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Scientific Article

Assessing Radiology and Radiation Therapy Needs for Cancer Care in Low-and-Middle-Income Countries: Insight From a Global Survey of Departmental and Institutional Leaders

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Data Sharing Statement: Country and individual level data, including respondent comments, from this confidential survey are restricted but may be available on reasonable request from the corresponding author pending permission from the associated survey participants. Global and region-specific results have been reported in this manuscript in Appendix E2 and, therefore, are publicly available.

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Purpose: The global cancer burden and mortality rates are increasing, with significant disparities in access to care in low- and middle-income countries (LMICs). This study aimed to identify radiology and radiation therapy needs in LMICs from the perspective of departmental and institutional leaders.

Methods and Materials: A survey was developed and conducted by the American Association of Physicists in Medicine Global Needs Assessment Committee and the American Association of Physicists in Medicine International Council. The survey, organized into 5 sections (Introduction, Infrastructure Needs, Education Needs, Research Needs, and General Information), was open to respondents from March 1, to August 16, 2022.

Results: A total of 175 responses were received from 6 global regions: Africa (31.4%), the Americas (17.7%), the Eastern Mediterranean (14.3%), Europe (9.1%), Southeast Asia (23.4%), and the Western Pacific (4.0%). The greatest reported need was for new or updated equipment, particularly positron emission tomography/computed tomography imaging technology. There was also a high demand for clinical and equipment training. Approximately 25% of institutions reported a lack of radiology-based cancer screening programs because of high health care costs and a shortage of specialized equipment. Many institutions that expressed interest in research face funding and grant challenges.

Conclusions: The findings highlight critical areas where organizations can support LMICs in enhancing radiology and radiation therapy services to mitigate the growing cancer burden.

Introduction

Cancer is the second leading cause of premature death worldwide, responsible for nearly 10 million deaths annually.[1,2] Awareness of cancer as a global public health issue is intensifying, with projections indicating it will become the leading cause of death by the end of this century.[3] The burden of cancer is increasing disproportionately in low- and middle-income countries (LMICs), where the majority of cancer deaths are expected to occur by 2030, thereby fueling a global health crisis.[4] LMICs remain underserved, with significant disparities in disease burden and mortality because of a lack of access to diagnostic and treatment facilities.[5]

Several reports from the Lancet Oncology Commission identified critical deficiencies in infrastructure and workforce development in these regions.[6-8] For instance, in 2015, it was highlighted that >25 countries in sub-Saharan Africa had no access to radiation therapy.[6] In West Africa, one of the most economically underprivileged regions, only 4 of 16 countries had radiation therapy facilities.[9] This issue gained significant attention in 2017 when the British Broadcasting Corporation used data from the International Atomic Energy Agency's Directory of Radiotherapy Centers (DIRAC) to report that dogs in the United States had better access to radiation therapy than humans in Nigeria, West Africa's most populous nation.[10,11]

The sources of inequity in cancer care are complex, involving economic, historical, political, and ethnic factors. Addressing these underlying issues requires significant coordinated efforts and time. However, some immediate solutions are within reach. Efforts to expand access to cancer care in LMICs have focused on developing cost-effective technologies and improving infrastructure through equipment donations.[12-17] Training opportunities and fostering research collaborations have also been key strategies.[18,19]

In response to the increasing number of medical physicists interested in international engagement, the American Association of Physicists in Medicine (AAPM) established an International Council (IC) in 2020. The AAPM-IC aims to advance the practice of medical physics globally by addressing health care disparities and developing mitigation strategies in collaboration with other stakeholders.[20]

To support these efforts, the AAPM-IC tasked the Global Needs Assessment Committee (GNAC) with conducting a series of surveys to assess radiology and radiation therapy needs in LMICs. Although previous studies have reported on global oncology surveys and specific aspects of radiation therapy and radiology infrastructure, as well as general medical physics barriers in developing countries, this study is unique in its global scale assessment of radiology and radiation therapy needs.[21-23]

Methods and Materials

Survey design

This investigation was approved by the institutional review board at the University of Massachusetts Lowell (IRB#21-179-NGW-EXM) and funded by an American Institute of Physics grant. Informed consent was obtained from all survey participants. The survey introduction included a statement explaining the purpose of the survey, voluntary participation, and confidentiality of responses (Appendix E1). The AAPM supplied staff time, access to the survey platform, and survey promotion support.

The survey targeted departmental and institutional leaders providing radiation therapy and radiology services in LMICs, including administrators, managers, department chairs, medical directors, and chief medical

physicists. A separate survey targeted at medical physicists practicing in LMICs is in development.

The survey was developed by GNAC members in collaboration with Survey Design & Analysis, LLC, who consulted on survey content. AAPM staff assisted with survey deployment using a web-based platform (QuestionPro). Input on questions was solicited from other AAPM-IC Committees, including the Clinical Education and Training Committee, the Global Data and Information Exchange Committee, the Global Medical Physics Education and Training Committee, and the Global Research and Scientific Innovation Committee. GNAC members reviewed all questions for clarity, redundancy, and appropriate placement within the survey.

The survey comprised the following 5 sections with a total of 40 questions: Introduction (3), Infrastructure Needs (14), Education Needs (11), Research Needs (7), and General Information (5). Of the 40 questions, 36 were primary questions, and 4 were nested questions (asked based on previous responses). Seven primary questions were mandatory and indicated with an asterisk (*) in Appendix E1. The Introduction and General Information sections provided summary and demographic information. The Infrastructure section covered core equipment, personnel, and facility upkeep demands. The Education section addressed training resources and personnel recruitment. The Research section included questions about ongoing research, clinical trial participation, and available research funding. A copy of the disseminated survey is available in Appendix E1.

