Published in final edited form as:

Semin Radiat Oncol. 2017 April ; 27(2): 184–188. doi:10.1016/j.semradonc.2016.11.011.

Challenges and Prospects for Providing Radiation Oncology Services in Africa

Onyinye Balogun, MD^{*}, Danielle Rodin, MD, MPH[†], Wilfred Ngwa, PhD^{‡,§}, Surbhi Grover, MD^{||}, and John Longo, MD[¶]

^{*}Department of Radiation Oncology, Weill Cornell Medicine/New York Presbyterian Hospital, New York, NY.

[†]Department of Radiation Oncology, University of Toronto, Toronto, Ontario, Canada.

[‡]Department of Radiation Oncology, Dana Farber Cancer Institute, Harvard Medical School, Boston, MA.

[§]Department of Radiation Oncology, Brigham and Women's Hospital, Harvard Medical School, Boston, MA.

^{||}Department of Radiation Oncology, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA.

[¶]Department of Radiation Oncology, Medical College of Wisconsin, Milwaukee, WI.

Abstract

There are considerable challenges to meeting the demands of the impending cancer crisis in Africa. These include a rising incidence of cancer and cancer-related deaths, equipment and maintenance costs, and deficits in human resources and training. Addressing these issues would be crucial to tackling the increasing burden of cancer on the continent. Innovations in technology and collaborative efforts within the global oncology community have created promising solutions for establishing quality cancer care in Africa and eradicating the massive disparities that currently exist. A multifaceted approach that establishes access to quality radiation oncology services is needed to curtail this alarming trend. In this article, we describe the current status of radiotherapy services in Africa, barriers and opportunities to improve this integral component of comprehensive cancer care.

In 2012, there were 847,000 new cancer cases and 591,000 cancer-related deaths in African countries.¹ These estimates are projected to increase by at least 70% by 2030. Without any interventions to address this epidemic, African countries are faced with the grim prospect of nearly 1 million cancer deaths each year.² A multifaceted approach that establishes access to quality radiation oncology services is needed to curtail this alarming trend. We present the current status of radiotherapy services in Africa, barriers and opportunities to improve this integral component of comprehensive cancer care.

Address reprint requests to O. Balogun, Department of Radiation Oncology, Weill Cornell Medicine/New York Presbyterian Hospital, New York, NY. onyi.balogun@gmail.com.

Conflict of interest: none.

Current Status of Radiotherapy Services in Africa

In 2013, Abdel-Wahab et al³ published a detailed overview of existing radiotherapy services in Africa. At that time, less than half of African countries (23 of 54) had teletherapy services and only 20 had high-dose or low-dose brachytherapy resources. There were a total of 277 radiotherapy machines (88 cobalt-60 machines and 180 linear accelerators [LINACs]) serving 1 billion individuals. At 1 machine per 3.6 million people, this falls far below the International Atomic Energy Agency (IAEA) recommendation of 1 machine per 250,000 people.⁴ Moreover, there were regional disparities. Overall, 90% of machines were housed in north and southern Africa with 60% of machines located in Egypt or South Africa. However, three-quarters of cancer cases in Africa occurred in the 47 countries of Sub-Saharan Africa.¹ Since this initial report, a few new radiotherapy centers have been constructed. Mali⁵ and Mozambique⁶ constructed new radiotherapy facilities where none had existed. A newly constructed site at the Bugando Medical Center in Mwanza, Tanzania⁷ is also scheduled to begin treatment in the near future; however, Gabon reinstated radiotherapy services after a decade-long hiatus⁸ These are important initial steps to improve access to radiotherapy services on a continent where this issue looms large.

