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# Understanding the challenges of delivering radiotherapy in low- and middle-income countries in Africa

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ABSTRACT

*Background:* Access to high quality radiotherapy (RT) continues to be a major issue across Africa with Africa having just 34% of its optimal capacity.
*Methods:* We co-developed a survey with clinical, academic and policy stakeholders designed to provide a structured assessment of the barriers and enablers to RT capacity building in Africa. The survey covered nine key themes including funding, procurement, education and training. The survey was sent to RT professionals in 28 countries and the responses underwent qualitative and quantitative assessment.
*Results:* We received completed questionnaires from 26 African countries. Funding was considered a major issue, specifically the lack of a ring fenced funds from the Ministry of Health for radiotherapy and the consistency of revenue streams which relates to a lack of prioritisation for RT. In addition to a significant shortfall in RT workforce disciplines, there is a general lack of formal education and training programmes. 13/26 countries reported having some IAEA support for RT for education and training. Solutions identified to improve access to RT include a) increasing public awareness of its essential role in cancer treatment; b) encouraging governments to simplify procurement and provide adequate funding for equipment; c) increasing training opportunities for all radiotherapy disciplines and d) incentivizing staff retention.
*Conclusion:* This survey provides unique information on challenges to delivering and expanding radiotherapy services in Africa. The reasons are heterogonous across countries but one key recommendation would be for national Cancer Control plans to directly consider radiotherapy and specifically issues of funding, equipment procurement, servicing and training.
*Policy summary:* The study demonstrates the importance of mixed methods research to inform policy and overcome barriers to radiotherapy capacity and capability in LMICs.

## 1. Introduction

Radiotherapy is one of the main modalities of cancer cure, control, and palliation, with 50% of patients requiring radiotherapy during their disease course [1]. The shortfall in availability of radiotherapy in low-middle income countries (LMICs) is well established, with Africa having just 34% of its optimal capacity [2,3]. A previous systematic review of radiotherapy access in LMICs highlighted that the African continent has the fewest resources available for radiotherapy globally [4]. There is also noticeable variation in access to radiotherapy across the African nations and limited 'on the ground' data regarding the specific challenges that individual African countries face in building

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workforce capacity to provide high quality radiotherapy.

In 2015, the Global Taskforce on Radiotherapy for Cancer Control (GTFRCC) highlighted the need to increase radiotherapy treatment capacity in LMICs by 25% by 2025, to realise the health, societal and economic benefits of scaling up global access to this vital cancer treatment modality [5].

Subsequent to the GTFRCC report, a number of local efforts have been initiated in Africa to improve access to radiotherapy [6] and to improve the quality and availability of medical physics [7]. Looking forward, global co-ordination is pivotal in working towards the aims of the GTFRCC [8].

In November 2016, the International Cancer Expert Corps (ICEC) sponsored a workshop hosted by the European Organization for Nuclear Research (CERN), to define the characteristics of a novel medical linear accelerator (LINAC) for radiotherapy delivery in challenging environments [9]. Attendees included a multidisciplinary team of international experts including accelerator physicists, medical physicists, clinical and radiation oncologists, engineers, policy makers, public health and healthcare systems experts and representatives from industry.

One of the recommendations from this workshop was to ascertain more direct information regarding the functional status of radiotherapy in LMICs, by disseminating a survey on radiotherapy service capacity and capability to institutions in resource-limited countries. The aim was to gain insight from radiotherapy providers on the ground into the barriers preventing expansion of access to radiotherapy in individual centres, and to identify areas for engagement to effect positive change. The data obtained from the responses to this survey are presented here.

