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RESEARCH ARTICLE

An Insight into the Current Status of the Radiotherapy Landscape in Africa: A Cross-sectional Survey Study on the Available Infrastructure and Human Resources

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ABSTRACT

Radiotherapy infrastructure and human capital are crucial for effective cancer control, yet their availability in Africa remains severely limited. This study addresses this critical gap in knowledge by providing a comprehensive assessment of radiotherapy resources across the continent. A cross-sectional descriptive web-based survey was conducted using the Research Electronic Data Capture (REDCap) system, a secure and validated online survey platform. The survey questionnaires which adhered to Content Relevance, Order, Source, and style were disseminated via email and WhatsApp to a representative sample of health professionals in 54 African countries. Data was collected through the REDCap survey while descriptive statistical methods were employed to analyze the data. In this study, 25 countries (46.3%) participated, revealing a distribution of 43 Linear Accelerators (LINAC) and 18 Cobalt-60 machines. Southern Africa (30.2%) and North Africa (30.2%) led in LINAC availability, while East Africa (38.8%) had a higher representation of Cobalt-60 machines. The healthcare practitioner distribution across Africa highlighted that the majority (35.3%) had less than four years of experience, with a minority (21.9%) having approximately 11-20 years of experience. A smaller percentage (6.0%) had over 20 years of experience, and the fewest individuals were still in training (5.0%). Most countries recorded over 20 newly diagnosed breast, cervical, and prostate cancer patients per month. North Africa had the highest proportion of practitioners administering the highest fractional dose (8.0 – 12.0 Gy). Notably, Cameroon had the longest waiting time (10.4±7.6 weeks), while South Africa had the shortest waiting time (4.0±3.0 weeks). The scarcity of radiotherapy machines and human resources in Africa is apparent, potentially leading to prolonged waiting times for patients before treatment initiation, particularly given the high incidence of more than 20 newly diagnosed patients per month in most countries. This survey underscores the urgent need to address identified gaps to improve access to both radiotherapy and human resources across the continent.

Keywords: Human capacity, Radiotherapy infrastructure, Survey, LINAC, and Cobalt-60

Introduction

The rising incidence of cancer in Africa highlights the existing healthcare challenges.[1] This is primarily attributed to the limited infrastructure and insufficient human resources dedicated to the effective diagnosis and treatment of this complex disease.[1,2] Consequently, the challenges transcend beyond the sheer prevalence of cancer, encompassing the inadequacy of healthcare facilities, diagnostic capabilities, and the shortage of trained professionals essential for delivering optimal care.[3,4]

Africa, home to over 1.4 billion people across 54 recognized sovereign countries, is facing an escalating cancer crisis (5). In 2020 alone, an estimated 1.1 million new cancer cases were diagnosed, and over 711,000 individuals succumbed to the disease.[1,5] Breast, cervical, prostate, colorectal, and liver cancers are the leading culprits, posing a significant threat to the continent's health.[1] Despite remarkable strides in cancer research and treatment modalities, clinical management remains a challenge in the 21st century, further exacerbated by the rising incidence of cancer.[6] The complexity of cancer treatment is evident in the diverse selection of available options, such as radiation therapy, immunotherapy, surgery, chemotherapy, and hormonal therapy.[7] Among these treatment modalities, radiation therapy stands as a cornerstone, with approximately half of all cancer patients receiving radiation therapy at some stage of their treatment.[8] Notably, radiation therapy constitutes a substantial 40% of curative cancer treatments.[2] Utilizing high-energy beams to eradicate cancer cells while minimizing harm to healthy tissue, radiation therapy can be employed as a standalone treatment or in conjunction with other modalities, such as surgery or chemotherapy.[8]

Radiation therapy, a crucial component of cancer treatment, encompasses two primary methods: external beam radiation therapy (EBRT) and internal beam radiation therapy (IBRT).[9-11] EBRT employs machines like linear accelerators and cobalt-60 sources to deliver high-energy radiation beams from outside the body to target specific tumor sites. In contrast, IBRT involves placing radioactive sources directly within or very close to the tumor, a technique known as brachytherapy.[10] EBRT utilizes three primary types of beams: photons, protons, and electrons. Photons, also used in diagnostic X-rays albeit at lower doses, are the most common type of EBRT beam.[9,12] Various EBRT techniques include three-dimensional conformal radiation therapy (3D-CRT), intensity-modulated radiation therapy (IMRT), image-guided radiation therapy (IGRT), tomotherapy, stereotactic radiosurgery, and stereotactic body radiation therapy (SBRT).[13,14] 3D-CRT, the most common EBRT method, employs CT, MRI, and PET scans to precisely plan the treatment area, a process called simulation.[14,15] Each EBRT technique relies on sophisticated computer algorithms to analyze images and calculate the most precise dose and treatment path possible.[9,16]

While access to advanced cancer treatments, including radiotherapy, is often taken for granted in developed nations, the situation is rather different in developing countries. An estimated shortage of approximately 5000 radiotherapy machines exists in the developing world. In regions like Africa, millions lack access to both diagnostic services and treatment.[17] Despite its proven efficacy and cost-effectiveness as a crucial cancer treatment modality, radiotherapy remains largely inaccessible in Africa,[10] with a growing gap between the need for radiotherapy and the current capacity.[18] Over half of African countries lack radiotherapy services altogether, and even in those with facilities, coverage is often inadequate.[13] In 2012, only 20 of 52 African countries had radiotherapy facilities.[18] Furthermore, financial challenges hinder the acquisition of radiotherapy machines.[19] African countries face a dilemma between choosing linear accelerators, which offer superior cancer care and reduced radiological security risks but come at a higher cost, and cobalt-60 machines, which are inferior in both aspects but are more budget-friendly and operate more reliably in challenging environments.[20] In the past decade, the International Atomic Energy Agency (IAEA) initiated a plan to address the significant shortage of cancer care resources in many economically disadvantaged nations, with an initial emphasis on Africa.[21-23]

The GLOBOCAN 2020 initiative, a comprehensive global cancer statistics project, estimates a three-fold increase in cancer cases and deaths by 2040.[24] Despite the continent's escalating cancer burden, the knowledge of available radiotherapy machines; and human capacity remains inadequate.[25] To address this critical knowledge gap and inform strategic planning, this cross-sectional survey study aims to provide a timely overview of the current state of radiotherapy infrastructure and human resources in Africa. The study's findings will serve as a resource for policymakers, healthcare providers, and international organizations dedicated to strengthening cancer care in Africa.

Materials and Methods

ETHICAL CONSIDERATIONS

Ethical approval for this study was obtained from the Biomedical Research Ethics Committee of the University of KwaZulu-Natal (Ethics Number: BREC/00003031/2021) and the Public Health Research Committee of the Department of Health in 2022. Ensuring the utmost confidentiality, informed consent was acquired from all participants, safeguarding their identities, and ensuring anonymity throughout the study. A unique study identity number, instead of personal identifiers, was utilized to preserve participant privacy. Data were securely stored and exclusively used for research purposes.