Distribution

To ensure comprehensive regional coverage, GNAC members compiled a list of LMICs based on World Bank data and a legacy list of developing countries from the AAPM.[24,25] The 154 identified survey-eligible countries (SCs) were grouped into 6 geographic regions based on the World Health Organization global regions: Africa, the Americas, the Eastern Mediterranean, Europe, Southeast Asia, and the Western Pacific (Fig. 1A).[26] The Global Representatives Subcommittee under GNAC identified key contacts in each region based on regional and local medical physics associations and worked closely with regional contacts to establish a network of 280 individuals for survey dissemination. The key contacts were encouraged to further share the survey with their networks. The survey was distributed through various channels, including e-mail, the AAPM website, social media posts, and presentations at global regional conferences. Because of the distribution method, the number of individuals that received the survey is unknown. The survey was open from March 1, to August 16, 2022.

Analysis

Data were analyzed to identify the resources reported to be in the highest demand and the availability of health care services compared with those desired. Both global and regional analyses were conducted.

Descriptive statistics (percentage of regional and overall responses) were used to summarize the results. Data analysis used spreadsheet software (Microsoft Excel, Microsoft Corporation), which facilitated the processing and analysis of the responses. Partial and complete responses were included in the analysis. Duplicate responses from the same individual were removed after consulting with respondents to determine which response to include.

To assess response distribution, the regional distribution of respondents reporting that their institutions offered radiation therapy was benchmarked against the regional distribution of radiation therapy centers reported in the DIRAC database[10] for the SCs.

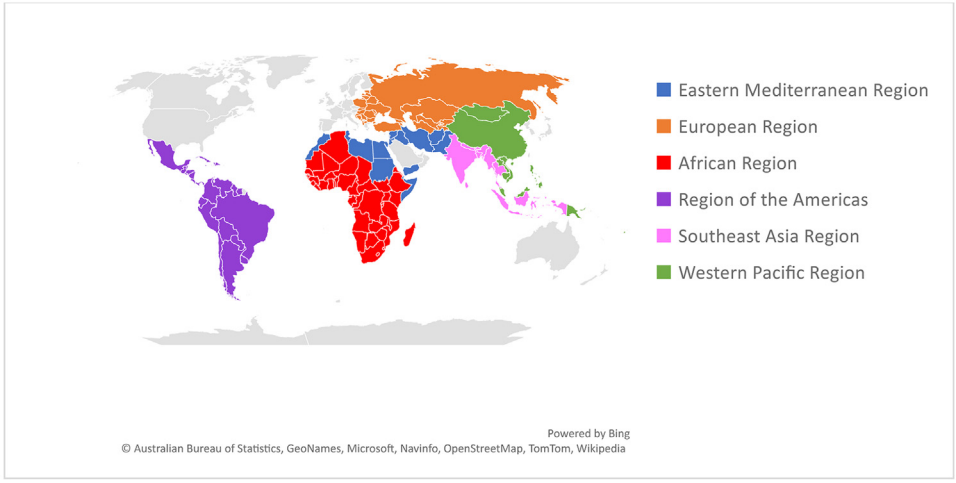
Role of the funding source

The funders had no role in the study design, data collection, data analysis, data interpretation, or writing of the manuscript.

Results

A total of 175 responses were used in the analysis, with 102 fully completed and 73 partially completed surveys. The mean and median completion times of the survey were 20.3 and 14.5 minutes, respectively. Responses spanned the following 6 global regions: Africa (31.4%), the Americas (17.7%), the Eastern Mediterranean (14.3%), Europe (9.1%), Southeast Asia (23.4%), and the Western Pacific (4%). Responses were received from 48 of 154 (31.2%) potential countries. Per country, responses ranged from 1 to 21, with 3 or fewer responses from 35 countries and 16 or more responses from 3 countries (Fig. 1B). The regional percentages of SCs represented in the responses were Africa (25.5%), the Americas (43.8%), the Eastern Mediterranean (43.8%), Europe (26.7%), Southeast Asia (40.0%), and the Western Pacific (15.8%). The distribution of survey respondents reporting radiation therapy compared with the distribution of radiation therapy centers as reported in the DIRAC database[10] was the most similar for the Southeast Asia region and differed the most for the African and Western Pacific regions (Fig. 1C).

Results for all survey questions are available in Appendix E2, where global results are provided in graphical



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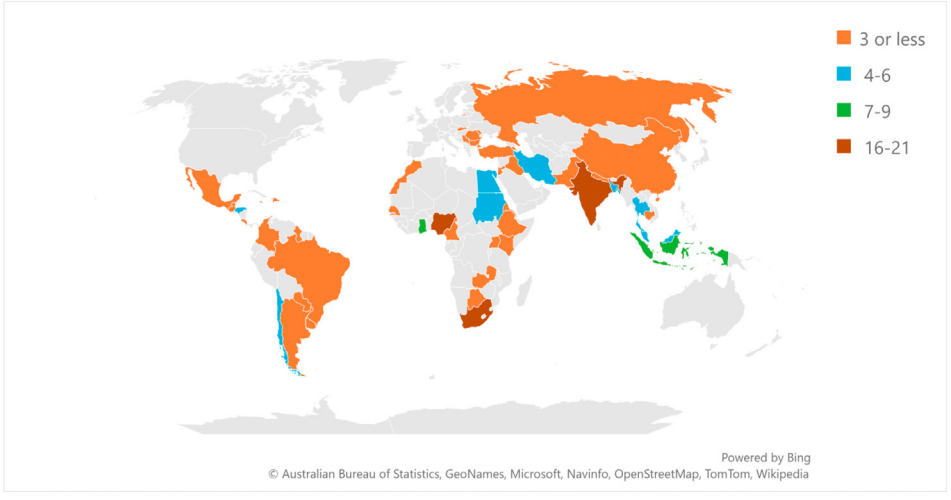