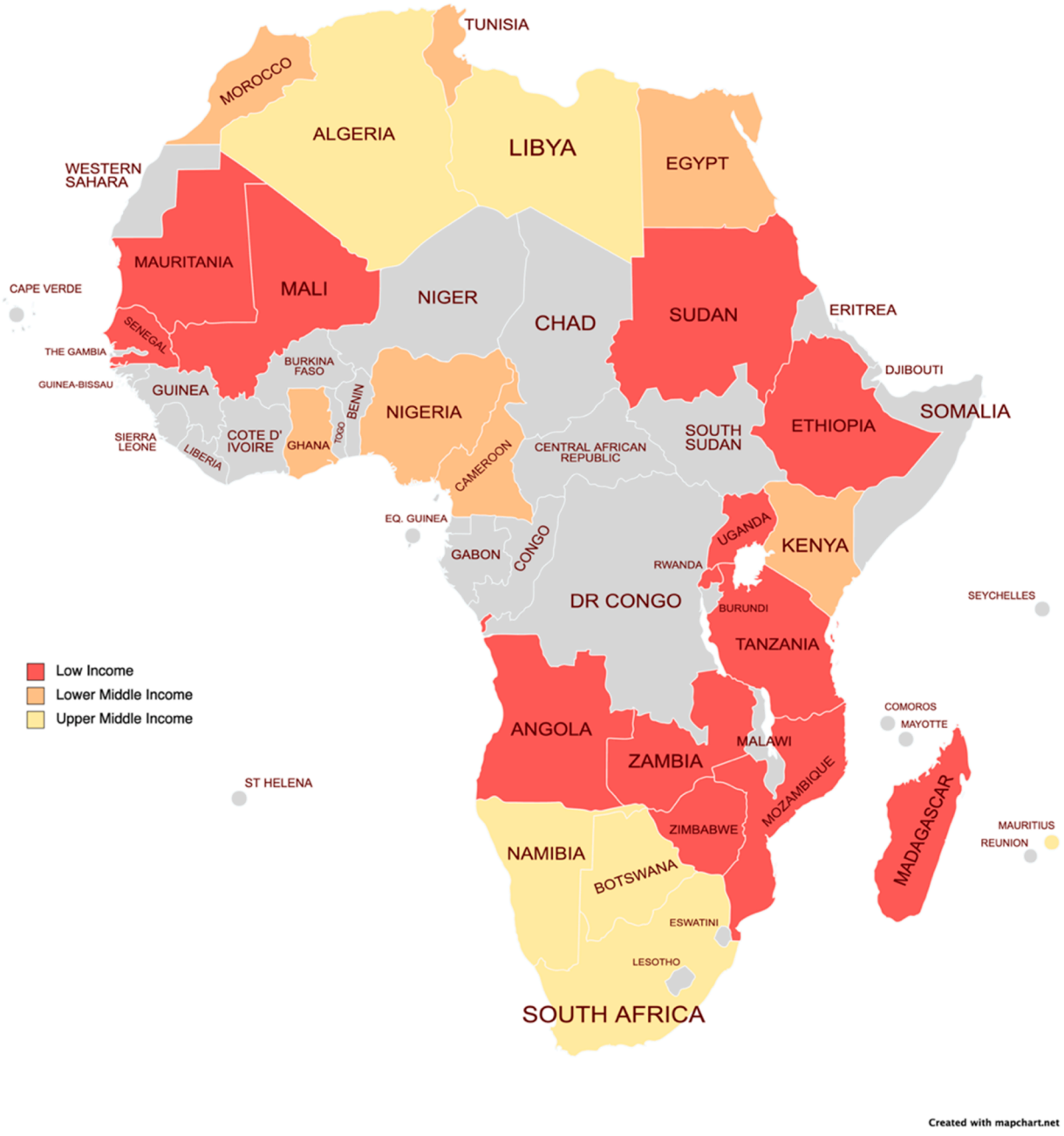


**Fig. 1.** Map displaying African countries which submitted survey responses. *Notes: 1) Colour shaded countries represent surveyed respondents (n = 26). 2) Grey shaded countries are not included in the survey* 3) Low Income Countries (LICs) shaded red are those with a Gross National Income (GNI) per capita of < =$1005 in 2016; LMICs shaded orange with a GNI per capita of $1006-$3955; and Upper-Middle Income Countries (UMICs) shaded yellow with a GNI per capita of $3956-$12,235.

## 2. Materials and methods

The survey content was designed by MD, TI, DP, and CNC, and contained 9 questions to generate a combination of quantitative and qualitative data (See Appendix 1). The survey questionnaire was sent to individuals in 28 African countries including Official Development Assistance (ODA) attendees at the second CERN workshop, co-sponsored by the UK Sciences and Technology Facilities Council (STFC), held in 2017. It was also sent to clinical leads of radiotherapy facilities in other ODA countries who could not attend. Later, it was disseminated over the course of two further workshops, in the UK and Botswana, both co-sponsored by STFC, ICEC and CERN, in 2018 and 2019, respectively [10]. Responses were collected *via* email from 26 countries. TI and MD made additional efforts to acquire missing data fields and to clarify incomplete responses. The responses represent data collected between 2019 to December 2021. Following preliminary analysis and initial discussions among AA, MD and PL, the data were analysed in detail by PL, CS and AA.

Survey responses relating to radiotherapy infrastructure (including equipment and treatment capability) were cross-referenced against the International Atomic Energy Agency's (IAEA) Directory of Radiotherapy Centres (DIRAC) [11].

Free-text responses to the remaining questions were initially analysed by identifying individual emerging themes and grouping them into broad categories. A secondary analysis was then performed to consolidate the information into two main categories reflecting 1) funding and procurement; and 2) education and training. Finally, respondents were asked to name the three major challenges in radiation therapy faced by their country, and to identify how the physical infrastructure in the country might change in the coming five to ten years.

## 3. Results

Respondents from 26 African countries returned completed surveys (see Fig. 1 for map of countries). The 26 countries (with the number of respondents per country listed as co-authors) were: Algeria (2), Angola (1), Botswana (4), Cameroon (2), Egypt (2), Ethiopia (1), Ghana (3), Kenya (1), Libya (2), Madagascar (1) Mali (2), Mauritania (1), Mauritius (1), Morocco (1), Mozambique (1), Namibia (2), Nigeria (1), Rwanda (1), Senegal (1), South Africa (1), Sudan (2), Tanzania (2), Tunisia (2), Uganda (1), Zambia (1) and Zimbabwe (1).

3 surveys were completed in French and these responses were translated in English for analysis using *Google Translate*. The respondents of the survey were classified according to the Development Assistance Committee (DAC) list of ODA recipients' gross national income (GNI) per capita[12], 50% were from low-income countries (LICs) (see Fig. 1).

The data from the surveys are discussed in four sections, representing the key themes identified from the questionnaire responses: 1) radiotherapy infrastructure and physical environment 2) funding and procurement, 3) education and training, and 4) major challenges and looking ahead.

### 3.1. Radiotherapy infrastructure and physical environment

20/26 countries reported reliable and consistent power supplies for their radiotherapy centres, however, respondents from Cameroon, Ethiopia, Uganda, and Zimbabwe reported needing back-up generators or having significant frequent power outages at their treatment centres. Senegal reported fluctuations in power supply, and in Mali, frequent power cuts are experienced in hot weather. Individual responses from all the countries surveyed reported having reliable water supplies for their radiotherapy centres, and all have air-conditioned LINAC facilities. Individual respondents reported specific environmental conditions such as extreme heat and/or heatwaves (Botswana and Egypt), dust (Senegal) and humidity (Cameroon) which have the potential to affect LINAC functionality.

Funding and procurement of radiotherapy resources (see Table 1).

**Funding**

Table 1 collates the information provided by survey respondents regarding radiotherapy funding and procurement processes. All the information has been taken from free text responses to eight questions on this topic within the survey.

When asked whether they felt that funding was adequate for their radiotherapy centres, all respondents other than those from Mauritius replied that it was not. Additionally, when asked if funding was reliable year-on-year, respondents from only four countries (Angola, Botswana, Mauritius, and Tunisia) agreed that it was.

