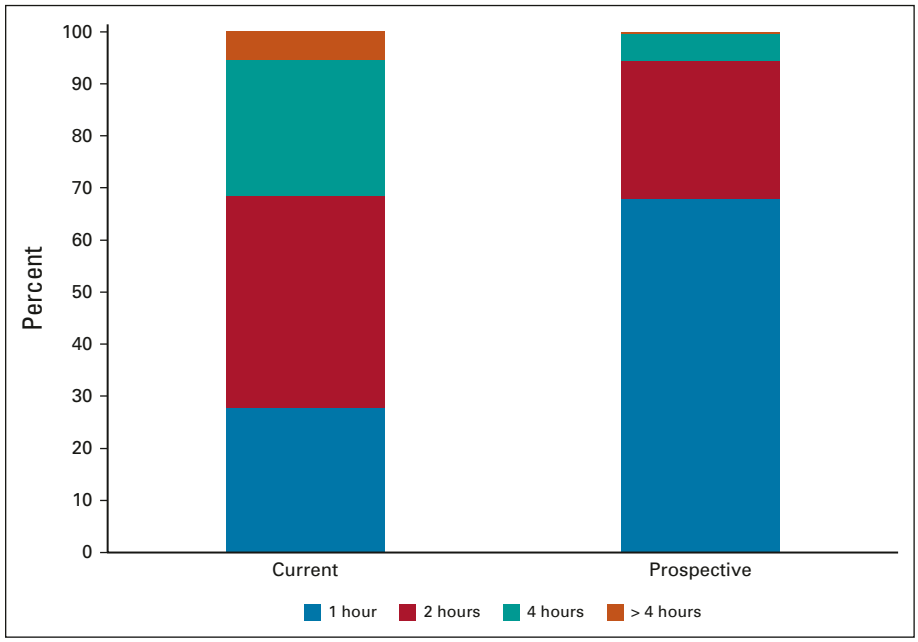

FIG 3. Cumulative access within time benchmarks under the current and prospective scenario.

Southern and Western provinces, from 195 minutes and 200 minutes to 80 minutes and 95 minutes, respectively. In the Western province, the 2-hour and 4-hour accessibility coverage increased from 1.3% and 64.7% to 70.6% and 97.5%, respectively. Further details of variation in population coverage by province are summarized in Table 1.

Access by Poverty Level and Urbanization

There was a substantial variation in care accessibility by levels of poverty and urbanization, as outlined in Tables 2 and 3. Rural areas and areas with a higher level of poverty had less access to CCCs. In the current scenario, although 64.7% of individuals in very low-poverty sectors lived within an hour of a CCC, only 4.8% of individuals in moderately high-poverty sectors and 11.6% of those in high- and very high-poverty sectors had similar access. With care expansion, there was a notable increase in the aggregate percentage of the population within 1-hour access to CCCs in moderately high-poverty sectors (33.7%) and high- and very high-poverty sectors (29.8%). This expansion would result in nearly two million Rwandans residing in moderately high-, high-, and very high-poverty sectors gaining better access to CCCs. Table 3 shows that rural areas currently have lower CCC access across all time thresholds. Similarly, expansion of services closed the rural-urban gap. Although the percentage of rural dwellers within 1 hour and 2 hours of a CCC currently stands at 7.8% and 37.0%, respectively, the care expansion scenario markedly increased

TABLE 1. Accessibility to Cancer Care Centers by Province

	Population in Thousands (%)				
Travel Time	**Eastern Province**	**Kigali City**	**Northern Province**	**Southern Province**	**Western Province**
Current state					
1 hour	233 (7.1)	1,062 (97.8)	323 (14.8)	72 (2.2)	0 (0)
2 hours	1,394 (42.4)	1,086 (100.0)	1,959 (89.8)	799 (24.4)	39 (1.3)
4 hours	3,182 (96.8)	1,086 (100.0)	2,162 (99.1)	2,612 (79.8)	2,020 (64.7)
	Median travel time in minutes (IQR)				
	137 (94-186)	26 (20-31)	96 (77-106)	195 (128-230)	222 (170-396)
Prospective state					
1 hour	769 (23.4)	1,082 (99.7)	1,171(53.7)	1,080 (33.0)	637 (20.4)
2 hours	2,337 (71.1)	1,086 (100.0)	2,142 (98.2)	2,998 (91.6)	2,205 (70.6)
4 hours	3,208 (97.6)	1,086 (100.0)	2,162 (99.1)	3,250 (99.3)	3,045 (97.5)
	Median travel time in minutes (IQR)				
	91(65-150)	11(7-16)	57 (35-90)	80 (25-101)	95 (72-130)

Abbreviation: IQR, interquartile range.