Challenges—Equipment

The expense of equipping new radiotherapy centers or upgrading existing machinery remains a critical barrier to improving access to cancer care in low- and middle-income countries (LMICs). In fact, cancer centers in Rwanda and Kenya have been constructed without radiotherapy owing to cost concerns.⁹ Despite both perceived and real financial constraints, radiotherapy has been shown to be a cost-effective way to both definitively treat and palliate many cancers.^{10–12} Calculating the cost of delivering safe and effective radiotherapy is complex and involves many facets including infrastructure and construction, acquiring equipment, staffing, patient throughput, maintenance, and patient expenses. Owing to many different factors ranging from political instability to geographic location, the costs of commissioning and sustaining a radiotherapy center vary substantially among countries. Equipment, including teletherapy machines, brachytherapy afterloaders and the requisite accompanying components such as planning software; radioactive isotopes, and staffing, including physicians, medical physicists, radiation therapists, and nurses, account for a sizeable proportion of the cost of administering radiotherapy. In LMICs, financing equipment is, perhaps, an even greater challenge than paying personnel.¹² The capital costs of equipment can reach as high as 81% in low-income countries, whereas in high-income countries, equipment accounts for 30% of costs and salaries predominate.⁹

Although there are limited data regarding the country-specific costs of procuring radiotherapy equipment in African countries, models exist that serve as a guides. van der Giessen et al¹³ with the support of the IAEA reported the results of a study characterizing the costs of delivering teletherapy in developing countries. Radiotherapy centers in 11 countries in Africa, Asia, Europe, and Latin America of varying income status reported their productivity and costs in the year 2002. A mathematical model using this information elicited the cost per fraction. The median cost per fraction was greater for a LINAC when compared with a cobalt machine: US\$11.02 vs US\$4.87. The authors also reported that the

prices for both types of machines increased significantly from the mid-1980s to 2001. During this period, LINAC costs ranged from US\$129,532–US\$1,800,000, whereas cobalt teletherapy machine costs ranged from under US\$70,000–US\$480,000. In 2015, the Lancet Oncology Commission outlined an investment calculation to estimate both the capital costs and operating expenses for increasing radiotherapy capacity.⁹ They described a one-off cost to create capacity as being equal to the building costs, equipment costs, and training costs divided by the number of fractions per year. This upfront cost per fraction ranges from US\$352–US\$357 in LMICs to US\$803 in high-income countries.

Another challenge to procuring equipment can be the decision to install cobalt teletherapy machines vs LINACs. The IAEA advocates cobalt teletherapy machines for many LMICs owing to their lower cost and the relative ease of treatment delivery, planning, and maintenance as compared with LINACs.¹⁴ However, the use of cobalt machines raises issues of source security and costs associated with appropriate source disposal. Vendors have designed lower-cost teletherapy units, including single energy LINACs and cobalt machines, and marketed them in developing countries.^{9,15} However, some LMICs have been reluctant to purchase these more affordable models, regarding them as second-class equipment.⁹

Publications regarding the cost of brachytherapy are more limited. In 2002, the IAEA published an article recommending the implementation of high dose rate (HDR) Iridium-192 brachytherapy in the developing world.¹⁶ The authors provided a detailed outline of expected capital costs, which include the remote afterloading unit with associated computer hardware, modification of shielding, imaging equipment, applicators, and quality assurance (QA) equipment. Their estimated HDR brachytherapy start-up cost is approximately US\$440,000. To defray import costs, some countries are developing their own brachytherapy equipment. In the 1990s, India was able to manufacture its own remote after-loading cesium low dose rate unit, which was one-fifth the cost of an imported unit. More recently, the Board of Radiation and Isotope Technology (BRIT) in India has been developing an HDR applicator with its associated software.¹⁷ The push toward self-sufficiency in manufacturing brachytherapy equipment in India and other developing countries serves as a model for countries in Africa. The expected reduction in cost would make brachytherapy more widely available to patients.

