Experiences of barriers and facilitators to establishing and sustaining radiotherapy services in low- and middle-income countries: a qualitative study

Running Title

Establishing Radiotherapy services

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Abstract

Aim: The factors contributing to the establishment of high-quality radiotherapy services in low- and middle-income countries (LMICs) are poorly understood. The aim was to identify and describe barriers and facilitators to establishing and sustaining high-quality and accessible radiotherapy services in LMICs based on the experience of successful and unsuccessful attempts.

Method: An exploratory-descriptive qualitative study using semi-structured telephone interviews was undertaken. Purposive and snowball sampling techniques were used to recruit participants. The World Health Organisation Innovative Care for Chronic Conditions Framework informed the interview guide. A constant comparative data analysis approach was adopted.

Findings: Seventeen participants were interviewed. Ten were working permanently in nine LMICs and seven were permanently employed in four high-income countries. Three themes were developed: committing to a vision of improving cancer care; making it happen and sustaining a safe service; and leveraging off radiotherapy to strengthen integrated cancer care. Identified barriers included lack of political leadership continuity, lack of a coordinated advocacy effort, non-Member State of the IAEA, lack of reliable epidemiological data, lack of a comprehensive budget and lack of local expertise. Facilitators identified included strong political support, vision champion, availability of a regulator, costed cancer control plan, diversified sources of funding, responsible project manager, adoption of evidence-based practice, strategic partnerships, motivation to provide patient-centred care and availability of supportive technology.

Conclusion: Assessing the level of readiness to establish and sustain a radiotherapy service is highly recommended. Future research is recommended to develop a readiness assessment tool for radiotherapy services implementation at LMICs.

Keywords: Implementation, Low- and middle-income countries, Neoplasm, Radiotherapy, Sustainability

Introduction

Cancer is a major contributor to the global disease burden, particularly in low- and middle-income countries (LMICs) with more than 10.3 million new cancer cases and 6.4 million cancer deaths in 2018. These numbers are projected to increase because of population growth, ageing, changes in lifestyle and socioeconomic development (1). Radiotherapy is a critical component of cancer patients' management. In LMICs, almost two out of three cancer patients will require radiotherapy to cure or improve quality of life (2).

Achieving universal radiotherapy access is desirable, and global advocacy and supports are crucial (3, 4). For more than six decades, the international community has worked collaboratively with LMICs to improve radiotherapy access (5). Efforts include the development of technical documents regarding safety, quality assurance, commissioning and staffing of radiotherapy services (6-10). The Programme of Action for Cancer Therapy (PACT) established by the International Atomic Energy Agency (IAEA) has been assisting LMICs to evaluate and plan their national cancer control programmes. Progress of PACT is attributed to the buy-in and commitment of the World Health Organisation (WHO) and the International Agency for Research on Cancer (IARC) to control cancer (11). Global efforts also culminated in the Global Task Force on Radiotherapy for Cancer Control (GTFRCC), which quantified the investment required to achieve equity in radiotherapy access and the substantial return on that investment (4).

It is important to assess candidate LMICs' readiness to establishing radiotherapy services and capacity to sustain these to avoid wasting limited resources. Assessing a country's readiness involves appraisal against likely barriers and facilitators related to policy, healthcare organisation and community (12). However, there has been a lack of empirical evidence to inform understanding of which factors might be important to consider. The aim of this study is to identify and describe barriers

and facilitators to establishing and sustaining high-quality radiotherapy services in LMICs based on the experience of successful and unsuccessful attempts.

Methods and analysis

Study design

A descriptive qualitative design was used to develop an in-depth understanding of barriers and facilitators from the perspectives of people involved in introducing radiotherapy services in LMICs. Semi-structured interviews were used to explore participants' experiences. The study design, data collection, analysis and reporting were conducted in accordance with consolidated criteria for reporting qualitative research(13). The study was approved by the Human Research Ethics Committee at the University of Technology Sydney, and all participants gave verbal informed consent. Data collection took place between August 2018 and March 2019.

Conceptual framework

The WHO Health System Building Blocks Framework for Action (14) and Innovative Care for Chronic Condition Framework (ICCCF) (15) informed the interview guide and the analysis framework [refer to Fig 1]. The WHO Framework for Action is an internationally recognised building block for strengthening health systems and consists: service delivery; information; medical products, technologies; financing; and leadership and governance (14).

Participants and setting

Clinical/radiation oncologists, medical physicists, radiation therapists and administrators primarily involved in establishing, strengthening, sustaining and/or providing radiotherapy services in LMICs were eligible to participate in this study if they had: at least 2years experience; and spoke English. We excluded individuals who were involved with only high-income countries' (HICs) radiotherapy service improvements; had limited or no information about the radiotherapy initiative; and were unable to communicate in English.

Recruitment of participants

A purposive sample using a snowball recruitment strategy was adopted to maximise the recruitment. Potential participants were recruited from the authors of relevant studies identified by a systematic

review (12), international reports, recommendations, personal and professional networks. Participants were approached by AD, with an email introduction by SA or JP. The number of participants recruited into the study was determined by theoretical saturation.