TABLE 2. Accessibility of Cancer Care Centers by Poverty Level

	Population in thousands (%)				
	Poverty Level				
Travel Time	Very Low (< 20%)	Low (20%-29.9%)	Average (30%-39.9%)	Moderately High (40%-49.9%)	High and Very High (≥ 50%)
Current state					
1 hour	613 (64.7)	266 (20.4)	141 (5.1)	217 (4.8)	396 (11.6)
2 hours	802 (84.7)	827 (63.4)	1,104 (40.0)	1,264 (27.9)	1,344 (39.4)
4 hours	909 (96.0)	1,240 (95.1)	2,351 (85.2)	4,077 (90.0)	2,428 (71.2)
	Median travel time in minutes (IQR)				
	27 (21-86)	104 (67-148)	147 (104-228)	166 (114-196)	208 (98-252)
Prospective state					
1 hour	758 (80.0)	589 (45.2)	897 (32.5)	1,527 (33.7)	1,016 (29.8)
2 hours	909 (96.0)	1,172 (89.9)	2,263 (82.0)	3,660 (80.8)	2,844 (83.4)
4 hours	947 (100.0)	1,275 (97.8)	2,716 (98.4)	4,462 (98.5)	3,355 (98.4)
	Median travel time in minutes (IQR)				
	9 (6-14)	66 (46-100)	81(54-102)	88 (49-110)	87(55-104)

Abbreviation: IQR, interquartile range.

1-hour and 2-hour access percentages to 32.5% and 82.3%, respectively. At the 1-hour threshold, care expansion would result in nearly three million rural Rwandans gaining improved access to CCCs. In aggregate, the median travel time to a CCC for rural Rwandans would also fall from 164 minutes to 84 minutes.

DISCUSSION

In this geospatial analysis of CCC access in Rwanda, our results indicate that currently, more than 87% of patients live over an hour from tertiary cancer care and nearly 60% live over 2 hours from care. However, significant variations exist on the basis of geography, poverty, and level of urbanization. Geographically, the Western province is currently the most underserved, with none (0%) of the population being within an hour of a CCC, compared with 98% in Kigali city. In addition, rural areas and areas with higher rates of poverty were more underserved compared with urban areas and those with lower rates of poverty. Although these findings are somewhat expected and on par with results from other low-HDI countries, to our knowledge, this study is the first from the East Africa region to quantify the magnitude of variation in access to tertiary cancer care.

TABLE 3. Accessibility to Cancer Care Centers in Rural and Urban Areas

	Population in Thousands (%)	
Travel Time	Rural	Urban
Current state		
1 hour	880 (7.8)	757 (45.4)
2 hours	4,175 (37.0)	1,172 (70.3)
4 hours	9,421 (83.5)	1,584 (95.0)
	Median travel time in minutes (IQR)	
	164 (102-258)	83 (24-142)
Prospective state		
1 hour	3,667 (32.5)	1,124 (67.4)
2 hours	9,286 (82.3)	1,559 (93.5)
4 hours	11,091 (98.3)	1,661 (99.6)
	Median travel time in minutes (IQR)	
	84 (56-133)	17 (9-70)

Abbreviation: IQR, interquartile range.

