Cancer Control in Africa 4

Status of radiotherapy resources in Africa: an International Atomic Energy Agency analysis

May Abdel-Wahab*, Jean-Marc Bourque*, Yaroslav Pynda, Joanna Iżewska, Debbie Van der Merwe, Eduardo Zubizarreta, Eduardo Rosenblatt

Radiation therapy is an important component of cancer control programmes. The scarcity of radiation oncology resources in Africa is becoming more severe as cancer incidence increases in the continent. We did a longitudinal assessment of the status of radiation oncology resources in Africa to measure the extent of the problem and the effects of programmes designed to enhance radiation services in the continent. Radiation oncology departments in Africa were surveyed through the Directory of Radiotherapy Centres, and this information was supplemented by that available from International Atomic Energy Agency Regional African and Interregional project reports for 2010. Of 52 African countries included, only 23 are known to have teletherapy. These facilities are concentrated in the southern and northern states of the continent. Brachytherapy resources (high-dose rate or low-dose rate) were only available in 20 of the 52 African countries. Although progress has been made in the establishment of radiation oncology services in some countries, a large need still exists for basic radiation services, and much resource mobilisation is needed for services to keep pace with the burgeoning populations of many countries.

Introduction

Morbidity and mortality from communicable diseases have been reduced substantially in the past century. Although these remain a major affliction for many countries in Africa, increases in chronic, non-communicable diseases are characteristic of an epidemiologic transition. Worldwide, non-communicable diseases are expected to cause more deaths than communicable diseases by 2015. Cancer currently causes more deaths around the world than HIV, tuberculosis, and malaria combined.

Radiation therapy is an important component of cancer control programmes (figure 1). The scarcity of radiation oncology resources in Africa is becoming more severe with the increase in cancer incidence in the continent. In 2008, the total population of low-income and middle-income countries worldwide was 5.625 billion, among whom there were 7.82 million new cancer cases. This population is expected to reach 6.656 billion in the year 2020, with 9.28 million new cases of cancer in that year. This number will constitute almost two-thirds of the total new cases of cancer in the world, which is expected to reach more than 15 million. Moreover, from 1990 to 2020, the International Agency for Research on Cancer has predicted that cancer incidence will increase from 1.0 to 1.5 new cases per 1000 people in low-income and middle-income countries as life expectancies increase. Increases in life expectancy in all economic groups and low fertility rates in high-income countries are among the reasons that account for why 70% of all cancer deaths already occur in low-income and middle-income countries.

Assessment of the status of radiotherapy services in Africa is essential so that interventions can be planned to improve the situation and minimise the effect of scarce cancer resources on the population.

Data sources and collection

The Directory of Radiotherapy Centres (DIRAC) is a computerised international registry of radiotherapy centres that was created in 1995 and is the only centralised, comprehensive database of its type. It is estimated to include 90% of existing radiotherapy facilities worldwide, and contains information about external beam radiotherapy, brachytherapy, dosimetry, ancillary equipment, and personnel. This information is essential for assessment of the availability and accessibility of radiotherapy in specific geographical contexts. The DIRAC database is maintained by personnel at the International Atomic Energy Agency (IAEA). The directory is updated daily with information provided to IAEA by radiotherapy centres or national organisations. To keep the database as accurate as

Figure 1: A radiotherapist working at the Korle Bu Teaching Hospital, Accra, Ghana
possible, a link is sent to the registered centres to ask them to update their institutional data online every 2 years. The institutional contact checks, corrects, and completes the data in DIRAC. New records for new installations are also inputted. If a piece of equipment is no longer operational (decommissioned, etc) it is not deleted, but recorded as non-operational from a pull-down menu in the database.

One of the limitations of DIRAC is that institutions self-report, which is subject to compliance issues. This situation would limit the usefulness of the database if updates were not done regularly. However, the IAEA contacts centres that fall behind and proactive efforts are made on a regular basis to ensure that the database is kept up-to-date.

We did a longitudinal assessment of the status of radiation oncology resources in Africa during the past 12 years to assess the effect of IAEA programmes designed to enhance radiation services in the region. Radiation oncology departments in Africa were surveyed through DIRAC and this data was supplemented by information from IAEA Regional African and Interregional project reports for 2010. Countries were grouped according to the regions defined by the US Centers for Disease Control and Prevention (appendix). 6

Radiotherapy machines are the basic equipment necessary to provide radiation treatment. The number of teletherapy machines per million people is often used as an indicator for access to radiation therapy for a given region. Because cobalt-60 units are also regarded as teletherapy machines and are widely used, we have included these alongside linear accelerators in our analysis. We have recorded numbers of radiotherapy machines and brachytherapy services for 52 African countries and compared these with the numbers recorded in 1991 and 1998. Countries with populations of fewer than 100000 people6 were excluded.