STUDY DESIGN

A cross-sectional descriptive study was undertaken to examine the availability of radiotherapy facilities and human resources in Africa. Primary data collection employed a comprehensive online questionnaire, facilitating systematic information gathering from stakeholders across the continent.

SAMPLE DEVELOPMENT

The survey adhered to the CROSS (Content Relevance, Order, Source, and Style: Appendix 1) approach to guarantee clarity, validity, and reliability. A questionnaire, incorporating expert insights from radiation oncologists, medical physicists, and public health professionals, was developed. It encompassed a comprehensive set of both closed-ended and open-ended questions addressing critical aspects of radiotherapy facilities and human resources. The questionnaire consisted of 27 questions, some with various sub-quest. (Appendix 2). Analysis excluded incomplete questionnaires, focusing solely on cases with complete data. Prior to widespread distribution, the survey underwent a pre-testing phase with a representative sample of three respondents to refine its clarity, validity, and appropriateness.

SURVEY SELECTION

Through simple random sampling (SRS) the study targeted key representatives from radiotherapy centers and healthcare institutions involved in cancer management in Africa. A purposive sampling method was employed to ensure the inclusion of countries representing different geographic regions and levels of economic development. A list of radiotherapy centers and hospitals was compiled from various sources, including the International Atomic Energy Agency (IAEA) database and national cancer registries. Participants were identified based on their roles in cancer treatment and radiotherapy administration.

DATA COLLECTION

A cross-sectional descriptive web-based survey was conducted utilizing the Research Electronic Data Capture (REDCap) system, a secure and validated online survey platform specifically designed for research data collection. The survey targeting 54 African countries was disseminated via email and WhatsApp channels, reaching out to Global Health Catalyst contacts and professional associations. Invitations were extended to members of organizations such as AORTIC, Association of Radiation Oncology of Nigeria, and South Africa Society for Clinical Radiation Oncology. To enhance response rates and minimize non-response bias, multiple reminder emails and messages were sent to potential participants. Additionally, the questionnaire was translated into French to ensure accessibility and understanding among healthcare professionals across the continent. Data collection occurred securely over a five-month period from May 1st to October 31st, 2022, through the REDCap survey was securely stored and managed within the platform. Upon survey completion, data was cleaned, coded, and tabulated to ensure accuracy and consistency.

VARIABLES OF INTEREST

The survey collected data on radiotherapy facilities, including machine type and number, treatment capacity, and geographical distribution. Information on radiotherapy techniques (external beam radiation therapy), utilization rates, and barriers to implementation were also gathered. Additionally, the survey assessed the number and specialization of healthcare professionals involved in radiotherapy administration.

DATA ANALYSIS

Descriptive statistical methods, including frequencies, percentages, and measures of central tendency, were employed to analyze the data. Results were interpreted through descriptive and inferential statistical methods aligned with the study's objectives and hypotheses.

Results

A survey conducted across 54 African countries resulted in a response rate of 46.3%, with 25 countries participating. This survey involved the distribution of 1,000 questionnaires, yielding a total of 210 responses. The key findings from these 25 countries, highlighted the competency level of radiotherapy professionals, the distribution of LINACS and Cobalt-60 machines, the monthly patient workload of radiotherapy specialists in Africa.

As shown in Figure 1, among the African countries included in the study, Nigeria (n = 48, 22.8%) and South Africa (n = 43, 20.4%) had the highest number of radiation therapy professionals in West and Southern Africa, respectively. Among the 48 professionals in Nigeria, 29 (64.0%) identified as radiation oncologists, 10 (22.2%) as medical physicists, 5 (11.1%) as radiation therapists, and 1 (2.2%) as a nuclear medicine physicist, with the remaining 3 (6.3%) not specifying their area of expertise. South Africa's 43 healthcare professionals included 18 (42.9%) radiation therapists, 12 (28.6%) radiation oncologists, 9 (21.4%) medical physicists, 2 (4.8%) nuclear medicine physicians, and 1 (2.3%) unspecified. In East Africa, Kenya had the highest number of radiation professionals (n = 17, 8.1%), followed by Egypt (n = 5, 2.4%) in North Africa and Cameroon (n = 4, 1.9%) in Central Africa. In Kenya, the 17 reported healthcare professionals comprised 10 (58.9%) radiation therapists, 2 (11.8%) medical physicists, 2 (11.8%) radiation oncologists, 2 (11.8%) administrators, and 1 (5.9%) nuclear medicine physician. Egypt reported 4 (80.0%) medical physicists and 1 (20.0%) radiation oncologist. Cameroon's healthcare workforce included 3 (75.0%) radiation oncologists and 1 (25.0%) medical physicist.

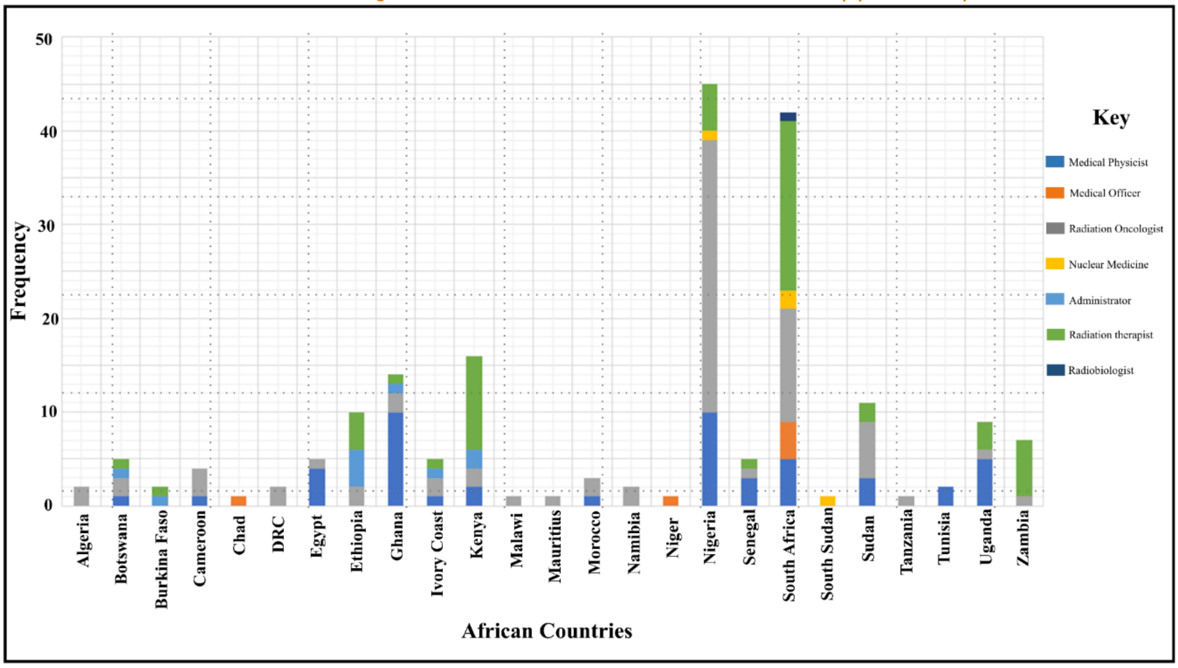

Figure 1: *Illustrates the distribution of radiotherapy specialty areas among the 25 African countries that were part of the survey.*

RADIOTHERAPY PRACTITIONERS' YEARS OF PRACTICE

The distribution of healthcare practitioners across Africa based on their work experience revealed that the majority (n = 71; 35.3%) possessed less than four years of experience. This was followed by those with 5-10 years (n = 64; 31.8%) and 11-20 years (n = 44; 21.9%) of experience. A smaller percentage (n = 12; 6.0%) held over 20 years of work experience, with the fewest individuals still in training (n = 10; 5.0%) (Figure 2).