Although most countries undertake a national funding allocation process for radiotherapy annually, there is significant competition from other medical departments locally for these funds. For example, respondents from both Ghana and Kenya specifically mentioned communicable or infectious diseases taking 'centre-stage' for funding. One respondent from Ghana noted that "*only a tiny fraction of funding is local. The majority is via loan or credit*". Respondents from Libya and Rwanda did not provide answers to the funding questions.

### 3.2. Procurement

Procurement processes for radiotherapy equipment varied amongst the survey respondents. Procurement is predominantly undertaken nationally, and most countries have a multi-year future procurement plan set out by the Ministry of Health – although, as noted by one respondent from Nigeria, these are not necessarily implemented. Additionally, in Zimbabwe, procurement planning has been hampered by lack of funds. Respondents from 13/26 countries reported that procurement was a complicated process, with individual responses from Cameroon and Ethiopia specifically mentioning "red tape" as problematic. In contrast, however, respondents from Tunisia and Zambia stated that procurement was "*not unduly complex*", and a "*fair, transparent and simple*" process respectively. Survey responses from individuals from Madagascar, Mauritania, Mauritius, and Tanzania reported simple procurement processes. The single survey response from Ethiopia noted that "*radiotherapy healthcare professionals are inadequately involved in the specification. There is a governmental multi-year procurement plan, but this is not well known to clinical staff.*" No other respondents specifically mentioned the involvement of clinical staff in procurement. Angola's equipment acquisition is done externally as there are no in-country suppliers, and although their Ministry of Health has a multi-year procurement plan, this does not include radiotherapy equipment. One respondent from Ghana noted that "*since the equipment is purchased through loans via partnerships, the lender is also involved in the procurement process.*" (Education and training (see Table 2)).

Table 2 summarises comments from individual respondents related to education and training opportunities in each country, taken from free text answers to the survey questions.

### 3.3. Education and training

In terms of education and training, the overarching sentiment was a lack of any standardised curriculum, formal education, or training programmes in radiation oncology. Higher degrees in radiotherapy-related disciplines are not widely available. For example, one respondent from Madagascar said that there is a university course for radiation oncology but not for medical physicists – "*a basic degree in nuclear physics is all that is available.*"

Many other survey respondents also reported a lack of in-country training programmes for medical physicists. In Nigeria where MSc and PhD programmes in medical physics exist, these are "*predominantly academic with minimal clinical components*". Where there are opportunities for promising and motivated students to attend training programmes out

**Table 1**
Individual perspectives regarding funding & procurement. MoH; Ministry of Health, IAEA; International Atomic Energy Agency.