A current, widely accepted standard for a basic radiotherapy center includes at least 2 teletherapy units, a HDR afterloading brachytherapy system, a treatment planning system, mold room, a simulator, and adequate dosimetry and QA equipment. The estimated cost for this equipment reaches US\$3,000,000.¹⁸ Through its Advisory Group on increasing access to Radiotherapy Technology (AGaRT), the IAEA seeks to encourage manufacturers to design affordable radiotherapy equipment for LMICs.¹⁹

The costs and logistics of operating and maintaining radiotherapy equipment can be as prohibitive as the initial capital investment. The paucity of a robust radiotherapy maintenance infrastructure and the disparate distribution of radiotherapy centers in Africa magnify this problem.³ Datta et al¹⁸ estimate that annual recurring costs, under which maintenance and source replacement are included, can range between 5.5% and 15% of the initial capital investment. Just as the initial capital investment varies between cobalt

teletherapy and LINACs, so do the maintenance costs. Cobalt machine operation and QA are more straightforward, and the power costs are less.¹³ Although the cobalt machines can be useful for up to 20 years, the cobalt source must be replaced every 5–7 years. The cost of cobalt sources varies but has been increasing with machine complexity.¹⁵ Cobalt sources tend to be cheaper in those countries that can reprocess their own source.¹³ Additionally, security concerns in the post-9/11 era increase the complexity and cost of cobalt source replacement.¹⁵ The median annual cost for QA and maintenance for LINACs calculated by van der Giessen et al¹³ was US\$41,390 vs US\$5790 for cobalt. LINACs consume more electricity and, subsequently, have higher power costs. Iridium-192 has a half-life of 74 days, requiring quarterly source changes. This ongoing operational cost, which ranges from US\$15,000–25,000, must also be considered.¹⁶

Most manufacturers of teletherapy units offer a warranty or service contract, which is incorporated into the overall maintenance costs. As most manufacturers are in North America and Europe, timely access to engineers for maintenance and repairs is limited in Africa. This is particularly problematic for countries lacking domestic maintenance workers or those radiotherapy centers outside of major metropolitan areas who rely on people to travel from afar, driving up the cost of maintenance.¹² In scenarios, in which a warranty or service contract has expired or does not meet repair costs, radiotherapy centers can be left with nonoperational equipment.¹⁵ Addressing the critical radiotherapy maintenance deficit requires greater coordination among vendors, international organizations such as the IAEA, health ministries, and radiotherapy centers.

Challenges—Human Resources

Cancer control strategies aimed at reducing morbidity and mortality from cancer cannot be effectively executed without skilled manpower. Human resources in radiation delivery is a huge challenge in LMICs and especially in Africa, with the sub-Saharan region being worst affected.^{3,20} To operate a radiation oncology facility, not only are well-trained radiation oncologists needed, it is also very critical to have well-trained and highly skilled medical physicists, radiation therapists, dosimetrists, and nurses. Further, to deliver appropriate, timely, multidisciplinary, and evidence-based oncology care, there is a need for medical oncologists, surgical oncologists, pathologists, and radiologists. The Directory of Radiotherapy Centers (DIRAC) database maintained by IAEA supplies information on radiation therapy infrastructure available in all countries.²¹ It is, therefore currently, one of the only reliable resources of radiation infrastructure in LMICs. A recent review conducted of IAEA-DIRAC database and the needs projections for 2020 based on GLOBOCAN cancer incidence data for 84 LMICs suggested that looking at the current state, a deficit of 61.4%, 38.9%, 68.4%, and 66.5% was observed in radiation machines, radiation oncologists, medical physicists, and radiation therapy technologists, respectively.²⁰ By 2020, these countries would additionally need 9169 teletherapy units, 12,149 radiation oncologists, 9915 medical physicists, and 29,140 radiation therapy technologists. Another systematic review conducted on existing literature in radiation therapy in Africa highlighted lack of adequate human resources as a major challenge for radiation therapy delivery in Africa.⁴ Available literature from South Africa, which along with Egypt possesses most radiotherapy resources

on the continent, suggested that the country had 1 radiation oncologist per 350 patients falling short of the IAEA recommendation of 1 radiation oncologist per 200 patients.²²