Examining specific regions, West Africa exhibited the highest proportion of practitioners with less than four years of experience (n = 28; 39.4%), followed by East Africa (n = 19; 26.8%), South Africa (n = 13; 18.3%), North Africa (n = 7; 9.9%), and Central Africa (n = 4; 5.6%). In contrast, South Africa emerged as the region with the most practitioners having 5-10 years of work experience (n = 22; 34.4%), followed by West Africa (n = 20; 31.3%), East Africa (n = 11; 17.2%), North Africa (n = 9; 14.1%), and Central Africa (n = 2; 3.1%).

West Africa held the highest number of practitioners with 11-20 years of experience (n = 22; 50%), followed by South Africa (n = 15; 34.1%), North Africa (n = 3; 6.8%), East Africa (n = 3; 6.8%), and Central Africa (n = 1; 2.2%). Although South Africa (n = 9; 75.1%) reported the most practitioners with over 20 years of working experience, followed by East (n = 1; 8.3%), Central (n = 1; 8.3%), and North (n = 1; 8.3%) Africa. Central Africa did not report any practitioners with over 20 years of work experience. In terms of training, West Africa (n = 4; 40%) and North Africa (n = 4; 40%) reported training the most healthcare practitioners compared to other African regions (Figure 2).

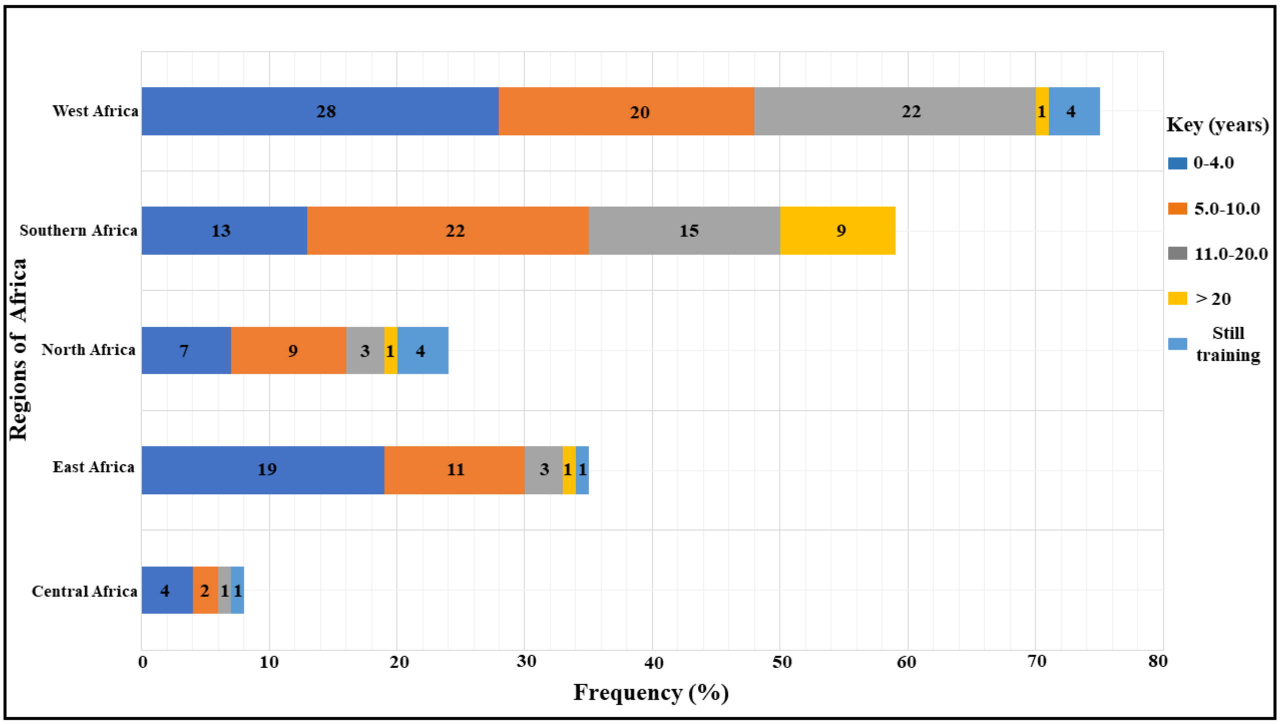

Figure 2: *Graphical representation of radiotherapy professionals' experience levels across the 25 surveyed African countries*

DISTRIBUTION OF LINACS AND COBALT-60 MACHINES IN AFRICA

LINAC Machines

As shown in Figure 3, a total of 43 LINAC machines were reported by the participating African regions in the survey. Southern Africa (n = 13; 30.2%) and North Africa (n = 13; 30.2%) led with the highest number of LINAC machines, followed by West Africa (n = 9; 20.9%), East Africa (n = 7; 16.3%) and Central Africa (n = 1; 2.4%). Breaking down the numbers by participating countries, South Africa, Nigeria, and Egypt held the lead with an equal number of LINAC machines (n = 5; 11.6%). Following closely were Botswana and Morocco, each reporting 4 (9.3%) LINAC machines, while Kenya documented 3 (7.0%). Namibia, Ghana, and Senegal contributed 2 (4.7%) machines each. Additionally, Cameroon, Ethiopia, Mauritius, Sudan, Tanzania, Tunisia, Uganda, and Zambia each reported 1 (2.3%) LINAC machine. Notably, Chad, DRC, Ivory Coast, Malawi, Niger, and South Sudan did not report any LINAC machines.

Cobalt-60 Machines

A further analysis of the study's findings revealed that a total of 18 cobalt-60 machines were collectively reported across all African regions. East Africa emerged as the region with the highest concentration of cobalt-60 machines, accounting for 7 (38.8%) of the total number. Central Africa, West Africa, and North Africa each reported 3 (16.7%) cobalt-60 machines, while South Africa contributed 2 (11.1%). Among the participating countries, Nigeria (n=3; 16.7%) held the highest number of cobalt-60 machines, followed closely by Cameroon, Tanzania, and Uganda, each reporting 2 (11.1%) machines. Algeria, Egypt, Ethiopia, Ivory Coast, Kenya, Mauritius, South Africa, Sudan, and Zambia each reported 1 (5.6%) machine. The remaining participating countries (Botswana, Burkina Faso, Chad, DRC, Ghana, Malawi, Morocco, Namibia, Niger, Senegal, South Sudan, and Tunisia) did not report any available cobalt-60 machines (refer to Figure 3).