| | Procurement | Funding |
|---|---|---|
| Algeria | *Procurement of equipment is done at country level, but can be complicated. The Ministry of Health (MoH) has a multi-year procurement plan.* | *Funding is agreed annually by the MoH, and is administered at country level rather than locally. There is no competition for funds, however funding is not always adequate and is not reliable year on year.* |
| Angola | *Equipment acquisition is done regionally. There are no in-country suppliers. The procurement process is complicated. The MoH has a multi-year procurement plan but this does not include radiotherapy equipment.* | *Financing is done annually, and all funding is local. There is competition for funds. Although funding is reliable year on year, it is not adequate.* |
| Botswana | *Procurement of equipment is both local and regional depending on the equipment needed. It is a simple process. There is a multi-year procurement plan from the MoH.* | *The MoH allocates national funding annually, which is reliable. Some local funding is also available. Other departments compete for funding and currently funding is inadequate.* |
| Cameroon | *Procurement of radiation therapy equipment is done at private and governmental level, supported by the International Atomic Energy Agency (IAEA) Technical Co-operation projects. The MoH has a multi-year procurement plan, but this is complicated by red tape.* | *Funding is agreed annually at MoH level. There is significant competition with other departments for limited local funds. Current funding is not adequate. Allocation of funds is extremely unreliable year on year.* |
| Egypt | *Procurement is done at both national and local levels. The MoH has an annual procurement plan. The process can be complicated. Procurement for private or charity-funded centres is more straightforward.* | *Funding is allocated at national and local levels. It is subject to competition with other departments. The MoH has an annual funding plan. Funds for radiotherapy centres are not always reliably allocated. Current funding is inadequate for needs.* |
| Ethiopia | *Procurement is a national process subject to significant red tape. Radiotherapy professionals are inadequately involved in the specification. The governmental multi-year procurement plan is not well known to clinical staff.* | *Most funding comes from central government. It is allocated on a competitive basis locally. The funding is not reliable year on year. Currently it is insufficient for the needs of radiotherapy providers.* |
| Ghana | *Procurement is at a national level. Equipment is purchased through loans via partnerships. External lenders are involved in the complicated procurement process due to multiple stakeholders and long policies to ensure transparency and minimise mismanagement.* | *Funding is allocated at both national and local levels. The majority of funding is through loans and credit with specified partners. It is neither reliable nor adequate for radiotherapy providers. Competition for local funding is an issue, particularly with departments dealing with communicable diseases.* |
| Kenya | *Procurement is done at country level. It is a complex process. The MoH has an annual procurement plan, with a five year strategic plan.* | *Funding is done yearly at national level. External funding is also sought. Infectious diseases take 'centre stage' for funding. Currently, funding is neither reliable nor adequate.* |
| Libya | *Procurement is done at country level, but is a complicated process. The MoH has a multi-year procurement plan.* | *No information on funding was provided.* |
| Madagascar | *Procurement is done internationally and is a simple process.* | *There can be competition for funds depending upon national policy.* |
| Mali | *Procurement is done at country level, through an annual purchasing plan by the Department of Health.* | *Funds are allocated nationally, but there is competition with other departments. Funding is not adequate for needs.* |
| Mauritania | *Procurement is done at country level, and is simple. The Department of Health does not have a multi-year purchasing plan.* | *Funding is done annually by the MoH. All or part of the funding is allocated locally, and there is no competition for funds. Funding is not adequate.* |
| Mauritius | *Procurement of radiation equipment is done locally and is not overly complicated.* | *Funding is done annually at a national level, and is felt to be reliable and adequate year on year.* |
| Morocco | *Procurement is done locally. It is a complicated process. Private centres have procurement procedures separate from the MoH (e.g. Fondation Lalla Salma).* | *Funding is currently not adequate for the needs of radiotherapy providers, whether in private or public sector.* |
| Mozambique | *Procurement is done at country level with IAEA technical support through expert missions.* | *Funding is done yearly by the MoH. It is currently not adequate for the needs of radiotherapy providers.* |
| Namibia | *Procurement is done nationally. It is a complicated process. There are annual procurement plans.* | *All funds are from the MoH. There is an annual national budget, which is inadequate. The funds for the entire hospital are allocated by an 'economising procurement committee'.* |
| Nigeria | *Procurement is done at both local and national levels. It is not a simple process. It is uncertain if the MoH has a multi-year procurement plan.* | *Funding is officially done annually at a national level. It is unreliable and not closely monitored. Unreliable funding streams do not meet the needs of radiotherapy. Some local funding is obtained through 'hospital internally generated revenue'. There is local competition for funds with other departments.* |
| Rwanda | *Procurement is done at a national level and is deemed 'simple'. There is a multi-year procurement plan.* | *No information on funding was provided.* |
| Senegal | *The MoH has a multi-year procurement plan. The process is not unduly complicated. Some help from the IAEA.* | *Some funding is local (i.e. within the hospital). It is inadequate for current needs. It is not subject to competition from other departments, and is unreliable year on year.* |
| South Africa | *Procurement for equipment is predominantly organised locally through the hospital's equipment budget. The hospital creates an equipment list which forms part of a multi-year procurement plan – the equipment is prioritised according to need with other departments.* | *The hospital has an annual budget and management allocates the funds. Larger equipment will be requested through provincial/ national funds. There is competition with other departments and the funding is inadequate.* |
| Sudan | *The procurement of equipment is organised at a national level. It is a complicated process. The MoH does not have a multi-year procurement plan.* | *Funding is allocated yearly at a national level. There is competition between other departments for funds. Funding is inadequate and unreliable.* |
| Tanzania | *Procurement is done at both local and country levels with significant recent IAEA input. The process is not complicated. There is a multi-year MoH procurement plan that follows international procedures.* | *The MoH allocates funds annually. The budget varies from year to year. There is no competition from other departments for local funds. Despite this, funds are not sufficient for the needs of the population.* |
| Tunisia | *For the public radiotherapy services, procurement is done at country level. It relies on a simple 'call for tender', and thus is not unduly complex. The government has a multi-year procurement plan.* | *Funding is allocated yearly at a national level. Funds are provided locally for specific projects. Funding is not reliable year on year. Current funding levels are marginally adequate.* |
| Uganda | *Procurement is done at an international level. It is very complicated and often unsuccessful. There is no multi-year procurement plan.* | *The MoH can reserve funds for multi-year projects. Most funds are from local government with help from IAEA. There is competition with other departments.* |
| Zambia | *Most procurement procedures take place at a national level, depending* | *Funding is received on a monthly basis dependent upon planned* |

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**Table 1** (*continued*)

| | Procurement | Funding |
|---|---|---|
| | *upon the source of funding. A multi-year procurement plan is in place. If funds are available, the process is fair, transparent and simple.* | *clinical activities – i.e. it is locally allocated. There is competition with other departments for activity-based funding. Thus, funds are not reliable, nor adequate for the needs of the radiotherapy department.* |
| Zimbabwe | *Procurement is done at a national level. A State Procurement Board oversees the process, which can be complicated at times. There is a multi-year procurement plan, however funding challenges can affect this.* | *Funding is allocated annually at national level, with some local funds available. These are subject to local competition with other departments. Funding is not adequate for the needs of the radiotherapy department at present.* |

of country, funding to support this is limited.

The role of the IAEA in education and training is evident, with 13/26 countries reporting IAEA support either through scholarships, fellowships, or medical physics training - as in Senegal, *via* the International Centre for Theoretical Physics (ICTP). Promising evidence of development came from a Zambian respondent, where with support from the IAEA, they have recently started an RTT training programme, and in 2019 a newly established radiation oncology programme commenced with backing from the Zambian government. In Ethiopia, an RTT training programme at BSc degree level was started in 2021.

Individuals from most countries surveyed identified that training was available through radiotherapy equipment suppliers – exceptions being respondents from Algeria, Madagascar, and Mozambique. However, they noted that this training was limited, and tended to be in the form of short-term training for staff when new equipment is installed. The duration of training varied from 3 to 4 days as reported by one individual from Egypt, to 1–2 years of intermittent training in one response from Ghana "*based on the machine and the warranty*". It was also noted that this training was directed towards operational and maintenance staff and did not constitute clinical training. (Major challenges and looking ahead (see Table 3)).

When asked to identify the three major challenges faced by their radiotherapy department, respondents identified a number of issues with common themes (see Table 3). Unifying issues were: a) lack of human resources with sufficient training or expertise, b) lack of treatment facilities across the country for the needs of the population, c) lack of funds to purchase and maintain equipment and d) poor availability of spare parts or maintenance engineers to manage the frequent breakdown of treatment machines. Finally, a number of respondents noted that radiotherapy is poorly recognised as a specialty, and as such, there is a dearth of formal training programmes in-country to address the shortfall in staffing.

Other challenges of note were the identification of patients presenting late with advanced disease, and the prohibitive cost of diagnosis and treatment for the poorest in the population. One response from Cameroon reported that there was little governmental interest in upscaling radiotherapy services, with subsequent poor budgetary allocation. The lack of investment in radiotherapy can have a knock-on effect on the tenure of trained staff – "*brain drain*" is a challenge specifically mentioned by individuals from Ethiopia and Egypt in this survey, which is previously well documented by many healthcare professionals in LMICs [13].