Although there is no universally accepted threshold in the literature for optimal CCC access, as has been reported in multiple studies of other health services such as surgery and emergency services, the general principle holds that health ministries should work to mitigate transportation and geographic barriers.[25,36,37] Our modeling analysis, which estimates the impact of expanded CCC services throughout Rwanda, demonstrates that the greatest benefit from cancer care expansion would be seen in rural areas and most notably, in some of the poorest regions of the country. For example, the percentage of rural dwellers within an hour of a CCC more than quadruples with care expansion. Although care expansion to all these sites may not be feasible in the short term, our analysis provides a framework and rational model for RMOH to guide national CCC expansion plans. In addition, similar modeling analysis can be conducted as new CCC or specialized services are established to analyze the impact of the new centers on geographic access for vulnerable populations in rural and poor areas. Coordinated patient navigation and targeted transportation support to populations with the greatest geographic access barriers can also be implemented

before care expansion. BCCOE provides comprehensive social and economic support to the most vulnerable patients in the form of food packages, transportation assistance, and waivers of insurance copays.[4,5] There is also an ongoing patient navigation pilot at RMOH that connects patients, nurse navigators, and providers across several tertiary institutions to identify and address barriers during care transitions.[39]

Although the impact of geographic access has been evaluated in epidemiology and clinical studies in SSA for other diseases, there are very few studies that look specifically at cancer care.[17-20,25] This study contributes to this growing body of work and underscores the importance of various physical and spatial dimensions that may affect cancer care delivery and outcomes. Similar recent studies in Nigeria (Knapp et al) and Gambia (Sanyang et al) have modeled the impact of cancer care expansion on population access. In our results, both studies showed wide variation in cancer care access nationwide, with services concentrated in urban regions with relatively less poverty compared with the general population.[10,13] Sanyang et al modeled accessibility to breast cancer care on the basis of straight-line distances, which tend to be less accurate and more prone to misclassification errors. Although our analytic methods are similar to Knapp et al, the significant geographical differences in landmass and population distribution between Rwanda and Nigeria limit the ability to make direct comparisons between both countries of the resulting population access estimates to CCC. Our analysis also provides a new dimension by modeling the impact of care expansion on reduction of inequity in access to CCCs.

Moreover, there are multiple dimensions to ensuring equitable care access. In addition to geographic and physical accessibility, other dimensions include availability, affordability, accommodation, and acceptability.[40] The Rwanda National Cancer Control Plan 2020-2024 outlines the RMOH's vision for addressing components of all these dimensions.[7] A multipronged approach with clear metrics, an implementation strategy, and continuous monitoring and evaluation of progress will be important for achieving this vision.

There are a few limitations of our analysis. Although we used travel accessibility thresholds of 1 hour, 2 hours, and 4 hours, there are currently no studies to support optimal travel thresholds for cancer care. Recent studies in the surgical and emergency care literature suggest that a 2-hour benchmark may be adopted for hospital services.[25,36,37] A lower threshold of 1 hour, 30 minutes, or even shorter may be necessary for primary care services, and cancer prevention and early detection services. In addition, there are some assumptions for our GIS model; patients are assumed to have uninterrupted travel from their homes using motor vehicles and at the recommended speed limits on public roads. These assumptions are likely to lead to underestimation of travel times, resulting in biased overoptimistic estimates of population coverage by CCCs. Recent studies from Rwanda indicate that self-reported travel times may be significantly longer than GIS estimates; there is also variation in travel mode and travel routes, especially with patients' use of public transportation.[16,35] We accounted for these factors by including a 1.5-fold correction factor on the basis of a previous study in Rwanda by Rudolfson et al.[35] Still, it is likely that our travel time estimates will be overly optimistic in comparison with self-reported travel times.

The current analysis also does not directly account for other determinants of physical access, which have been reported as significant barriers, such as travel costs.[16] Although these are recognized limitations, ongoing surveys of patient-reported travel experiences and costs are underway in Rwanda to improve and validate GIS modeling estimates. Finally, with increasing urbanization across SSA, it is likely that updated census and demographic surveys will show a higher proportion of Rwandans living in urban areas and closer to CCCs. More studies will be needed to explore how these demographic changes affect levels of poverty and the disparities that may persist for the population that remains in rural areas.

In conclusion, there are substantial variations in geographic access to cancer care in Rwanda. GIS modeling methods can be a valuable tool for describing the magnitude of this variation and for highlighting cancer care access inequity in vulnerable populations. These methods also have potential for influencing planning of national care expansion and monitoring of care access inequity over time. Expansion of CCCs to Rwanda's referral hospitals would meaningfully improve access to cancer treatment for all Rwandans and decrease care inequities especially faced by vulnerable populations in rural and poor areas.