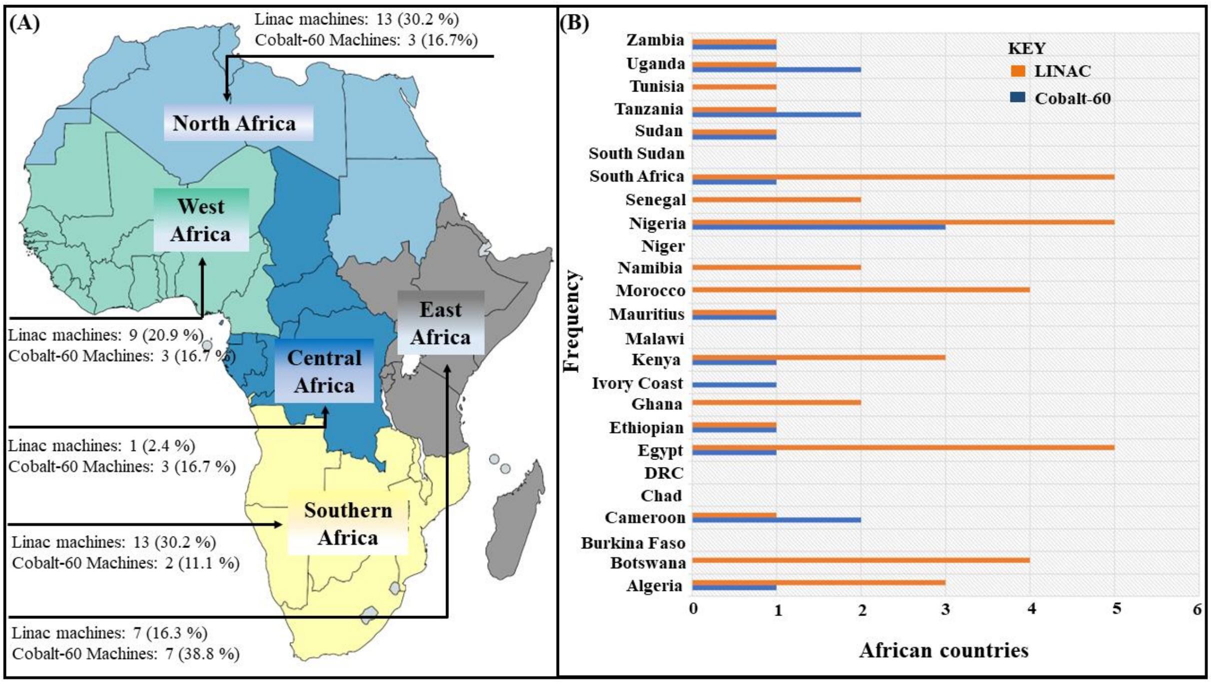

Figure 3: *Illustrates the distribution of available LINACs and Cobalt-60 machines across African regions (A), and (B) and in specific African countries.*

NUMBER OF CANCER PATIENTS RADIOTHERAPY PROFESSIONALS SEE PER MONTH IN AFRICA

The number of newly diagnosed breast, cervical and prostate cancer patients who needed radiation therapy per practice of the participating countries are as follows:

BREAST CANCER

In Figure 4.(A), most participating African countries (n = 12; 48%), including Botswana, Egypt, Ethiopia, Ghana, Kenya, Namibia, Nigeria, Sudan, South Africa, Tanzania, Uganda, and Zambia, exhibited an average monthly incidence of more than 20 newly diagnosed patients. Conversely, 12% of the countries (Algeria, Mauritius, and Algeria) reported an average patient count ranging from 15 to 20, while 8% of the countries (Tunisia and South Sudan) observed an average patient count between 10 and 14. Nevertheless, 32% of the countries (n = 8), including Burkina Faso, Cameroon, Chad, DRC, Ivory Coast, Malawi, Morocco, and Niger, reported encountering an average of 5 to 9 newly diagnosed patients per month.

CERVICAL CANCER

Figure 4.(B) illustrates the monthly incidences of newly diagnosed cervical cancer, as reported by participating African countries. Most countries (40%), including Ethiopia, Ghana, Kenya, Malawi, Niger, Nigeria, Uganda, South Africa, Tanzania, and Zambia, documented the observation of more than 20 newly diagnosed patients per month. In contrast, 24% of the countries (Botswana, Egypt, Ivory Coast, Mauritius, Namibia, and South Sudan) reported encountering 15-20 newly diagnosed cervical cancer cases monthly. Conversely, a lower incidence of 5-9 patients was reported in 16% of the countries (Algeria, Burkina Faso, Cameroon, and Chad), while 20% of the countries (DRC, Morocco, Senegal, Sudan, and Tunisia) reported observing 10-14 newly diagnosed patients monthly.

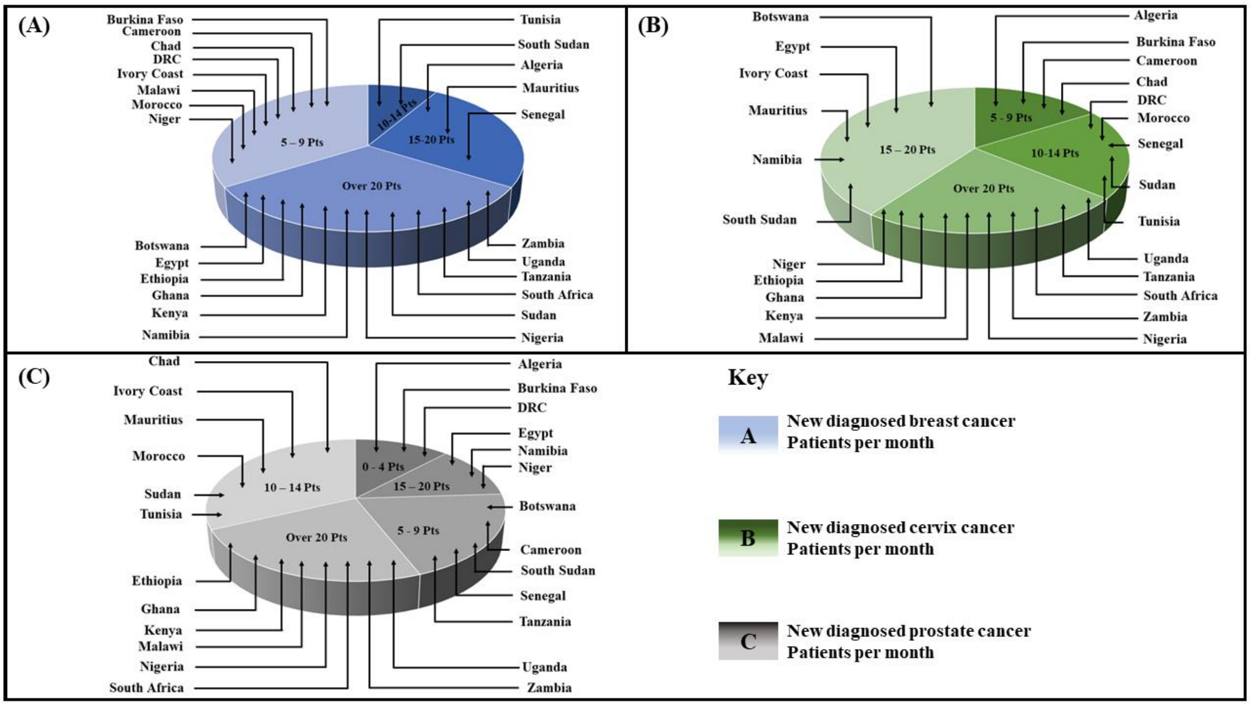

Figure. 4: *A pie-chart illustrating the average monthly number of newly diagnosed patients with (A) breast, (B) cervical and (C) prostate cancer requiring radiation therapy, according to data derived from the participating countries.*