Despite the manifest problems encountered day to day in radiotherapy centres across Africa, in response to questions about 'looking forward', respondents expressed cautious optimism regarding positive developments in radiotherapy provision in the coming years. Plans are in place for expansion of services and increasing numbers of LINACs as reported by individuals from Ethiopia, Tanzania, and Zambia, who all expect to have increased treatment capacity available within the next

**Table 2**
Individual perspectives regarding education & training. RTT; treatment radiographer, IAEA; International Atomic Energy Agency, MoH; Ministry of Health.

| | Education & Training |
|---|---|
| Algeria | *There is no in-house education programme in radiation oncology, and no in-country degree awarding programmes for physicists or other staff. There is a residency programme for radiation oncologists. There is a Masters/ PhD programme for medical physicists, but no residency programme. Equipment suppliers do not provide training. If necessary, external training for staff can be arranged through workshops.* |
| Angola | *In-house training is available for radiation protection and for treatment radiographers (RTTs). External training can be arranged through agreements with other countries or institutions. This is funded through the International Atomic Energy Agency (IAEA) or local budget. Equipment suppliers will provide 2 days of training. The Faculty of Sciences awards a Physics degree.* |
| Botswana | *Suppliers of new equipment provide limited training in the private sector. The IAEA fund additional training and applications for African Regional Cooperative Agreement for Research (AFRA) projects are sought. There are no in-house degree-awarding programmes for physicists and no other in-house training opportunities.* |
| Cameroon | *Suppliers of new equipment provide training only when the machine is commissioned. In-house training is available for RTTs. If external staff training is required it is usually funded by the IAEA in the form of scholarships. The local university awards degrees in applied physics – but not medical physics.* |
| Egypt | *Suppliers of new equipment usually provide 3–4 days' worth of training when the equipment is installed. There are a number of degree-awarding programmes for physicists and radiation oncologists.* |
| Ethiopia | *Suppliers of new equipment provide 1–3 weeks of training, depending upon the type of machine installed. There is a 4-year MSc radiation oncology residency programme, a 2-year MSc in radiation oncology nursing and BSc. Degree-awarding programme for RTTs. Medical physics training programme is planned. For staff training elsewhere, most commonly IAEA Fellowships are sought (particularly to South Africa, Ghana, and Italy).* |
| Ghana | *Suppliers of new equipment provide training for operational and maintenance staff upon installation that can continue intermittently for 1–2 years depending upon the machine and the warranty. There are internal fellowship programmes. There are bilateral staff training opportunities with partner universities and the IAEA. The Ghana Graduate School of Nuclear and Allied Science provides postgraduate training for radiation physicists and nuclear technicians.* |
| Kenya | *Training by suppliers of new equipment is minimal – maximum 2 weeks. Most in-house staff training is "on-the-job" training. For additional staff education or training, fellowships and scholarships are required to cover costs. In country, degree-awarding programs are available for RTTs, radiation oncologists, medical physicists and oncology nurses.* |
| Libya | *Suppliers of new equipment provide training for up to 2 weeks. There is a Libyan Board for doctors to become radiation oncologists. The Ministry of Health (MoH) can help with external training. There are no degree-awarding training programmes.* |
| Madagascar | *There is a university course for radiation oncology but not for medical physicists. A basic degree in nuclear physics is available. There is also a school for RTTs. External training can be arranged and financed by IAEA, and radiation oncology internships in collaboration with French universities exist – but are difficult.* |
| Mali | *There is no in-house education or training, and no degree-awarding programmes. With support from the state and the IAEA, staff education and training can be organised elsewhere. Equipment suppliers offer training for a total of 5 weeks.* |
| Mauritania | *There is no in-house training or education, no degree-awarding programmes, and no training available from equipment suppliers.* |
| Mauritius | *There is in-house training for RTTs only. External training happens through scholarships or fellowships. Suppliers provide short term training for RTTs. There are no degree-awarding programmes.* |
| Morocco | *Suppliers of new equipment will provide variable length short-term training. There are no in-house training opportunities for radiotherapy staff. There are a number of Masters-level academic programmes. Some staff volunteer for external training opportunities; these are not mandated.* |
| Mozambique | *There is an undergraduate radiology technician course, and a section of medical physics in the applied physics branch of the University's physics department. Staff training happens through international technical support (from IAEA, Brazilian government and Calouste Gulbenkian Foundation).* |
| Namibia | |

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**Table 2** (*continued*)