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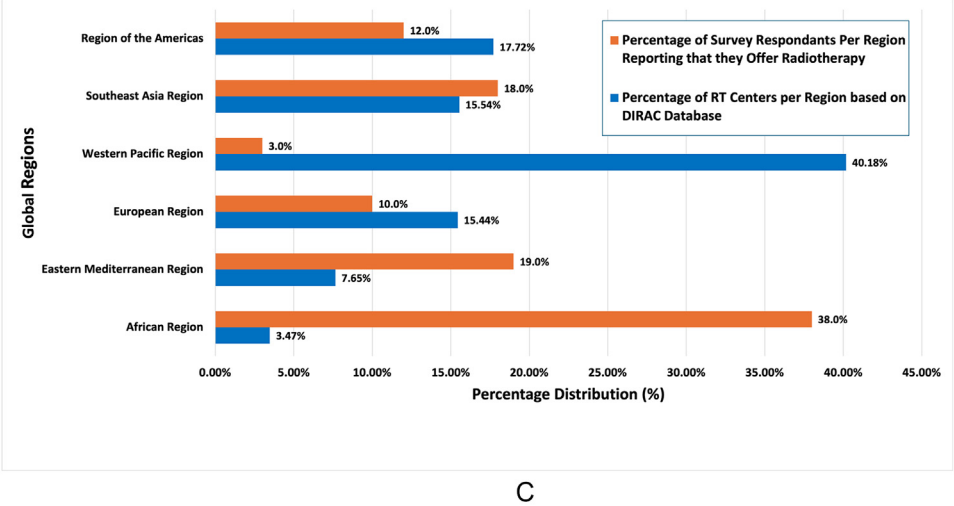

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Figure 1 (A) Map of survey-eligible countries grouped into World Health Organization global regions. (B) Map of the number of survey responses per country. (C) Regional distribution of survey respondents reporting radiation therapy (RT) compared with regional distribution of RT centers based on the Directory of Radiotherapy Centers (DIRAC) database. (Microsoft product screen shot(s) reprinted with permission from Microsoft Corporation.)

format (Figs. E1-E40), and Tables E1 to E40 summarize both the global and region-specific results.

Question response rate and distribution

The number of responses per primary question varied, with the highest number (175) for the initial questions and a gradual decrease in subsequent sections. The lowest response (98) was in the Research Needs section. Nested questions had fewer responses (29-70) than primary questions, reflecting the complexity and specificity of these questions.

Key results

1. Infrastructure needs
   The highest reported need was for new or updated equipment (Fig. 2A), particularly positron emission tomography (PET)/computed tomography (CT) imaging technology (Fig. E12). Equipment training and continuous education were also a high priority (63.1%) (Fig. 2B).
   A total of 40.5% of respondents from the African region reported issues with inadequate power supply, highlighting a critical infrastructure challenge (Fig. 2C).
2. Education needs
   The greatest educational support needed was clinical training (58.4%), followed by course development in medical physics (45.1%) (Fig. 3A).
   Training updates for radiation oncologists and radiologists were particularly needed (69%) (Fig. 3B), and 49.1% of respondents noted insufficient training provided by equipment suppliers (Fig. E28).
3. Research needs
   The primary barriers to conducting research were funding and obtaining grants (64.9%), lack of equipment (45%), and expertise (39.6%) (Fig. 3C).
   Only 25.5% of respondents had access to research funding opportunities, underscoring the need for financial support (Fig. E33).
4. Radiology cancer screening programs
   More than 25% of institutions reported no annual radiology cancer screening programs, primarily because of health care costs (Fig. 4A).
5. Safety programs
   Although approximately 60% of respondents report that magnetic resonance imaging (MRI) and fluoroscopy are available at their institutions, less than half of those report MRI and fluoroscopy safety programs. The relative numbers of safety programs were particularly low for the African region and the region of the Americas (Fig. 4B).
6. Brachytherapy
   The number of respondents reporting high-dose-rate and low-dose-rate brachytherapy at their institutions was 55.7% and 17.4%, respectively (Fig. 5).
7. External beam radiation therapy
   A total of 64.3% and 50.4% of respondents report that intensity modulated radiation therapy and volumetric modulated arc therapy are offered at their institutions, respectively. Additionally, only 33.9% of respondents report the use of Stereotactic Body Radiaton Therapy, and 45.2% report the use of image guided radiation therapy (Fig. 5).
8. Workforce
   Qualified staff was the second largest overall need (Fig. 2A), further highlighting the need for education and training.
9. Increasing cancer burden
   A total of 77.4% of institutions reported an increase in the number of patients with cancer over the past 3 years (Fig. 6A).
10. Collaboration
    Encouragingly, 86.2% of respondents reported that they would support collaborations with global partners (Fig. 6B).

Discussion

Overview

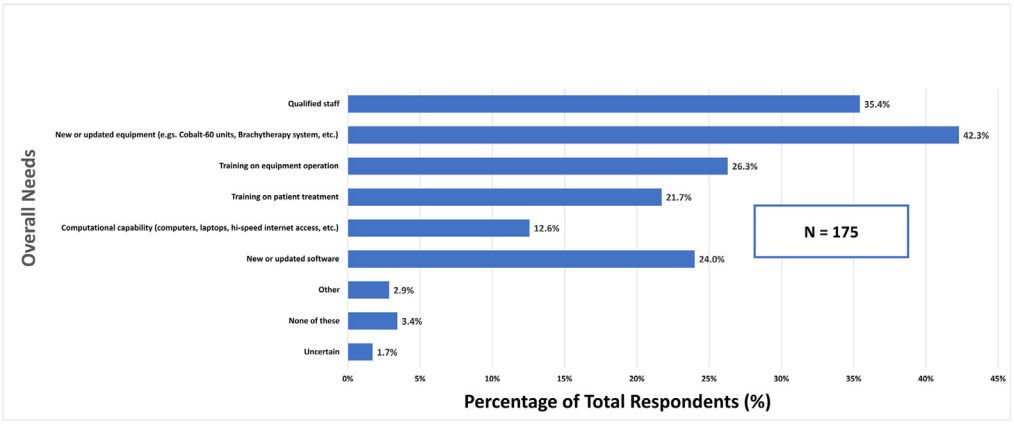
This survey provides a comprehensive overview of the radiology and radiation therapy needs for cancer care in LMICs from the perspective of departmental and institutional leaders. The findings highlight critical areas where support is needed to improve cancer care in these regions.