PROSTATE CANCER

Figure 4(C) depicts the distribution of monthly newly diagnosed prostate cancer cases across the participating African countries. The majority (32%), encompassing Botswana, Ghana, Kenya, Malawi, Nigeria, South Africa, Uganda, and Zambia, reported observing over 20 new prostate cancer diagnoses per month. In contrast, 25% of the countries, including Chad, Ivory Coast, Mauritius, Morocco, Sudan, and Tunisia, encountered 10-14 newly diagnosed prostate cancer cases monthly. Similarly, 20% of the countries (Botswana, Cameroon, South Sudan, Senegal, and Tanzania) reported identifying 5-9 newly diagnosed prostate cancer cases monthly. Conversely, Algeria, Burkina Faso, and DRC (12%) had a lower incidence of 0-4 diagnosed patients, while Egypt, Namibia, and Niger (12%) recorded 15-20 newly diagnosed patients

RADIOTHERAPY DOSE FRACTIONATION AND WAITING TIMES IN AFRICA

Subsequently, the investigation sought to ascertain the radiotherapy dose fractionation (Figure 5) and waiting time for the initiation of radiotherapy (Figure 6). Dose fractionation involves the division of the total radiation dose into multiple smaller doses administered over several days, thereby mitigating the impact of toxic effects on healthy cells.[26]

APPLICATION OF RADIOTHERAPY IN DOSE FRACTIONATION

According to Figure 5; most healthcare practitioners in Southern Africa (n = 32; 37.2%) and West Africa (n = 30; 34.9%%) expressed a preference for a fraction dose ranging from 2.0 to 5.0 Gy, closely followed by < 2.0 Gy (Southern Africa: n = 18; 20.9%, and West Africa: n = 34; 39.5%). Conversely, in East Africa (n=20; 23.2%), North Africa (n=9; 10.4%) and Central Africa (n=5; 5.8%), a fraction dose of < 2.0 Gy was favored. North Africa (n=2; 50%) exhibited the highest proportion of practitioners administering the highest fractional dose (8.0 – 12.0 Gy), followed by Southern and West Africa (n=1; 25% each). Notably, no practitioners reported using this highest fractional dose in East Africa and Central Africa. Conversely, practitioners in Kenya exhibited a preference for a fractional dose of < 2 Gy (n = 11), followed by 2.0 – 5.0 Gy (n = 6). Specifically, practitioners from South Africa (n = 26), Nigeria (n = 24), and Sudan (n = 2) reported administering doses in the range of 8.0 – 12.0 Gy, while no practitioners from other participating African countries indicated the use of such high doses. Notably, the utilization of a dose range of 5.0 – 7.0 Gy was reported only in South Africa.

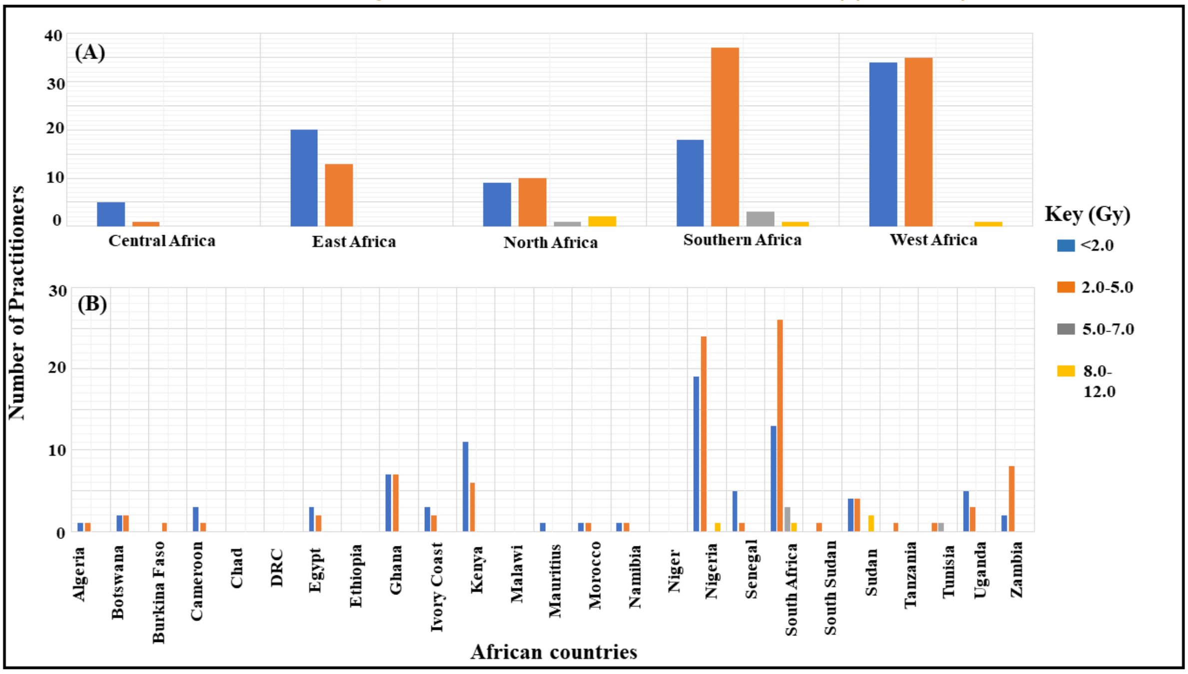

***Figure. 5:** A bar-graph illustrating the radiotherapy fraction dose administered by health practitioners across participating Africa (A) regions and (B) countries.*

PATIENT WAITING TIMES FOR TREATMENT IN AFRICA

An investigation of the average waiting time after histological diagnosis to consultation of 16 countries that gave feedback showed that, Cameroon had the longest waiting time (10.4±7.6 weeks), followed by Ghana (9.5±3.8 weeks), and Zambia (7.0±18.3 weeks). On the other hand, South Africa and Nigeria had waiting times of 4.6±3.0 weeks and 4.0±3.0 weeks, respectively (Figure 6.(A).

As shown in Figure 6.(B), Namibia had the longest average waiting time of 14.0±6.4 weeks from Multi-Disciplinary Team (MDT) discussion to commencement of the actual treatment. Egyptian healthcare workers reported the shortest waiting time of 2.6±1.3 weeks. South African and Nigerian healthcare practitioners reported average waiting times of 5.6±4.9 weeks and 6.4±5.5 weeks, respectively.