| | Education & Training |
|---|---|
| | *Suppliers of new equipment provide 1 week of training. There are no in-house training programmes for radiotherapy staff. Training is usually through IAEA fellowships. There are no degree-awarding programmes for physicists.* |
| Nigeria | *Suppliers of new equipment provide training for 1–3 weeks. There is a radiation oncology residency programme and a School of Oncology Nursing. RTTs are trained infrequently with IAEA support. MSc and PhD medical physics programmes exist but are predominantly academic with minimal clinical components. External training is usually arranged through IAEA.* |
| Rwanda | *The equipment supplier provides 3 weeks of training. There is in-house radioprotection training. Some staff have undertaken training in France. There is no degree-awarding programme for physicists.* |
| Senegal | *Suppliers of new equipment provide training for 3–4 weeks for radiation oncologists, medical physicists and RTTs. In-house training is provided for radiation oncologists, radiographers and oncology nurses. IAEA supports training in medical physics via the International Centre for Theoretical Physics (ICTP). There is no degree-awarding programme for physicists.* |
| South Africa | *Equipment suppliers provide 1 week of training when they install new equipment and they also have a training centre for physicists locally to provide further support. Stellenbosch University offers degree-awarding programmes for physicists and also training for Oncologists and RTTs.* |
| Sudan | *Equipment suppliers provide training, usually between 1 and 2 weeks. It is difficult to arrange education and staff training elsewhere. There are formal in-house training programmes. There are degree-awarding programmes.* |
| Tanzania | *Suppliers of new equipment provide short periods of in-house training (5 days). Accredited in-house training at Ocean Road Cancer Institute includes a BSc in Radiation Technology for RTTs and MMed postgraduate study in Clinical Oncology for doctors. There is no degree-awarding programme for medical physics, but this is expected to begin in 2023. Depending upon the needs of the trainee, external educational opportunities can be sought subject to funds allocated for specific training.* |
| Tunisia | *Suppliers of new equipment will provide short-term training. Three universities have a radiation oncology residency programme and there are three schools of nursing and three schools of RTTs. There is an in-house refresher training programme for radiation oncologists, medical physicists and RTTs. A degree-awarding programme is available for medical physicists, RTTs and nurses.* |
| Uganda | *No current degree-awarding programme for radiation oncologists or medical physicists, they currently train in South Africa. There is a plan for local staff training to start in 2021. Suppliers of new equipment provide both on-site and off-site training for between 1 and 4 weeks.* |
| Zambia | *A Government supported newly established radiation oncology training programme commenced in 2019. The IAEA is supporting an RTT training programme. The radiotherapy centre hosts a number of students from across Africa. A curriculum for a degree in medical physics is being developed currently at the University of Zambia.* |
| Zimbabwe | *Suppliers of new equipment provide short duration training. An MSc programme in medical physics, with a clinical internship, is available in Zimbabwe. For external educational opportunities, foreign sponsorship and support is sought – e.g. from IAEA.* |

5–10 years. In Angola, there is a "*tendency towards an average growth of radiotherapy services in the country, that is, to meet the needs of patients regarding radiation therapy*". In Mozambique, the hope looking forward is that there is "*availability of more radiation therapy centres to allow more radiation therapy job opportunities in the country to motivate future professionals to engage in the radiation therapy profession*". Individual responses from Cameroon, Morocco, and Nigeria expressed more guarded optimism, citing the need for significant funding agreements to be in place before any proposed expansion of services could proceed. Responses from every country reported that there was a sense of increased interest among healthcare providers in the care of patients with cancer.

## 4. Discussion

Experiential data from frontline healthcare professionals is imperative in understanding the context of the many issues faced by LMICs in providing high quality radiotherapy services. The results of this survey provide essential on-the-ground strategic intelligence from individuals working across the breadth of the African continent, providing grass root experience of the challenges and barriers they face, as they work towards improving radiotherapy capacity. It is evident from the responses that the calls for action outlined by the GTFRCC[5] still present huge difficulties to LMICs. The specific action points of the GTFRCC report included expanding access to radiotherapy with sustainable financing, enhancing human resources for radiotherapy, and including radiotherapy in national cancer control plans. Each of these themes has been highlighted by the survey respondents here as presenting a significant challenge to quality radiotherapy provision.

The information gathered reveals wide variation in facilities and significant disparities between training and educational opportunities across the African nations. At the same time, many common themes emerge - as also reported by Ristova et al. in a recent Balkan Study [14] – particularly with respect to lack of awareness of radiotherapy at a governmental level, lack of regular, reliable funding, and complicated procurement processes hampering efficient running of services with a lack of forethought around long-term service provision and service development.

Numbers of radiotherapy machines per country have not been presented here, however it was highlighted repeatedly in the free text responses that a lack of radiotherapy centres - and teletherapy machines within those centres - remains a significant issue across the whole continent. Estimating how many radiotherapy machines are required to cover demand within a country is essential when planning radiotherapy services. This is complex and requires knowledge of the radiotherapy utilisation rate within that country, which reflects the expected requirement for radiotherapy in the cancer disease course, according to disease burden and stage of presentation. The optimal radiotherapy utilisation rate has been calculated at 54% in Africa [15], which is higher than the approximate 50% radiotherapy utilisation rate in high-income countries (HICs) [16], perhaps explained by late presentations of cancer patients in LMICs - as noted by individual responses from Botswana and Tanzania in this survey - and a lack of oncological surgery. Elmore et al. recently published an IAEA update, estimating a deficit of 1018 megavoltage units from the number needed to treat more than 1.1 million cancer patients in Africa in 2020 [17], assuming a radiotherapy utilisation rate of 64%. Cancer registry data from LMICs is therefore essential to provide Health Ministries with reliable estimates of radiotherapy need within countries, to lend weight to business cases for the provision and upscaling of radiotherapy equipment and maintenance plans.

Much work is being undertaken to develop radiotherapy treatment machines more suitable for the environmental challenges faced by many LMICs, but the problem of servicing and maintenance of existing machines continues to be a major hurdle for radiotherapy departments.

A recent related study on LINAC-based radiotherapy by Ige et al. reported and confirmed the detailed challenges faced by users on the ground [18]. Recent evidence comparing LINAC downtime and failure between a HIC (UK) and Nigeria and Botswana showed that lack of experienced engineers and the long waiting times for spare parts contributed to the significantly greater amount of downtime seen in the African centres [19]. A number of respondents in this survey echoed this, reporting that machine breakdown and lack of access to (or funds for) maintenance engineering are significant challenges. Addressing this need is critical to improving the quality and efficiency of radiotherapy services in LMICs – particularly where centres rely on a single treatment machine.