Availability of radiotherapy machines

The DIRAC database in 2010 listed 13250 registered radiotherapy machines, which served a world population of about 6.68 billion people. A direct association exists between the number of teletherapy machines per million people and the gross national income per head: the average number of teletherapy machines per million people was 1.99 for the whole world, 8.6 for high-income countries, 1.6 for upper-middle-income countries, 0.71 for lower-middle-income countries, and 0.21 for low-income countries (according to World Bank definitions for 2008). 8 These statistics suggest that many African countries are at a disadvantage with respect to availability of radiotherapy resources.

Of the 52 African countries included in our analysis, only 23 offered external beam radiotherapy in 2010 (figure 2, appendix). 160 radiotherapy centres were recorded in the continent; overall, these house 277 radiotherapy machines (88 cobalt-60 units and 189 linear accelerators). However, distribution of radiotherapy resources is far from uniform. Machines were concentrated in South Africa (92) and Egypt (76), which together accounted for 60% of the radiotherapy equipment resources in Africa. The regions of north Africa and southern Africa together contained 90% of the total number of machines and more than 70% of all brachytherapy services. An estimated 198 million people (or about 20% of the population of the continent) live in one of the 29 African countries that do not have any teletherapy facilities.

Furthermore, Africa on the whole was the least developed world region with respect to radiotherapy services, with an average capacity of fewer than one teletherapy machine per million people. The countries with the highest capacities in Africa were Mauritius (2.36 teletherapy machines per million people), South Africa (1.89), Tunisia (1.53), and Egypt (0.93). Among the poorest countries, capacities ranged from 0.02 teletherapy machines per million people (ie, two machines for the whole population of more than 80 million people) in Ethiopia to 0.89 teletherapy machines per million people (or roughly one teletherapy machine for every 1-1 million people) in Morocco. By contrast, the North American and western European regions have capacities of 14.89 and 6.12 teletherapy machines per million people, respectively. Investigators of a study in 25 European Union countries estimated the number of linear accelerators needed in each country on the basis of cancer incidence, and reported that necessary capacities were between 4.0 and 8.1 teletherapy machines per million people. 9

Changes from 1991 and 1998

Radiotherapy machines in Africa have increased in number in the past two decades, from 63 recorded in 1991 to 155 in 1998 and 277 in 2010, according to data from DIRAC and from regional and inter-regional project reports. The number of machines more than doubled between 1991 and 1998; 0 although the number increased by 75% between 1998 and 2010, this rate of increase was lower than in the previous decade. The number of operational teletherapy machines increased in 17 African countries between 1998 and 2010, with substantial increases seen in South Africa (from 40 to 92), Egypt (from 53 to 76), Morocco (from six to 28), Algeria (from 11 to 20), and Tunisia (from eight to 16). Angola, Botswana, Mauritania, Senegal, and Zambia developed new radiation therapy capabilities where none existed in 1998. Congo, Gabon, and Zimbabwe had a decrease in the number of machines, whereas four countries (Liberia, Mozambique, Uganda, and the Democratic Republic of Congo) lost some of their radiotherapy capabilities when their previously functioning cobalt-60 units’ sources were not replaced. 60% of radiotherapy machines in Africa
were cobalt-60 units in 1998, compared with 32% now. Decreases in radiotherapy machines per million people were due to an increase in population (with no change in the number of machines) in Ghana, Kenya, Madagascar, and Namibia.

Assessment of optimum radiotherapy use for each country, derived from evidence for disease-specific indications of radiation therapy, shows that the biggest gap between radiotherapy machine availability and need is in Nigeria, where there are currently seven teletherapy radiotherapy machines, compared with an estimated need of 145 (difference 138; table). The next biggest gap is in Ethiopia (72), followed by the Democratic Republic of Congo (48), Kenya and Uganda (both 38), Tanzania (27), Mozambique (23), and Sudan (24).

Most radiotherapy centres in Africa are fairly basic, delivering mostly palliative services and simple, curative treatments that are based on two-dimensional imaging and treatment planning. About 80% of centres are small, with one to two radiotherapy machines (56% of centres operate with only one machine) and basic imaging and treatment-planning equipment. About 18% of centres are equipped with three to four teletherapy machines. Some advanced centres in Egypt and South Africa are equipped with five or more radiotherapy machines, together with modern imaging equipment and treatment planning systems. These centres constitute, however, only about 2% of the radiotherapy equipment needed for full curative treatments that are based on two-dimensional dosimetry.

Availability of brachytherapy
Brachytherapy resources (high-dose rate [HDR] or low-dose rate [LDR]) were only available in 20 of the 52 African countries (appendix). Of the 99 brachytherapy services in the entire continent, the countries with the greatest numbers were South Africa (21), Morocco (15), Algeria (15), Egypt (nine), Tunisia (eight), and Nigeria (seven).