AFFILIATIONS

[1]Dana-Farber Cancer Institute, Boston, MA
[2]University of Pennsylvania Perelman School of Medicine, Philadelphia, PA
[3]Harvard T.H. Chan School of Public Health, Boston, MA
[4]Rwanda Biomedical Centre, Kigali, Rwanda
[5]Partners In Health, Kigali, Rwanda
[6]King Faisal Hospital, Kigali, Rwanda
[7]The Warren Alpert Medical School of Brown University, Providence, RI
[8]Abramson Cancer Center, University of Pennsylvania, Philadelphia, PA

CORRESPONDING AUTHOR

Temidayo Fadelu, MD, MPH, Dana-Farber Cancer Institute, 450 Brookline Ave, MA-1B-17, Boston, MA 02215; e-mail: temidayo_fadelu@dfci.harvard.edu.

EQUAL CONTRIBUTION

T.F. and P.N. contributed equally to this work.

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AUTHOR CONTRIBUTIONS

Conception and design: Temidayo Fadelu, Pranay Nadella, Hari S. Iyer, Francois Uwikindi, Cyprien Shyirambere, Timothy R. Rebbeck, Lawrence N. Shulman
Financial support: Lawrence N. Shulman
Administrative support: Temidayo Fadelu, Cyprien Shyirambere, Lawrence N. Shulman
Collection and assembly of data: Temidayo Fadelu, Pranay Nadella
Data analysis and interpretation: All authors
Manuscript writing: All authors
Final approval of manuscript: All authors
Accountable for all aspects of the work: All authors

AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

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Temidayo Fadelu
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APPENDIX

TABLE A1. Current State of Cancer Services Offered at Tertiary Health Care Facilities in Rwanda

Current Tertiary Cancer Services Offered	
Public facilities	
1. Butaro Cancer Center of Excellence (BCCOE)	Diagnostic: radiology (x-ray, US), pathology[a] (H&E, IHC, GeneXpert molecular diagnostics)
	Treatment: general oncologic surgery (breast, GI, gynecologic), systemic therapy (endocrine, chemotherapy, targeted therapy)
2. Rwanda Cancer Center/ Rwanda Military Hospital (RMH)	Diagnostic: radiology (x-ray, US, CT scan, mammography), endoscopy, pathology (H&E, IHC)
	Treatment: general and specialist oncologic surgery (such as orthopedic, pediatric, gynecologic oncology, and otolaryngology), systemic therapy (endocrine, chemotherapy, targeted therapy), radiation therapy
3. Butare University Teaching Hospital	Diagnostic: radiology (x-ray, US, CT Scan), endoscopy, pathology (H&E, IHC)
	Treatment: general oncologic surgery (breast, GI, gynecologic), systemic therapy (endocrine)
4. Kigali University Teaching Hospital (CHUK)	Diagnostic: radiology (x-ray, US, CT scan, mammography), endoscopy, pathology (H&E, IHC)
	Treatment: general and specialist oncologic surgery (such as orthopedic, pediatric, gynecologic oncology, and otolaryngology), systemic therapy (endocrine)
5. Kibungo Hospital	Diagnostic: radiology (x-ray, US, CT scan)
	Treatment: general and emergency surgery
6. Kibuye Hospital	Diagnostic: radiology (x-ray, US, CT scan)
	Treatment: general and emergency surgery
7. Ruhengeri Hospital	Diagnostic: radiology (x-ray, US)
	Treatment: general and emergency surgery
Private and other facilities	
King Faisal Hospital (operated by the government)	Diagnostic: radiology (x-ray, US, mammography, CT scan and MRI), pathology[a] (H&E, IHC)
	Treatment: general and specialist oncologic surgery (such as orthopedic, pediatric, gynecologic oncology, and otolaryngology), systemic therapy (endocrine, chemotherapy, targeted therapy, immunotherapy)
Legacy Clinics (outpatient only)	Diagnostic: radiology (x-ray, US, mammogram, CT scan, MRI)
Mediheal Clinic (imaging center)	Diagnostic: radiology (x-ray, US, mammogram, CT scan, and MRI)
Lancet Laboratories	Diagnostic: pathology[a] (H&E, IHC)

Abbreviations: CT, commuted tomography; H&E, hematoxylin and eosin; IHC, immunohistochemistry; MRI, magnetic resonance imaging; US, ultrasound.