Training oncology staff in Africa also poses a challenge. The cost of training a team consisting of 4 radiation oncologists, 3 medical physicists, and 7 radiation therapists is between €1,850,000 and €2,516,000 in Europe.²³ However, training in Western European countries often led to brain drain because of a perceived improvement in quality of life. A Lancet Oncology Commission article on global access to radiotherapy estimates that salaries make up 64% of operational cost of a radiotherapy facility in high-income countries compared with 10% in LMICs.²⁴

Prospects

Training Opportunities for RT Professionals

Radiation training programs in Africa have traditionally been developed and led by major international organizations, such as the World Health Organization (WHO) and the IAEA. These training programs have demonstrated local acceptance, capacity building, and sustainability in some centers. For example, a training program that was launched at the University of Zimbabwe medical school in 1990 has resulted in 8 radiation oncologists, 5 medical physicists, and 30 radiation technologists now situated in 2 cancer centers in that country.⁹ This training program was initially facilitated by consultants from the WHO, but has functioned independently with its own local staff since 1992.⁹ The IAEA plays a vital role in the training and maintenance of the workforce in Africa by coordinating their placements across Africa where training programs are available. Course content is modeled on a curriculum from international accredited organizations in combination with an IAEA syllabus, which is endorsed by American Society for Therapeutic Radiation Oncology (ASTRO) and ESTRO and is frequently reviewed to reflect local needs such as practical medical oncology content for radiation oncologists.²⁵

Currently, only 12 African countries (Algeria, Egypt, Libya, Tunisia, Morocco, Sudan, Nigeria, South Africa, Zimbabwe, Zambia, Ghana, and Tanzania) have developed training programs for radiation oncologists, radiation therapists, or medical physicists.²³ There are presently 9 documented medical physics programs that offer postgraduate MSc and PhD degrees in all of Africa, located in Algeria, Egypt, Ghana, Libya, Morocco, Nigeria, South Africa, Sudan, and Tunisia.²⁶ The IAEA has played a prominent role in medical physics training, with the launch in 2012 of a program entitled, “Developing the National Capacity to Train Medical Physicists to Support Radiotherapy Facilities in Tertiary Hospitals in Cancer Management.”²⁷ This program began with 7 resident trainees and is based on IAEA clinical training standards, ensuring that graduates would meet basic competencies.

More recently, innovative partnerships and delivery models have emerged for training in radiotherapy. As an example, the e-learning platform, Virtual University for Cancer Control (VUCCnet) Africa project was launched in 2004 by the Roche African Research Foundation, the US Government, and the IAEA. This project established training and mentorship networks within and among LMICs, while building a web-based platform to make educational materials more easily accessible and affordable to trainees.²⁸ It is being

piloted in 4 English-speaking countries: Ghana, Uganda, Tanzania, and Zambia. It is hoped that these efforts will standardize and improve training capacity. In October 2015, the Elekta Training Center Cape Town was established as a collaboration between Elekta, Tygerberg Hospital, and the Cape Town University of Technology (CPUT) in South Africa.²⁹ This facility was created to train physicists, radiation oncologists, radiographers, and neuroscience professionals from all African countries.

Online educational platforms are the new frontier in radiation oncology training, with high-income country partners increasingly working to develop appropriate and relevant educational material. Major professional societies, including the American Society for Therapeutic Radiation Oncology (ASTRO) and the American Association of Physicists in Medicine (AAPM) have developed online content specifically targeted to LMICs.³⁰ Many other institutions are also actively in developing degree-based online educational coursework for both radiation oncology and medical physics, although none are yet operational.³⁰