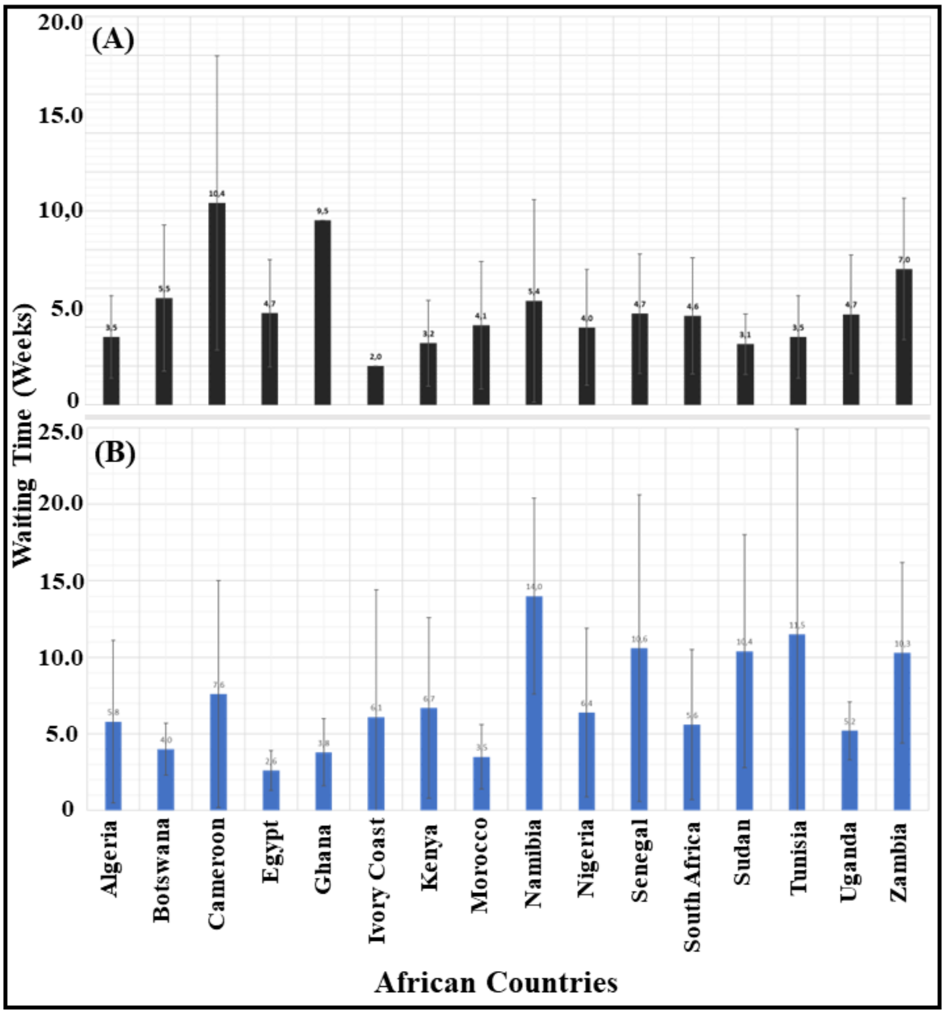

***Figure. 6:** A bar graph depicting the mean waiting time (in weeks) for two key intervals: (A) the duration from histological diagnosis to the initial consultation, and (B) the period between Multi-Disciplinary Team discussion and the commencement of the actual radiotherapy treatment.*

Discussion

Radiation therapy remains an important component of cancer treatment, with approximately 50% of all cancer patients receiving radiation during the course of the management.[8,26,27] Despite the availability of facilities in high-income countries, studies indicate that radiotherapy is often underutilized.[28] Notably, in Europe, where half of all cancer patients warrant radiotherapy at least once during their disease, one out of four cancer patients do not receive the necessary radiotherapy.[28] Conversely, in LMICs, more than 90% of the population lack access to radiotherapy.[29] Thus, accessibility of radiotherapy services is important for the assessment of the quality of cancer control programs.

In Africa, there are many contrasts regarding the availability of and access to radiotherapy in individual countries.[2] As of 2019, there was no radiotherapy in 51 countries worldwide, half of which were in Africa, such as Malawi, Burundi, Lesotho, and Chad.[18] Radiotherapy is increasingly becoming an essential component of comprehensive global cancer care, and the World Health Organization (WHO) in collaboration with the International Atomic Energy Agency (IAEA) has published a comprehensive list of priority devices, including recommendations for radiotherapy machines and technical specifications.[17,30,31] Despite progress, there is a substantial gap between the demand for radiotherapy and the existing capacity in Africa.[32-34] In 2012, only 20 out of 52 African countries with available data had functional radiotherapy facilities, highlighting the persisting challenge.[18] Elmore et al. (2021) reported that while some countries initiated or expanded radiotherapy services post-2012, an overall reduction in existing capacity was observed.[35] According to the IAEA report in 2020, there was a notable increase of 430 additional megavoltage units in Africa compared to 2012, signifying a 45% surge in installed capacity.[18] External beam radiotherapy (EBRT) was accessible in 28 (52%) out of 54 countries, up from 23 (43%) in 2012, with nearly half of the installed units located in Egypt (119 units) and South Africa (97 units).[18] The IAEA report further disclosed that, as of 2020, linear accelerators constituted 85% of the 430 megavoltage units. Since 2012, teletherapy cobalt-60 units have decreased by 28%, whereas linear accelerators have shown a remarkable 78% increase.[18]

Presently, half of African countries possess both linear accelerators and cobalt-60 units, 11 countries (20%) exclusively have linear accelerators, and three countries (11%) exclusively rely on cobalt-60 units. Among the 43 reported LINAC machines in this study, Southern Africa (30.2%) and North Africa (30.2%) emerged as the leading regions with the highest number of LINAC machines. Subsequently, West Africa accounted for 20.9%, followed by East Africa (16.3%) and Central Africa (2.4%). Conversely, a collective total of 18 cobalt-60 machines were reported across all African regions. East Africa exhibited the highest concentration of cobalt-60 machines at 38.8%, followed by Central Africa (16.7%), West Africa (16.7%), and North Africa (16.7%), with South Africa contributing 11.1%. While South Africa and Egypt are reported to have a high density of radiotherapy infrastructure and human resources, the reliability of conclusions drawn is impeded by a limited response, with only five professionals providing input from Egypt. Nevertheless, a notable trend observed across various African countries involves a transition from cobalt-60 to linear accelerator machines. This shift is attributed not only to the superior performance characteristics of LINAC machines but also to the escalating incidence of terrorist attacks and threats in Africa, as advocated by the IAEA.