Compared with western countries, in Africa more cancer cases occur in young patients, and a relative female preponderance in cancer incidence is seen. The large numbers of women affected by cancer in Africa is mainly due to the high incidence of cervical cancer, a highly preventable and potentially curable disease where adequate radiation therapy is available. Tatsuzaki and colleagues proposed a new quantitative indicator to better assess the potential capacity of brachytherapy in different countries or regions. Potential treatable capacity is defined as the total number of patients with cervical cancer that could be treated with full use of brachytherapy resources. The potentially treatable capacity (number of patients) of patients with cervical cancer in a year (brtx-cap) is calculated as follows:

\[
\text{brtx-cap/year} = (\text{Number of manual load brachytherapy kits} \times 50) + (\text{number of LDR machines} \times 80) + (\text{number of HDR machines} \times 500)
\]

When this formula was applied to data for brachytherapy resources in Africa, we calculated a potentially treatable capacity of 24 300 patients per year. Since the incidence of cervical cancer in Africa was 72 017 in 2008, a clear disparity exists between available services and need in the continent. By plotting potentially treatable capacity for individual countries with those countries’ gross national incomes per head, we can see that brachytherapy capacity is associated with economic development (figure 3).

Discussion
Radiation therapy is generally indicated for more than 50% of cancer cases. Thus, the accessibility of radiotherapy services is important in assessment of the quality of cancer control programmes. Barton and colleagues did a detailed analysis of the gap between the existing radiotherapy capacities of low-income and middle-income countries and the needs of their populations for radiation treatment. The investigators reported that, in 2002, Africa had only 18% of the radiotherapy equipment needed for full coverage of the population.
Australia serves as an example of adequate radiotherapy coverage. The overall estimate of radiotherapy use for all reported cancer cases in Australia is 52.3%. With 23% of patients retreated, an estimated 643 courses of radiation therapy would be needed for every 1000 patients diagnosed with cancer (64%). This estimate might not be applicable for all countries in Africa because of variation in presenting stages of disease, indications for treatment, and availability of equipment and trained personnel. However, we can assume that the optimum radiotherapy use would be higher in low-income and middle-income countries than a high-income country like Australia, because patients generally present with advanced-stage disease and treatment with a palliative intent is far more common than curative treatment.

Different screening and awareness programmes do, however, have an effect on the stage of disease that patients present with, and so on the number of machines needed in specific countries. The number of machines needed will also depend on cancer incidence, the types of incident cancers, accepted indications for radiation therapy, patient preference, whether or not other treatment modalities are available and offered, and the workload of each machine. Dependent on the centre, the number of patients treated per year with one machine can vary from roughly

<table>
<thead>
<tr>
<th>Population (thousands)</th>
<th>GNI per head (US$)</th>
<th>New cancer cases in 2008 (×10^3)</th>
<th>Patients who need radiotherapy (×10^3)</th>
<th>Machines needed</th>
<th>Existing machines</th>
<th>Teletherapy per million people</th>
<th>Additional machines needed</th>
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(Continues on next page)
300 to 1200. Despite this variability, one machine to cover a population of 10 million or more people, as noted here, is clearly highly inappropriate when compared with regions such as North America and western Europe, where they have roughly one machine per 70 000 and 160 000 people, respectively.

The annual incidence of cancer in Africa in 2008 was 713 206. Assuming a machine can treat 450 new cases per year, we can estimate that Africa needs more than 713 206.11 Assuming a machine can treat 450 new cases per year need radiotherapy. No GLOBOCAN data were available for São Tomé and Príncipe. ||No World Bank data were available for Somalia and Zimbabwe.

### Table: Number of radiotherapy machines needed in Africa, by country

<table>
<thead>
<tr>
<th>Country</th>
<th>Population (thousands)</th>
<th>GNI per head* (US$)</th>
<th>New cancer cases in 2008† (+×10⁶)</th>
<th>Patients who need radiotherapy‡ (+×10⁶)</th>
<th>Machine needed§</th>
<th>Existing machines</th>
<th>Teletherapy per million people</th>
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Countries are grouped according to the regions defined by the US Centers for Disease Control and Prevention (appendix). **Gross national income (GNI) per head is based on the World Bank Atlas method. †New cancer cases in 2008 are based on data from GLOBOCAN. ‡Radiotherapy need is calculated as 64% of incident cases in 2008. §Number of machines needed is based on the assumption that one machine treats an average of 450 patients per year (machines needed is listed as 0 if fewer than 450 patients per year need radiotherapy). ¶No GLOBOCAN data were available for São Tomé and Príncipe. ||No World Bank data were available for Somalia and Zimbabwe.
of linear accelerators. About 40% of the 189 linear accelerators in Africa registered in DIRAC were less than 5 years old in 2010. By contrast, about half of the 88 cobalt-60 units were older than 20 years and need to be replaced because of obsolescence.