Key findings and their implications

Infrastructure needs

Efforts to build a sustainable infrastructure are critical to improving health care quality and access for patients across the globe. The high demand for new and updated equipment, particularly PET/CT, indicates a substantial gap in the availability of advanced diagnostic tools in LMICs. PET/CT and other nuclear medicine-based imaging modalities play a critical role in the diagnosis, staging, and treatment assessment of many types of cancer. Challenges in implementing and maintaining PET/CT programs in LMICs include the complexities of importing radioisotopes, lack of trained personnel to maintain equipment, challenges associated with radioactive waste disposal, and lack of quality assurance equipment.[27] Addressing this need requires coordinated efforts for equipment procurement and sustainable infrastructure development.

The large number of respondents from the African region reporting issues with inadequate power supply indicates that the ability to reliably treat patients from day to day may be a challenge. Sourcing equipment



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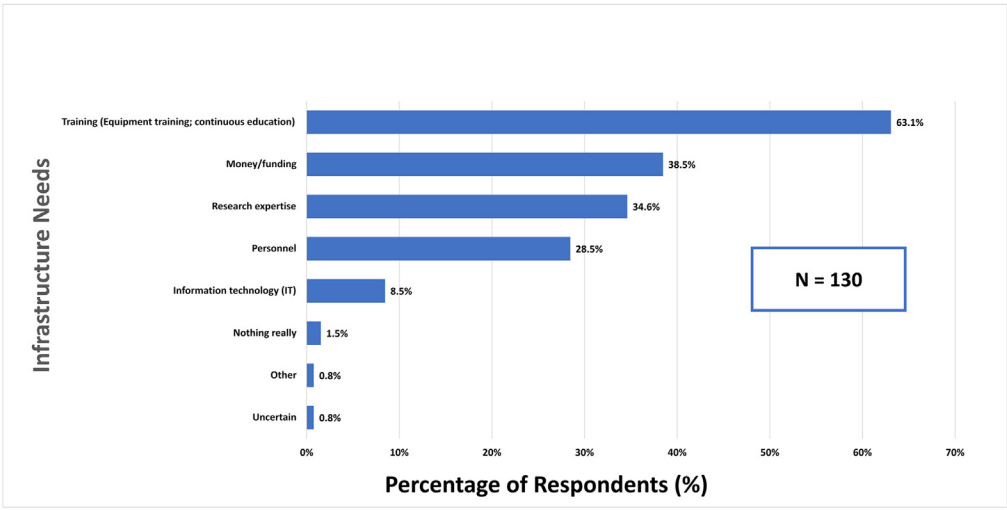

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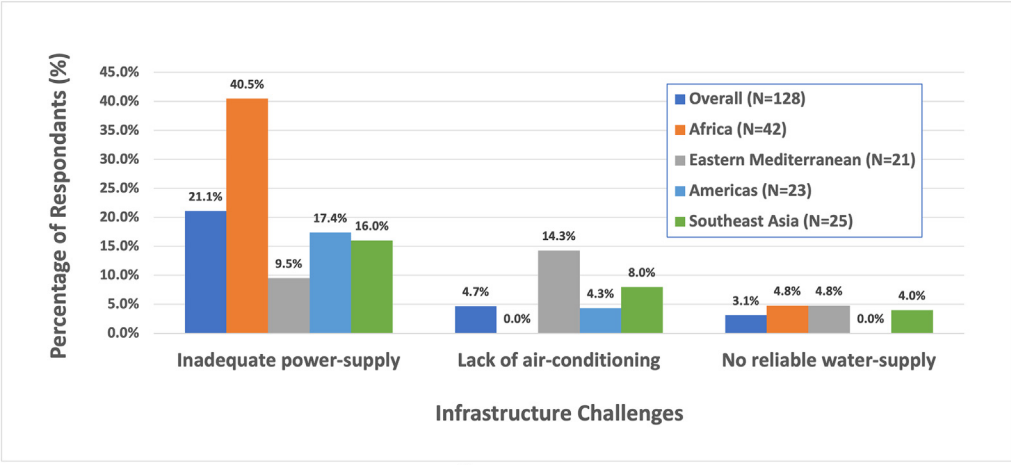