The effective implementation of radiotherapy within the context of cancer treatment transcends the mere availability of radiotherapy machines, emphasizing the important role of adequately trained personnel.[19] Trained workers play a multifaceted role in ensuring the success of radiotherapy interventions by upholding precision, optimizing treatment planning, operate, maintaining equipment, prioritizing patient safety, adapting to technological advancements, fostering interdisciplinary collaboration, and ensuring compliance with quality assurance and regulatory standards.[36,37] The challenges identified in addressing the Lancet Oncology Commission's calls for action underscore the formidable obstacles faced by the African healthcare landscape in achieving these objectives.[1] The Commission's specific action points, including expanding access to radiotherapy with sustainable financing and enhancing human resource capacity for radiotherapy, further highlights the critical importance of a skilled workforce in overcoming these challenges.[1] These factors collectively contribute to the delivery of effective and high-quality radiotherapy, ultimately enhancing the outcomes and well-being of individuals undergoing cancer treatment.[1,36,37] In this study, among the African countries included in the study, Nigeria (n = 48; 22.8%) and South Africa (n = 43, 20.4%) had the highest number of radiation therapy professionals in West and Southern Africa, respectively. In East Africa, Kenya had the highest number of radiation professionals (n = 17, 8.1%), followed by Egypt (n = 5; 2.4%) in North Africa and Cameroon (n = 4, 1.9%) in Central Africa. Most Nigerian professionals stated that they were radiation oncologists (40%), followed by 20.0% medical physicists. However, in South Africa, the majority, 42.9% (n=18), reported that they were radiation therapists, followed by radiation oncologists at 19.0% (n=8). Of all the 210 professionals surveyed in this study, from 25 African countries, only one professional reported to be a radiobiologist, in South Africa, emphasizing the need to train more radiobiologists in Africa. The IAEA recommends that one radiobiologist be required per Radiation Oncology Training Centre. This requirement seems to have been largely overlooked and needs to be enforced.

Furthermore, in this study, most participating African countries, including Botswana, Egypt, Ethiopia, Ghana, Kenya, Namibia, Nigeria, Sudan, South Africa, Tanzania, Uganda, and Zambia, demonstrated an average monthly incidence of more than 20 newly diagnosed breast, cervix, and prostate cancer patients. This stresses the critical importance of healthcare infrastructure and human resources in effectively addressing the needs of these patients, particularly those newly diagnosed, and ensuring the prompt initiation of treatment.[37] The observed disparities in access to preventative services and screening contribute significantly to late-stage diagnoses, emphasizing the urgency of strengthening the healthcare system to enhance early detection and intervention. Recognizing these trends is imperative for devising targeted interventions that enhance both diagnostic and treatment capacities to ultimately improve patient outcomes in the face of prevalent cancer incidences.[38,39]

Limited resources may have contributed to delayed initiation of treatment for many cancer patients, with notable variations observed among the studied African countries. Cameroon exhibited the lengthiest waiting time, with a duration of 10.4±7.6 weeks from histological diagnosis to consultation, followed by Ghana with 9.5±3.8 weeks and Zambia with 7.0±18.3 weeks. Conversely, South Africa and Nigeria reported comparatively shorter waiting times of 4.6±3.0 weeks and 4.0±3.0 weeks, respectively. Similarly, Namibia recorded the lengthiest average waiting time, with a duration of 14.0±6.4 weeks from Multidisciplinary Team (MDT) discussion to the initiation of radiotherapy. In contrast, Egyptian healthcare professionals reported the shortest waiting time at 2.6±1.3 weeks. Additionally, South Africa, and Nigerian healthcare practitioners reported average waiting times of 5.6±4.9 weeks and 6.4±5.5 weeks, respectively. These variations underscore the impact of resource constraints on the timeliness of cancer treatment initiation across diverse healthcare settings.

Strength and Limitations

i. Cost-effectiveness: This survey demonstrated cost-effectiveness typical of online surveys, eliminating the need for traditional methods like printing, mailing, or in-person data collection.
ii. Time efficiency: Administered rapidly and efficiently, this survey collected responses in real-time, enabling the acquisition of a substantial sample size within a short timeframe.
iii. Wide reach: While online surveys offer access to a broad and diverse population, only 25 out of 54 African countries that received the questionnaire responded, potentially impacting the representativeness of the research findings.
iv. Data quality: The survey minimized bias by utilizing online tools with built-in checks and validations, enhancing data accuracy and completeness.

Conclusion

Our findings, comparing the availability of radiotherapy infrastructure and trained personnel in Africa over the past decade, reveal that the distribution is grossly skewed, emphasizing the imperative to enhance both radiotherapy infrastructure and human resource capacity across the continent. The overarching goal is to attain a more equitable distribution of both infrastructure and human capital. Future applications of structural equation models hold promise for providing additional insights into addressing these challenges.

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The authors declare no conflict of interest. The funders played no role in the study design, data collection, analysis, interpretation, decision to publish, or manuscript writing.

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Appendix Materials:

Appendix 1: A sample of Content Relevance, Order, Source, and style (CROSS) approach applied in this study.

CROSS Checklist (Appendix 1); Rennison C, et al. BMJ Sex Reprod Health 2022; 48:210–216. doi: 10.1136/bmjsrh-2021-201387			
Section/topic	**Item**	**Item description**	**Reported**
Title and abstract			1-2
Title and abstract	1a	State the word "survey" along with a commonly used term in title or abstract to introduce the study's design.	
	1b	Provide an informative summary in the abstract, covering background, objectives, methods, findings/results, interpretation/discussion, and conclusions.	
Introduction			4
Background	2	Provide a background about the rationale of study, what has been previously done,and why this survey is needed.	
Purpose/aim	3	Identify specific purposes, aims, goals, or objectives of the study.	
Methods			5-6
Study design	4	Specify the study design in the methods section with a commonly used term (e.g., cross-sectional or longitudinal).	
	5a	Describe the questionnaire (e.g., number of sections, number of questions, number and names of instruments used). Describe all questionnaire instruments that were used in the survey to measure	
	5b	Particular concepts. Report target population, reported validity and reliability information, scoring/classification procedure, and reference links (if any)	
Data collection Methods	5c	Provide information on pretesting of the questionnaire, if performed (in the article or in an online supplement). Report the method of pretesting, number of times questionnaire was pre-tested, number and demographics of participants used for pretesting, and the level of similarity of demographics between pre-testing participants and sample population.	
	5d	Questionnaire, if possible, should be fully provided (in the article, or as appendices or as an online supplement).	
	6a	Describe the study population (i.e., background, locations, eligibility criteria for participant inclusion in survey, exclusion criteria).	
Sample Characteristics	6b	Describe the sampling techniques used (e.g., single stage or multistage sampling, simple random sampling, stratified sampling, cluster sampling, convenience sampling). Specify the locations of sample participants whenever clustered sampling was applied	
	6c	Provide information on sample size, along with details of sample size calculation.	
	6d	Describe how representative the sample is of the study population (or target population if possible), particularly for population-based surveys.	
	7a	Provide information on modes of questionnaire administration, including the type and number of contacts, the location where the survey was conducted (e.g., outpatient room or by use of online tools, such as SurveyMonkey	
Survey administration	7b	Provide information of survey's time frame, such as periods of recruitment, exposure, and follow-up days.	
	7c	Provide information on the entry process: For non-web-based surveys, provide approaches to minimize human error in data entry. For web-based surveys, provide approaches to prevent "multiple participation" of participants.	
Study preparation	8	Describe any preparation process before conducting the survey (e.g., interviewers' training process, advertising the survey).	
	9a	Provide information on ethical approval for the survey if obtained, including informed consent, institutional review board [IRB] approval, Helsinki declaration, and good clinical practice [GCP] declaration (as appropriate).	
	9b	Provide information about survey anonymity and confidentiality and describe what mechanisms were used to protect unauthorized access.	
	10a	Describe statistical methods and analytical approach. Report the statistical software that was used for data analysis	