The complex procurement strategies described by many respondents present a further major hurdle for radiotherapy providers to overcome, impacting on the reliability of budgetary allocation to cancer services at the local departmental level. This in turn prevents organised forward planning for departments to develop and upscale their resources. Optimal radiotherapy provision is attained when radiotherapy services are amalgamated into national cancer control plans [20], and when transparent funding pathways are enabled with resources from government, international organisations, and NGOs. Improving awareness

**Table 3**
Individual perspectives of the main challenges faced by radiotherapy centres.

| | Lack of sufficient radiotherapy treatment facilities for population | Insufficient staffing/ human resources | Lack of sufficient maintenance/ poor availability of spare parts/ frequent machine breakdown | Limited training opportunities | High cost of equipment and maintenance | Lack of recognition of specialty |
|---|---|---|---|---|---|---|
| Algeria | ✓ | | | ✓ | | |
| Angola | | | ✓ | ✓ | | |
| Botswana | ✓ | ✓ | ✓ | | | |
| Cameroon | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Egypt | | ✓ | | ✓ | ✓ | |
| Ethiopia | ✓ | ✓ | ✓ | ✓ | | ✓ |
| Ghana | | ✓ | ✓ | | | ✓ |
| Kenya | | | | | ✓ | |
| Libya | | ✓ | | ✓ | | |
| Madagascar | ✓ | | | | | |
| Mali | ✓ | | ✓ | | | |
| Mauritania | ✓ | | | | | |
| Mauritius | | ✓ | | ✓ | | |
| Morocco | | | | ✓ | ✓ | ✓ |
| Mozambique | ✓ | | | ✓ | | ✓ |
| Namibia | ✓ | | ✓ | | ✓ | |
| Nigeria | ✓ | ✓ | ✓ | | | |
| Rwanda | ✓ | ✓ | | | | |
| Senegal | | ✓ | | ✓ | | |
| South Africa | | ✓ | ✓ | | | |
| Sudan | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Tanzania | ✓ | | | | ✓ | ✓ |
| Tunisia | ✓ | | | | | ✓ |
| Uganda | ✓ | ✓ | | | | |
| Zambia | ✓ | | ✓ | | | |
| Zimbabwe | | | ✓ | | ✓ | |

of radiotherapy as an effective cancer treatment at governmental level is imperative to ensure that countries include it as an essential part of their national cancer control plan [21].

The need to prioritise radiotherapy within national cancer strategies extends to workforce planning [22]. There is clear evidence from these results that there is a lack of training programmes in all radiotherapy disciplines, and there are issues with retention of staff who have achieved specialised training – the "brain drain". The role of the IAEA is pivotal in addressing this, and their support for access to educational opportunities was indicated by many of the respondents. Bridging the gap to the creation of national degree-awarding programmes requires government buy-in and incentivisation of students to become part of the cancer workforce.

While equipment suppliers provide variable-length operational training to the majority of countries, there are two obvious limitations to this model: one, that the training provided is specific to the manufacturer and/or model of machine installed; and two, that this is limited to countries purchasing new machines, rather than those using existing equipment who have new, junior staff joining the radiotherapy faculty. Supplier-led training is not sufficient for any radiotherapy centre as its sole source of employee training, yet as demonstrated by this survey, frequently, it is all that is available.

The GTFRCC identified the need for new approaches to train radiotherapy professionals as being essential, with an estimated 7500 radiation oncologists, 20,000 radiation therapists and 6000 medical physicists needing to be trained for LMICs by 2025. A global survey of the clinical oncology workforce by Mathew et al. in 2018 found that of 27 countries showing an extreme shortfall of clinical oncologists (as defined by >1000 incident cancers per clinical oncologist), 25 were in Africa [23]. The results from this survey echo those findings. Uplifting stories from individual countries, however, have shown that with government support, the creation of training programmes can positively impact staffing levels. Despite a significant lack of radiotherapy machines for its population, Ethiopia implemented a 4-year clinical oncology residency program in 2013. Since 2017 when the first students graduated locally, the number of clinical oncologists has increased 4-fold [24]. With trainees needing to remain in Ethiopia following completion of their residency programme, there are now enough numbers to take forward the development of five new radiation oncology facilities.

The survey responses provide a detailed insight into the reality of problems faced by radiotherapy providers in resource-limited settings in Africa. The challenges in developing and completing such surveys were recently reported by Ristova et al.[15]; there are similar limitations to the data presented here. On review and analysis of the responses, it became clear that additional information was required from some respondents to provide a clearer picture of the workforce landscape. Additional detail was sought by TI *via* email, outside of the formal survey, to clarify answers and improve the quality of information provided. Despite this, there remained some inconsistencies in the data obtained particularly with regards to workforce numbers where it was difficult to partition numbers between public and private centres and to avoid ambiguity, this information has not been presented here.

The survey looked to collect data on numbers of functioning teletherapy and brachytherapy machines, along with treatment capability (such as 2D or 3D conformal radiotherapy, IMRT *etc.*). The clarity of responses to these questions varied significantly among respondents, and there was a lack of consistency when reporting whether numbers of machines related to single institutions, or the country as a whole. The inconsistencies in these responses were more evident when data was cross-referenced with the DIRAC database, which is updated on a voluntary basis, and does not report the presence of cobalt-60 teletherapy units and LINACs separately. For these reasons, the information gathered from the surveys does not reliably reflect the current status of machine availability in each country. For the avoidance of inaccuracy, the results have therefore not been analysed or presented here.

Finally, the spectrum of countries represented is reflective of those who answered the questionnaire and not necessarily those of other countries in Africa, or other LMICs. There may therefore be other African countries not included here, whose insights may reinforce the message conveyed – or, indeed, which might provide examples of how some of these issues have already been addressed in a resource-limited setting.

## 5. Conclusion

The data presented here highlight some of the most prominent issues faced by radiotherapy providers in LMICs today, which need to be forefront in the minds of all those working towards the improvement of radiotherapy services in LMICs. The major challenges reported by individuals from all responding countries highlight persistent barriers to achieving the aims of the GTFRCC in 2015, and underline the degree to which a holistic approach to upscaling of radiotherapy services is required. Despite geographical, financial, and cultural differences among all 26 countries, what unites them is their need for an organised, integrated approach. Improving awareness of radiotherapy and encouraging governmental buy-in as to its importance for improving cancer treatment outcomes is a common goal. This requires a simplified procurement and funding process, planning for future services by increasing training opportunities in all radiotherapy disciplines, and incentivising staff retention. Respondents from all 26 countries reported optimism about the future and a growing awareness of the need for safe and effective cancer care amongst their healthcare providers.