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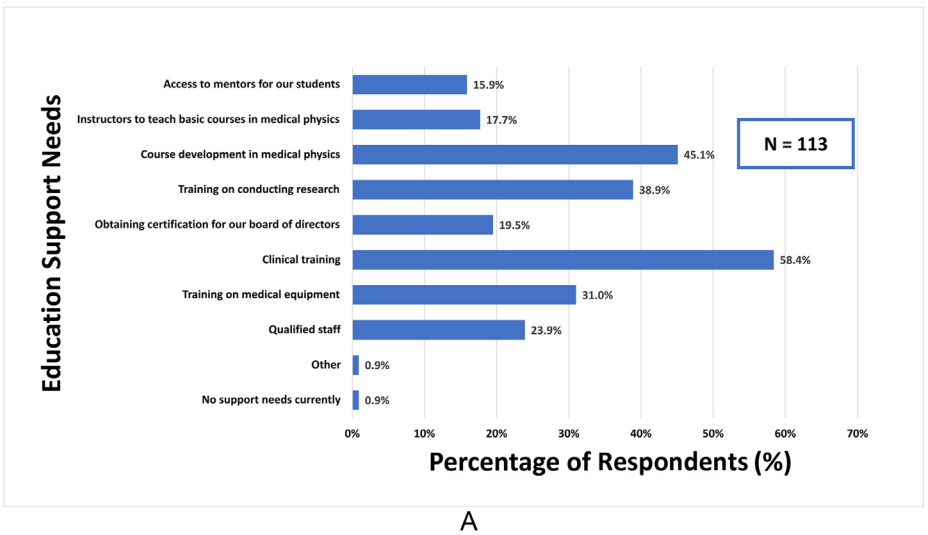
Figure 2 Survey results for greatest overall needs (A) and greatest Infrastructure Needs (B). Respondents could select up to 2 options. The specific needs are displayed on the vertical axes, and the percentage of respondents reporting each need is displayed on the horizontal axes. (C) Global and regional percentage of respondents reporting infrastructure challenges. The percentage of respondents is displayed on the vertical axis, and specific infrastructure challenges are displayed on the horizontal axis. Two regions (Western Pacific and Europe) are not included in the figure because these regions did not report infrastructure challenges.



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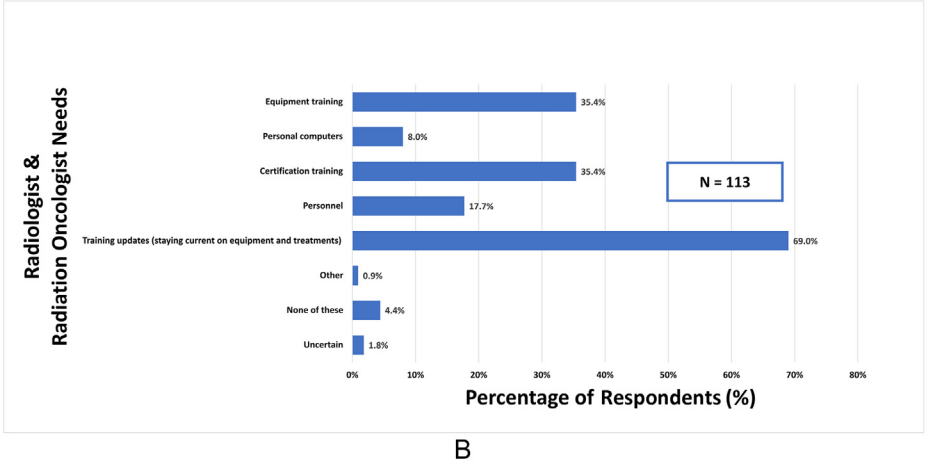

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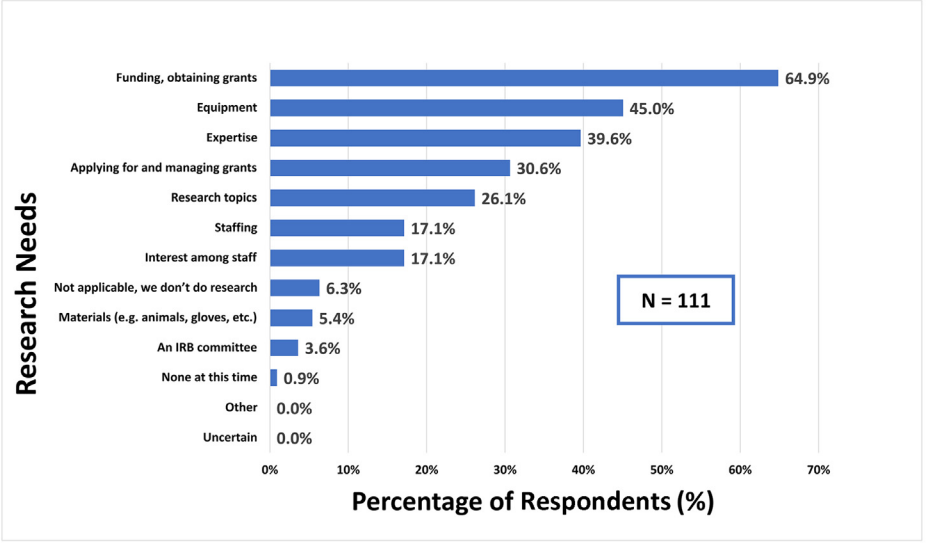

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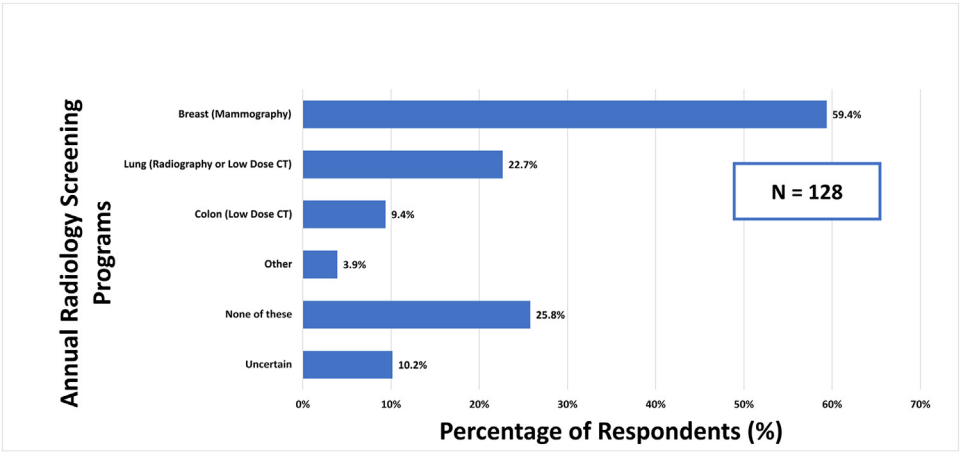
Figure 3 Survey results for greatest Education Needs (A), greatest needs for radiation oncologists and radiologists (A), and greatest Research Needs (C). Respondents could select up to 3 options for Education Needs and Research Needs and up to 2 options for radiation oncologist and radiologist needs. Needs are displayed on the vertical axis, and the percentage of total respondents for each need is displayed on the horizontal axis.