CROSS Checklist (Appendix 1); Rennison C, et al. BMJ Sex Reprod Health 2022; 48:210–216. doi: 10.1136/bmjsrh-2021-201387			
Section/topic	**Item**	**Item description**	**Reported**
	10b	Report any modification of variables used in the analysis, along with reference (if available).	
	10c	Report details about how missing data was handled. Include rate of missing items, missing data mechanism (i.e., missing completely at random [MCAR], missing at random [MAR] or missing not at random [MNAR]) and methods used to deal with missing data (e.g., multiple imputation).	
	10d	State how non-response error was addressed.	
	10e	For longitudinal surveys, state how loss to follow-up was addressed.	
	10f	Indicate whether any methods such as weighting of items or propensity scores have been used to adjust for non-representativeness of the sample.	
	10g	Describe any sensitivity analysis conducted.	
Results			7-8
Respondent characteristics	11a	Report numbers of individuals at each stage of the study. Consider using a flow diagram, if possible.	
	11b	Provide reasons for non-participation at each stage, if possible.	
	11c	Report response rate, present the definition of response rate or the formula used to calculate response rate.	
	11d	Provide information to define how unique visitors are determined. Report number of unique visitors along with relevant proportions (e.g., view proportion, participation proportion, completion proportion)	
	12	Provide characteristics of study participants, as well as information on potential confounders and assessed outcomes.	
	13a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates along with 95% confidence intervals and p-values.	
	13b	For multivariable analysis, provide information on the model building process, model fit statistics, and model assumptions (as appropriate).	
	13c	Provide details about any sensitivity analysis performed. If there are considerable amount of missing data, report sensitivity analyses comparing the results of complete cases with that of the imputed dataset (if possible).	
Discussion			8-10
Limitations	14	Discuss the limitations of the study, considering sources of potential biases and imprecisions, such as non-representativeness of sample, study design, important uncontrolled confounders	
Interpretations	15	Give a cautious overall interpretation of results, based on potential biases and imprecisions and suggest areas for future research.	
Generalizability	16	Discuss the external validity of the results.	
Other sections			11
Role of funding source	17	State whether any funding organization has had any roles in the survey's design, implementation, and analysis.	
Conflict of interest	18	Declare any potential conflict of interest.	
Acknowledgements	19	Provide names of organizations/persons that are acknowledged along with their contribution to the research.	

Appendix 2: A sample of questions used in the survey study.

1 Please provide your clinic's name:

2 Provide the country in which your clinic is located:

3 How would you describe your primary practice setting (select all that are applicable

- a Academic/University
- b Hospital-based, non-academic/University affiliation
- c Free standing, non-academic/University affiliation
- d Government employed, such as military or Government run facility
- e Other (please specify)____________________________

4 What is your area of speciality in the clinic? (select all that are applicable)

- a Radiation Oncologist
- b Medical Oncologist
- c Nuclear Medical Physician
- d Radiobiologis
- e Medical Physicist
- f Registrar
- g Medical Officer
- h Dosimetrist/Treatment Planner

i Quality Assurance/Quality control

j Radiation Therapist

k Administrator

l Regulator/Radiation Protection Officer

5 How many years have you worked in the area related to radiation oncology?

a 0 - 4 years

b 5 - 10 years

c 11 - 20 years

d > 20 years

e Still in training

6 Where did you complete your training (country)?

7 How many cobalt-60 machines are active in your clinic?

8 How many linear megavoltage accelerators (LINACs) are active in your clinic?

9 How many oncologists are in your clinic/s?

10 What are the radiotherapy machines in your centre capable of performing? (select all that are applicable)

a Direct dose monitoring

b Beam gating

c Millimeter precision

d None of above

11 Which imaging modalities and treatment planning systems are available for treatment planning and simulation, motion tracking, and management? (select all that are applicable)

a CT simulation

b Fluoroscopy simulation

c 2D

d 3D Conformal Radiotherapy

e 4D CT motion tracking

f PET simulation

g VMAT

h IMRT

i EPID

j CT fiducial marker

k Cone Beam CT

l None of the above

12 Which of the following are available at your clinic for patient immobilization? (select all that are applicable)

a Head frames

b Head rest/support

c Breast board

d Thermoplastic masks

e Knee/ankle support

13 On average, how many patients in need of radiation therapy for breast cancer do you see in consultation per month?

a 0 - 4

b 5 - 9

c 10 - 14

d 15 - 20

e > 20

14 On average, how many patients in need of radiation therapy for cervical cancer do you see in consultation per month?

a 0 - 4

b 5 - 9

c 10 - 14

d 15 – 20

e >20

15 On average how many patients in need of radiation therapy for prostate cancer do you see in consultation per month?

a 10 - 14

b 15 – 20

c > 20

16 What fractional dose does your clinic usually deliver in external beam radiotherapy?

a 0 - 2 Gy

b >2 - 5 Gy

c 5 - 7 Gy

d 8 - 12 Gy

17 Do you have multi-disciplinary team (MDT) in your clinic/s

a Yes
b No
c Unknown

18 What is the estimated waiting time for MDT after diagnosis?
a 4 - 6weeks
b 6 - 12weeks
c 12 - 16weeks
d 16weeks

19 What is the waiting time for radiotherapy from day of MDT to start Radiotherapy?
a 4 - 6weeks
b 6 - 12weeks
c 12 - 16weeks
d 16weeks

20 If applicable, which cancer subsite/s does your clinic perform curative treatment with hypofractionated radiotherapy?
I Curative:(select all that apply)
a) Breast cancer
b) Cervix cancer
c) Prostate cancer
d) Head and Neck cancers
e) Sarcoma
f) Rectal cancer
g) Lung cancer
h) Bladder cancer
i) CNS malignancies
j) Benign lesion
II Stereotactic body radiotherapy (SBRT)
a) CNS
b) Lung
c) Others; state
III Palliative radiotherapy
a) Pelvis RT
b) Whole brain RT
c) Bone
d) Mass

21 Describe your familiarity with hypofractionated radiation therapy?
a My clinic is usually engaged in hypofractionated radiation therapy
b My clinic uses hypofractionated radiation therapy at times
c I am familiar with hypofractionated radiation therapy
d I am not familiar with hypofractionated radiation therapy, but ready to learn and implement.

22 a Radical treatment
b Palliative Radiotherapy
c Single fractions
d Stereotactic Radiotherapy
e Others, specify please….

23 Have you ever used tele-consultations or tele-medicine?
a Yes
b No
c Unknown

24 Are you willing to commence tele-medicine/consultations?
a Yes
b No
c Unknown

25 Do you want training on contouring
a Yes
b No
c Unknown

26 According to you, what factors may hinder effective implementation of hypofractionated radiation therapy in your centre?

27 Please explain any of the above response/s in details, if need be, or any important finding you would like to provide in relation to hypofractionated radiotherapy