Understanding this provider-level context is an important step towards realising the multiple benefits of upscaling global access to radiotherapy. The establishment of this unique collaborative platform of 26 African countries provides a foundation that can be expanded as other African countries acquire LINAC-based radiotherapy, and can be utilised for subsequent studies in Africa.

These results will add to the growing body of evidence supporting the urgent need to improve radiotherapy provision in underserved regions worldwide, in order to capitalize on the optimism of providers and ensure that the positive changes already happening in global radiotherapy delivery are maximized.

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## Author's contributions

All authors contributed to the conceptualization of the data and the manuscript had input from all authors.

## Conflict of interest

None of the co-authors declares any conflict of interest for this research.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jcpo.2022.100372.

## References

[1] M. Barton, S. Jacob, et al., Estimating the demand for radiotherapy from the evidence: a review of changes from 2003 to 2012, Radio. Oncol. 112 (2014) 140–144.
[2] E. Zubizarreta, J. Van Dyk, Y. Lievens, Analysis of Global Radiotherapy Needs and Costs by Geographic Region and Income Level, Clin. Oncol. 29 (2) (2017) 84–92.
[3] N.R. Datta, M. Samiei, S. Bodis, Radiation therapy infrastructure and human resources in low- and middle-income countries: present status and projections for 2020, Int J. Radiat. Oncol. Biol. Phys. 89 (2014) 448–457.
[4] S. Grover, M.J. Xu, A. Yeager, et al., A systematic review of radiotherapy capacity in low- and middle-income countries, Front Oncol. 4 (380) (2014) 1–11.
[5] R. Atun, D. Jaffray, M. Barton, et al., Expanding global access to radiotherapy, Lancet Oncol. 16 (10) (2015) 1153–1186.
[6] N. Chofor, P. Bopda, R. Bücker, et al., Mobilising stakeholders to improve access to state-of-the-art radiotherapy in low- and middle-income countries, ecancer 15 (2021) 1227, https://doi.org/10.3332/ecancer.2021.1227.
[7] T. Ige, F. Hasford, S. Tabakov, et al., Medical Physics Development in Africa - status, education, challenges, future, Med. Phys. Int. J., Spec. Issue, Hist. Med. Phys. 3 (2020) 303–316.
[8] M. Barton, E. Zubizarreta, M. Gospodarowicz, Radiotherapy in Low- and Middle-income Countries. What Can We Do Differently? Clin. Oncol. 29 (2) (2017) 69–71.
[9] ⟨https://indico.cern.ch/event/560969/overview⟩ (accessed October 2022).
[10] ⟨https://indico.cern.ch/event/767986/overview⟩ (accessed October 2022).
[11] ⟨https://dirac.iaea.org/Data/Country⟩ (accessed October 2022).
[12] ⟨https://www.oecd.org/dac/financing-sustainable-development/development-finance-standards/daclist.htm⟩ (accessed October 2022).
[13] N. ElSaghir, B. Anderson, J. Gralow, et al., Impact of merit-based immigration policies on brain drain from low- and middle-income countries, JCO Glob. Oncol. 6 (2020) 185–189.
[14] M. Ristova, V. Gershan, M. Dosanjh, et al., Patients with cancer in the countries of SEE (the balkans) region and prospective of the particle therapy center: south-east european international institute for sustainable technologies (SEEIIST), Adv. Radiat. Oncol. 6 (2021), 100772.
[15] E. Zubizarreta, E. Fidarova, B. Healy, et al., Need for radiotherapy in low and middle-income countries – the silent crisis continues, Clin. Oncol. 27 (2015) 107–114.
[16] E. Rosenblatt, Planning national radiotherapy services, Front. Oncol. 4 (2014) 315.
[17] S. Elmore, A. Polo, J. Bourque, et al., Radiotherapy resources in Africa: an International Atomic Energy Agency update and analysis of projected needs, Lancet Oncol. 22 (9) (2021) e391–e399.
[18] T. Ige, A. Jenkins, G. Burt, et al., Surveying the challenges to improve linear accelerator-based radiation therapy in Africa: a unique collaborative platform of all 28 african countries offering such treatment, Clin. Oncol. (2021) e521–e529, https://doi.org/10.1016/j.clon.2021.05.008.
[19] L. Wroe, T. Ige, O. Asogwa, et al., Comparative analysis of radiotherapy linear accelerator downtime and failure modes in the UK, Nigeria and Botswana, Clin. Oncol. 32 (4) (2020) 111–118.
[20] M. Abdel-Wahab, E. Fidarova, A. Polo, Global access to radiotherapy in low- and middle-income countries, Clin. Oncol. 29 (2) (2017) 99–104.
[21] International Atomic Energy Agency & World Health Organisation. Roadmap towards a National Cancer Control Programme: Milestones for establishing nuclear medicine, diagnostic imaging and radiotherapy services. Available at ⟨https://www.iaea.org/sites/default/files/19/10/milestones-document-2019.pdf⟩ (Accessed October 2022).
[22] S. Aruah, O. Asogwa, F. Ubah, et al., Overcoming challenges in providing radiation therapy to patients with cancer in Nigeria and experience in the national hospital Abuja, Nigeria, JCO Glob. Oncol. 6 (2020) 1232–1236.
[23] A. Mathew, Global survey of clinical oncology workforce, JCO Glob. Oncol. 14 (2018) 1–12.
[24] T. Rick, B. Habtamu, A. Abreha, et al., Ethiopia: how the care of 100 million people pivots on a single cobalt teletherapy machine, Int J. Radiat. Oncol. Biol. Phys. 106 (2) (2020) 230–235.