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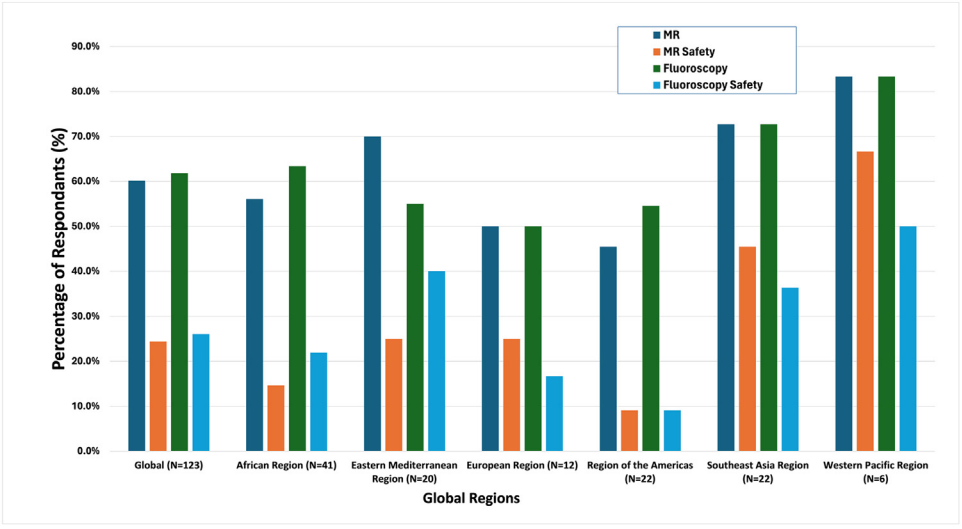

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Figure 4 (A) Annual radiology screening programs at the respondents' institutions. Screening programs are displayed on the vertical axis, and the percentage of respondents is displayed on the horizontal axis. (B) The percentage of respondents reporting MR and fluoroscopy at their institutions, along with safety programs for these modalities at the respondents' institutions. The percentage of respondents is displayed on the vertical axis, and the prevalence of magnetic resonance (MR) imaging and fluoroscopy, along with the respective safety programs, are displayed on the horizontal axis.
Abbreviations: CT = computed tomography.

that is less susceptible to power grid issues, such as Cobalt-60 teletherapy units, may be a better choice than linear accelerators where power grid issues are present.[15] The International Atomic Energy Agency's lists several advantages of Cobalt-60 teletherapy units, including increased tolerance to "environmental variability" with respect to power supply.[28] Of note, survey respondents from the African region reported the highest percentage of Cobalt-60 teletherapy units (35.1%), which may be because of the advantages of these units where power grid issues are present (Table E13). To better ensure that patients receive radiation therapy treatments, equipment procurement should take the local infrastructure and environment into account.

Educational needs

The emphasis on clinical training and continuous education reflects the need for ongoing professional development to keep pace with technological advancements. Global partnerships and remote training programs could play a crucial role in bridging this gap. Training in the form of virtual meetings and recorded video content can reduce the need for costly international travel while providing training to a broader audience.[19,29,30] Allowing low or no cost access to online education content to staff in LMICs should be considered by professional organizations. Although many respondents expressed interest in remote training and peer support on treatment planning and quality assurance, comments from the African region suggest that more in-person training is needed. Remote

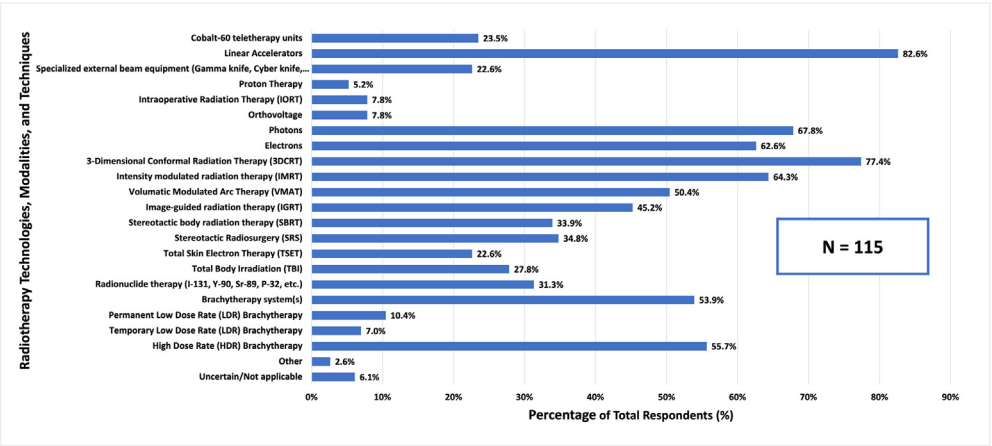


Figure 5 Prevalence of radiation therapy technologies, modalities, and techniques as reported by the respondents. The percentage of respondents is displayed on the horizontal axis, and the technologies, modalities, and techniques are displayed on the vertical axis.

training is perhaps not ideal for equipment training, where a more hands-on approach is needed.[31] Therefore, training programs should be designed and formatted to best meet educational goals.