Innovation in Treatment Technology

With the growing global burden of cancer and major disparities in radiotherapy services, there is great need for innovations in treatment technology that can make radiotherapy services more affordable and accessible. Examples of the necessary radiotherapy equipment include (1) megavoltage treatment units; (2) simulators (X-ray or computed tomography); (3) brachytherapy treatment units; (4) dosimetry equipment for QA, shielding blocks, port films, and immobilization devices. Lower-cost technologies have the potential to change the lives of millions of individuals living in LMICs. With the emerging global radiation oncology movement, physicists, engineers, and other scientists must also now focus on developing such technologies or adaptations of current technologies that can make radiotherapy more affordable and accessible in LMICs. The development of such technologies could lead to what is called trickle-up innovations, where technologies developed with LMICs in mind may find their way into the developed world. For instance, GE health care's Ultrasound Vscan technology, originally designed for LMICs, was later commercialized as a low-cost alternative for emergency departments in industrialized countries. Ideally, efforts to develop lower-cost technology would feature collaborations with LMIC partners who can provide appropriate input during design and feedback to optimize the designs, ensuring efficacy, and durability in the intended clinical settings. Cocreation with LMIC end-users can be powerful in allowing collaborators from various disciplines, institutions, and sectors to innovate around the challenges currently faced in global radiation oncology. The Table provides examples of some emerging low-cost technologies with potential applications in global radiation oncology.

Telecommunications

In today's hyperconnected world, information and communication technologies (ICTs) increasingly play an integral role in health care and may be instrumental in catalyzing global radiation oncology collaborations in cancer care, research, and education. From telemedicine (remote consultations, remote treatment planning support, remote QA, etc.) to online learning and e-research, ICTs are becoming an indispensable part of global health with the potential to elide some of the spatiotemporal or financial barriers to global radiation

oncology. Previous work by Ngwa et al³⁰ and Datta et al³⁷ highlighted the tremendous potential of ICTs for catalyzing global radiation oncology. Datta et al proposed a 3-tier system, whereby resources are shared among institutions with differing capabilities in computed tomography simulation, treatment planning, and treatment delivery. However, Amadori et al⁷ demonstrated the feasibility of an intercontinental platform that supports telemedicine and oncology-related applications.

Conclusion

In summary, there are considerable challenges to meeting the demands of the impending cancer crisis in Africa. These include costs for equipment and maintenance as well as deficits in human resources and training. Addressing these issues will be crucial to tackling the increasing burden of cancer on the continent. Innovations in technology and collaborative efforts within the global oncology community can identify sustainable paradigms for establishing quality cancer care in Africa and eradicating the massive disparities that currently exist.

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Table**Examples of Emerging Low Cost Technologies for Global Radiation Oncology**

Emerging Technology	Potential Application/Reference
High energy current (HEC) detector	A new low-cost x-ray radiation detector ³¹
Low cost enabling technology for image-guided photodynamic therapy of oral cancer	Low-cost photodynamic therapy devices for global health settings: characterization of battery-powered LED performance and smartphone imaging in 3D tumor models ³²
Tiny drones to target cancer (TiDTaC)	Devices designed substantially reduce radiotherapy treatment/wait times, allowing for hypofractionation with minimal collateral damage to healthy tissue ³³
NanoX	A compact radiotherapy system intended to lower the costs of building and operating a radiotherapy center ³⁴
High-Z nanoparticles	Targeted radiotherapy with high-Z nanoparticles ³⁵
Glass beads	Low-cost commercial glass beads as dosimeters in radiotherapy ³⁶
RO-ILS	An online portal that allows radiation oncology centers to provide nonpatient-specific data about the radiation therapy near misses and safety incidents that have occurred at their facility in a secure, nonpunitive environment.
computational environment for radiotherapy research (CERR)	CERR (pronounced "sir") is a software platform for developing and sharing research results in radiation therapy treatment planning.
Brainlab's Qentry	An online platform for image transfer, sharing, and collaboration. Built on a secure, HIPAA-compliant infrastructure, Qentry supports clinicians throughout the referral, diagnosis, planning, and treatment workflow. Physicians can join and connect with each other for free and build a medical referral network, either for individual or hospital use.

HIPAA, Health Insurance Portability and Accountability Act; LED, light-emitting diode.