[a]Select pathology samples can be sent outside Rwanda for molecular diagnostics.

TABLE A2. Travel Speeds and Modes of Transport Across Various Land Cover and Road Types Specified in the AccessMod 5 Algorithm

Land Cover Type	Speed (km/h)	Mode
Barren	6	Walking
Closed shrublands	4	Walking
Cropland natural vegetation mosaics	6	Walking
Croplands	6	Walking
Deciduous broadleaf forests	2	Walking
Deciduous needleleaf forests	2	Walking
Evergreen broadleaf forests	2	Walking
Evergreen needleleaf forests	2	Walking
Grasslands	6	Walking
Mixed forests	2	Walking
Open shrublands	4	Walking
Permanent wetlands	2	Walking
Savannas	6	Walking
Urban and built-up lands	15	Bicycling
Water bodies	1	Walking
Woody savannas	2	Walking
Major highway	60	Motorized
Medium highway	40	Motorized
Minor highway	27	Motorized
Residential streets	18	Motorized
Walking path	3	Walking

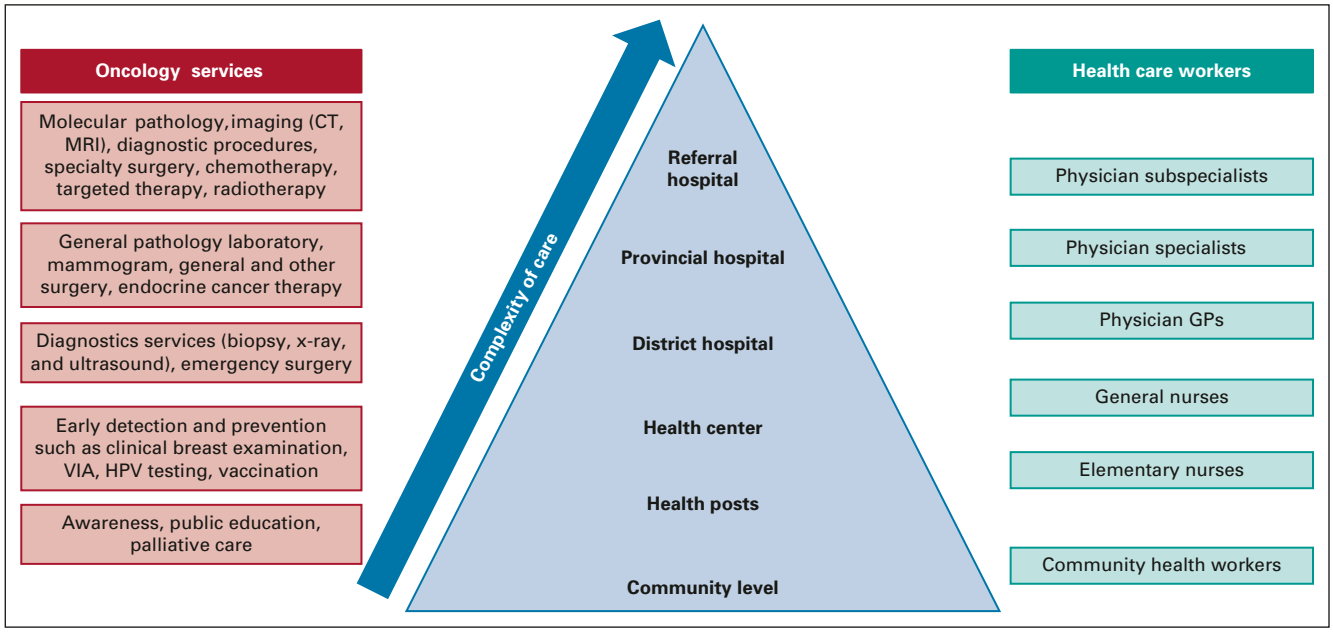

FIG A1. Rwanda health system and oncology services. CT, commuted tomography; GP, general practitioner; HPV, Human papilloma virus; MRI, magnetic resonance imaging; VIA, visual inspection with acetic acid.