One of the most important aspects of practicing radiation oncology at a high level is the use of advanced equipment.[32] A necessary part of that is sufficient equipment training provided by the vendor. Comments report the length of training as inadequate or the timing of the training as less than ideal. Unfortunately, some training expires, or more advanced training is given at installation when staff are still learning basic operations. Vendors should focus on optimizing training to suit the needs of the end user.

Research needs

Respondents expressed interest in the availability of personnel to conduct research but also identified barriers to engaging in research. The identified barriers, especially funding and equipment, highlight the need for targeted financial support and collaborative research initiatives. The lack of financial resources in support of research has been previously indicated by several investigators[33,34] and is further emphasized in this work. Identifying and allocating funding resources in support of research would greatly improve the state of research in LMICs.[33,34] International grants and partnerships could help mitigate these challenges.

Radiology cancer screening programs

The lack of radiology cancer screening programs in many institutions underscores the need for affordable and accessible screening programs. Cancer deaths relative to cancer incidence are higher in LMICs compared with high-income countries.[35] Early detection is crucial for reducing cancer deaths through early intervention. In LMICs, a significant proportion of women are diagnosed with breast cancer at later stages.[36] Similarly, with lung cancer ranking as the leading cause of cancer-related deaths worldwide for men and women combined, screening initiatives for lung cancer among smokers using radiography and low-dose CT scans have demonstrated effectiveness in detecting lung cancers earlier and reducing lung cancer mortality.[37] Efforts should focus on reducing costs and increasing the availability of specialized equipment and program infrastructure to expand screening programs worldwide.[38]

Safety programs

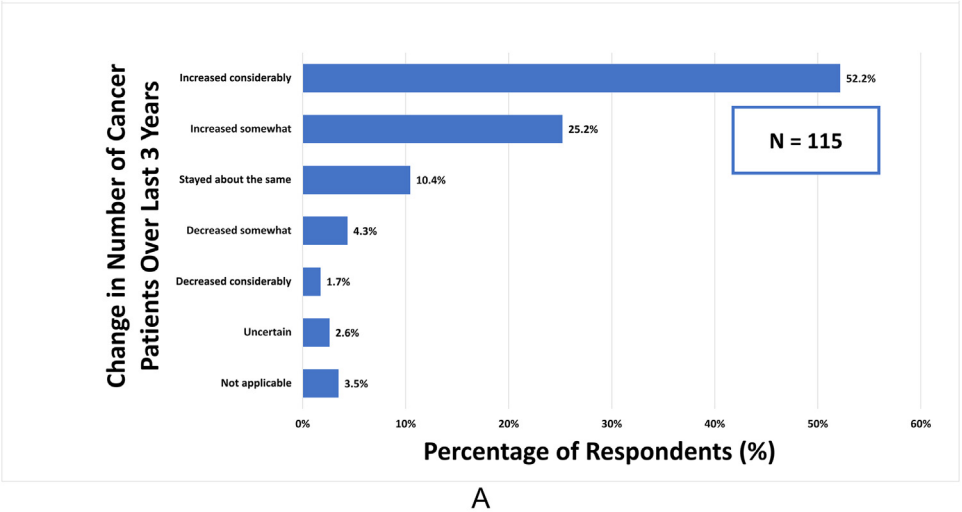
The low relative number of responses indicating MRI and fluoroscopy safety programs is concerning. Accidents in the MRI suite can be severe and lethal if the necessary precautions are not taken.[39] Fluoroscopy safety minimizes deterministic effects on patients and stochastic effects on staff.[40,41] Developing screening programs should be an area of focus for international medical physics collaborations.

Brachytherapy

The challenges of establishing and maintaining brachytherapy programs are numerous[42] and are similar to those for PET/CT. However, brachytherapy has the potential to have a significant impact on the treatment of gynecologic cancers.[43] In many LMICs, cervical cancer is the most common cancer among women and causes the most cancer deaths.[42] Building capacity in brachytherapy will require coordinated effort at the governmental level as well as through international collaborations.

External beam radiation therapy

One option for potentially improving cancer care is through hypofractionation. Hypofractionation could



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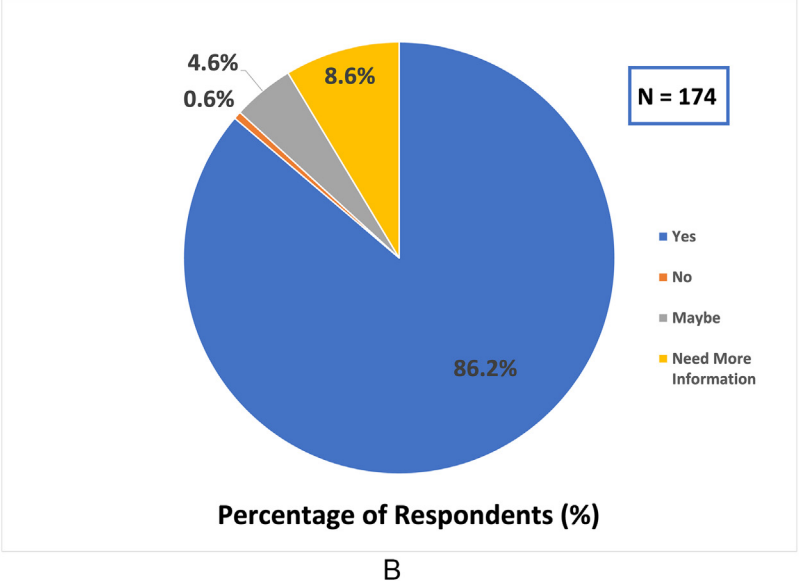

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Figure 6 (A) Change in the number of patients with cancer cared for by survey respondents over the last 3 years. The level of change is displayed on the vertical axis, and the percentage of respondents is displayed on the horizontal axis. (B) Support for international collaboration as reported by respondents. The percentage of respondents for the levels of support is displayed in the pie chart.

increase the number of people treated on a given radiation machine per unit of time and, therefore, potentially improve access to radiation therapy, increase treatment compliance, and reduce costs.[38,44] The efficacy of hypofractionation remains to be proven in lower resource settings.[45] Current clinical trials for prostate, breast, and cervical cancers are underway in 5 African radiation therapy centers.[46]

Intensity modulated radiation therapy, volumetric modulated arc therapy, and image guided radiation therapy serve to improve radiation therapy treatment accuracy and conformity and reduce normal tissue toxicity.[47,48] Such techniques are standard practice in high-income countries and are integral to most hypofractionation practices. The low number of survey respondents reporting their use indicates an opportunity for program development to further support hypofractionation.