Brachytherapy equipment does not necessarily follow the same patterns of distribution as teletherapy equipment, since these are two separate treatment modalities within the field of radiotherapy. Although brachytherapy can be quite cost-effective, its treatment indication is far narrower than that of teletherapy. Moreover, brachytherapy generally needs additional training to administer and different specifications in terms of infrastructure for treatment delivery. The paucity of brachytherapy resources as compared with teletherapy resources is a reflection of the challenge of obtaining the additional specialised education, training, and administrative infrastructure.

**Collaborative approaches**

Novel solutions to these issues have been made possible and continue through initiatives that allow collaboration between international organisations, local governments, and regional organisations. Advanced planning by governments and professional associations is essential to the success of these initiatives. The IAEA has been collaborating with different regions of Africa to help to build capacity for cancer control through a comprehensive programme that includes national, regional, and inter-regional technical cooperation projects, educational workshops, and fellowship training for radiation oncology professionals. The programme also provides technical assistance for the design, establishment, commissioning, implementation, and expansion of safe and effective national radiation therapy services, as well as the development of education and training programmes.

The agency also encourages advanced planning at a national level to prevent shortages of staff and to promote the procurement of equipment for radiation therapy centres (eg, relevant imaging, treatment planning, dosimetry, and quality control items) within a comprehensive technical cooperation programme. The programme includes clinical, medical physics, and radiation safety components, review of local infrastructure (room layout, shielding, utilities, and radiation safety) and review of the availability of qualified staff members (radiation oncologists, medical physicists, and radiation technologists and therapists). This planning and execution process is an excellent model that provides solutions to the scarcity of radiation therapy resources while ensuring a safe and effective increase in radiation oncology facilities and resources.

Regional coordination meetings are held where representatives from each member state identify needs and develop a strategic plan; visits by invited experts enhance local capacities and skills; fellowships allow professionals to enhance their competencies at other training institutions; regional training courses provide a setting in which professionals of different backgrounds...
Challenges for radiation oncology in Africa

Low awareness of cancer among African populations—
together with the dearth of facilities—contributes to
people in need of care not seeking medical attention,
and therefore to late-stage presentation. Other
contributing factors include an absence of
comprehensive screening and prevention programmes
and inadequate access to effective cancer treatments.20
Insufficient resources mean that all facets of health-care
systems are underfunded, including equipment,
staffing, and distribution, which results in an inability
to manage chronic disease.7,21 Similarly, access to care is
hindered by poorly functioning referral systems, and
either the complete absence of cancer registries or
inadequate data in those that do exist. Additional factors
include competing priorities, social or political
instability, conflict, and corruption.22 Barriers to access
to radiation treatment include a scarcity of trained
professionals, technical support, and proper equipment
(and their appropriate geographical distribution),
together with poor access to other multidisciplinary
care and diagnostic facilities (ie, radiology and pathology),
and the inadequate financial capacity of patients in
countries where there is no universal health care.

In resource-scarce settings, WHO suggests a strategy
of focusing on cost-effective prevention, early detection
and treatment, cancer awareness, good palliative care,
and data management to monitor development and
outcomes.23 Irrespective of the approach, recognition of
the extent of the problem, analysis of contributing
factors, and collaboration to implement solutions are
essential first steps to improve cost-effective
radiotherapy access for patients in Africa. The role of
national governments is essential to sustain the
radiotherapy infrastructure in African countries.
Without government efforts and support, adequate
progress in building radiotherapy capacity in Africa
would not be possible.

Conclusion

Progress has been made in the establishment of radiation
oncology services in some African countries. In time,
incidence data will change because of demographic
changes, but also because of an increase in cancer
awareness and improvement of cancer registration.
These changes will directly affect the demand for
radiotherapy services in Africa and reinforce the
increasing need for cancer prevention, early detection,
treatment, and palliation.

Nevertheless, a large shortfall still exists for basic
radiotherapy services and much work is needed to keep pace
with the burgeoning populations of many African
countries. DIRAC exemplifies a step in the right direction.
However, data registration could still be improved, and
other areas such as staffing, equipment, maintenance,
quality assurance, optimisation of resource use, and
especially access to care continue to need special attention.

Contributors

MA-W contributed to development, background research, data collection
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to data collection and analysis, and reviewed the draft version. JI was consulted on data collection and analysis, and
reviewed the draft report. DvdM contributed to data collection and
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EZ and ER were consulted for the report, and reviewed the draft version.

Conflicts of interest

We declare that we have no conflicts of interest.

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