Workforce

A shortage of qualified staff was evident in the results and further emphasized in the comments. The results agree with the literature, which shows that the global supply of medical physicists is far from meeting demand.[49] One study found that only 8 of the over 50 countries in Africa have greater than 20 physicists, with most having just 1 or 2.[8] Therefore, it is critical to increase the capacity to train medical

physicists in LMICs and to develop incentives to keep these physicists in their own country throughout their careers.

Increasing cancer burden

The reported increase in patients with cancer necessitates scaling up diagnostic and treatment capacities. This aligns with projections of an increase in global cancer rates of 47% between 2020 and 2040[1] and calls for urgent action to enhance health care infrastructure and workforce in LMICs.

Collaboration

The willingness of leaders to support collaboration with global partners was clear, with a high percentage (86.2%) of respondents reporting that they would support such collaborations. Support of institutional leaders is paramount to successful collaborations, and the survey responses are encouraging.

Key recommendations

1. Infrastructure investment: prioritize funding for new and updated radiology and radiation therapy equipment. Advanced imaging technology, such as PET/CT, is necessary for early detection and staging of cancer. Treatment equipment should be sourced appropriately for the local environment.
2. Training programs: develop comprehensive training programs, including remote and in-person options, to ensure continuous professional development. Optimizing equipment training should be an area of focus for equipment vendors.
3. Research support: increase financial support for research initiatives and facilitate international collaborations to enhance research capacity.
4. Radiology cancer screening programs: implement affordable radiology cancer screening programs and provide the necessary equipment to improve early detection rates.
5. Safety programs: develop training to ensure imaging technologies are used safely to prevent harm to patients and staff.
6. Brachytherapy: support the development of brachytherapy programs with a focus on both training and source procurement.
7. External beam radiation therapy: collaborate with radiation therapy facilities in LMICs to safely implement advanced treatment techniques with a focus on hypofractionation to provide cancer care more efficiently.
8. Workforce: increasing and supporting the radiology, radiation therapy, and medical physics workforce is imperative as we face the global cancer crisis.
9. Increasing cancer burden: efforts should focus on early detection, further emphasizing the need for radiology cancer screening programs. Additionally, hypofractionation should be incorporated to increase treatment capacity.
10. Collaboration: the results show that radiology and radiation therapy institutions in LMICs are open to global collaboration. Efforts should focus on key areas where they will have the most benefit, and solutions should be sustainable over time.

Limitations

Language and response rate

The survey was conducted in English, potentially limiting participation from non—English-speaking regions. Future surveys should include multiple languages to increase inclusivity.

Sample size

The relatively low response rate limits the generalizability of the findings. Additional efforts are needed to increase participation from underrepresented regions in future need assessments.

Response distribution

The distribution differences between survey responses and radiation therapy centers may further limit the generalizability of the findings and are likely because of the limitations previously discussed. The African region was overrepresented in responses, which may be because of the large relative number of contacts in the African region by the AAPM GNAC members. The DIRAC database[10] indicates that the Western Pacific region has more than double the radiation therapy centers of other regions. However, this region had the lowest number of survey responses, emphasizing the need to focus future survey efforts on increasing Western Pacific region participation.

Conclusions

This survey highlights critical needs in radiology and radiation therapy for cancer care in LMICs. Addressing these needs requires a coordinated global effort to provide equipment, training, and research support. Future surveys targeting medical physicists will provide further insight to guide these efforts.

Disclosures

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Additional conflicts of interest are listed below for each author, along with additional disclosures.

Stephanie A. Parker reports payment or honoraria for lectures, presentations, speakers bureaus, manuscript writing, or educational events: the American College of Radiology provides honoraria when she serves as an accreditation surveyor for radiation oncology practices; she receive honoraria for developing continuing education modules for the American Association of Physicists in Medicine (AAPM) Online Learning Center. Support for attending meetings and/or travel: support for attending conferences is provided by her primary employer, Atrium Health Wake Forest Baptist; AAPM provided travel assistance to attend a medical physics conference in Brazil, where she taught a workshop and gave 3 additional presentations. AAPM has also covered travel expenses for her to attend the Education Council and International Council meetings at AAPM Headquarters in Alexandria, Virginia. Leadership or fiduciary role in other board, society, committee, or advocacy groups, paid or unpaid: she serves as an AAPM delegate to the International Organization of Medical Physics (IOMP). In this role, the AAPM will fund travel to represent the AAPM at international conferences during her term as a delegate; Vice-chair of the GNAC, which conducted the survey and developed the manuscript (unpaid); she is a member of the IOMP Professional Relations Committee (unpaid). Joseph Weygand reports leadership or fiduciary role in other board, society, committee, or advocacy groups, paid or unpaid: member of the AAPM GNAC Committee and leadership role in RAD-AID International (all unpaid). Beata Gontova Bernat reports leadership or fiduciary role in other board, society, committee, or advocacy groups, paid or unpaid: member of the GNAC Committee and member of a subcommittee GRSC of the AAPM (all unpaid). Amanda M. 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Supplementary materials

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