Data collection

All interviews were conducted in English via telephone by AD (a male radiation therapist from Ghana with limited experience but has completed training in qualitative research), with seven interviews assisted by TL/JP (male and female Australian clinical academics from allied health and nursing backgrounds respectively, with substantial experience in qualitative research). Interviewers had no previous or ongoing relationships with the people they interviewed. The interviews were facilitated by an interview guide informed by the literature (12) and ICCCF. The guide was pre-tested with an international radiotherapy expert from Australia. The pre-test data was removed from the final analysis. All interviews were audio-recorded and transcribed verbatim. Detailed interview notes were taken.

Analysis

Integrated data analysis with inductive and deductive approaches was used to analyse the data (16, 17). Transcripts were imported into NVivo version–12. Inductive analysis began with AD closely listening to each audio recording multiple times, reading and re-reading the transcripts line-by-line to gain understanding (18, 19). The researcher remained open to new themes and multiple meanings without a pre-specified framework. Once a code was identified in the text, it was reused to capture new ideas in the text. Coded texts were grouped into categories reflecting the barriers and facilitators and they were discussed in a bi-weekly team meeting. Emerging themes were tested out in the interviews that followed.

Deductive analysis began by applying the ICCCF to provide a structured matrix, which allowed a systematic approach to data analysis (17). All data were indexed with identified codes and modified with the addition of new emergent ideas. The final coded results and categories with the transcripts were presented in a table and verified by the research team. Categories were synthesised into themes. To identify areas of convergence and discrepancy among participants, a constant comparison of themes was conducted.

Demographic data were analysed using descriptive statistics. To enhance trustworthiness, emerging themes were shared with selected participants for feedback.

Findings

Forty invitations were sent to potential participants and 23 were unable to participate for the following reasons: workload and annual leave restrictions; email address challenges; no response after follow-ups; travelled overseas; potential conflict of interest; and failure, without a reason to appear for the scheduled interview. A total of 17 participants took part in the study (42.5% response rate), including 12 males and five females. The majority were radiation/clinical oncologists (n=11) with a smaller number of medical physicists (n=3), radiation therapists (n=2) and an administrator. Ten participants were working permanently in either Ethiopia, Egypt, Brazil, Kenya (n=2), Jordan, India, Nepal, Peru and Zambia. All remaining participants (n=7) were permanently employed in four high-income countries [Australia, (n=3), Canada, (n=2), USA (n=1) or Qatar (n=1)] but had been involved in various initiatives to strengthen radiotherapy in multiple LMICs.

Interviews lasted an average of 35 minutes. Despite participants' diversity of experiences across LMICs, three major themes and 15 associated sub-themes were identified as critical to establishing and sustaining high-quality radiotherapy services in LMICs (see Table 1). The major themes were: 1) committing to a vision of improving cancer care; 2) making it happen and sustaining a safe service; and 3) leveraging off radiotherapy to strengthen integrated cancer care.

1. Committing to a vision of improving cancer care

Policy environment. There was unanimous agreement that committing to a cancer control vision, political stability and basic infrastructure like the quality supply of electricity were prerequisites to successful radiotherapy service establishment. A critical success factor was the political will to support establishing radiotherapy services with the capacity to meet the service demands of the population. Most participants perceived that a country's inability to commit and establish radiotherapy was linked to political impasses, periodic changes of political leadership, bureaucratic corruption, multiple competing political demands and policymakers' negative misperception about investing in radiotherapy:

There's a misperception that radiotherapy is expensive…and that comes from the fact that there is a barrier to entry associated with how much it costs to buy a linear accelerator…It's one of the reasons the GTFRCC…analysis is very important (P5, RO, International).

Advocacy. Participants described the availability of 'vision champions' as essential to convincing decision-makers that investing in cancer care was important. 'Vision champions' were recognised as good negotiators and networkers, resilient, enthusiastic and trustworthy individuals or groups who provided leadership and advocacy for improving access to radiotherapy services. A public figure being diagnosed with cancer often provided the impetus for country's political leaders to suddenly commit to radiotherapy. These opportunities needed to be carefully managed to optimise the country's investment to achieve the best outcome for the entire population:

…[even when] there are no resources, a First lady gets breast cancer…and suddenly these resources appear…often these VIPs would travel to Europe or North America for treatment and then they would come back and say, "We want all the bells and whistles that we saw" (P3, RO, International).

Radiation safety. Participants stressed that a critical first step was for a country to become a member of the IAEA, to develop country-wide radiation safety laws, including the establishment of a regulatory authority to ensure timely approval of the radiotherapy plan before the commencement of the facility construction:

…countries have to apply for membership in the IAEA...As part of membership, they may have to pay a modest fee…but then they are also required to have some legislation in place, for accountability of the radioactive materials (P3, RO, International).

Country-wide cancer control policy with radiotherapy implementation plan. Participants described the importance of having a country-wide radiotherapy implementation plan. Having a costed country-wide radiotherapy plan demonstrated the government's commitment to control cancer and theoretically address many of the barriers that participants identified namely, fragmented services and inadequate geographical coverage. Participants suggested a significant barrier to a comprehensive cancer control vision was the lack of reliable epidemiological data, essential to developing a country-wide radiotherapy plan. Epidemiological data was key to developing the

investment case, determining the optimal location and type of technology that would best serve the populations' needs:

> *…what we are doing is to prepare a roadmap as to which states should have equitable radiotherapy access. Because just stating that a country needs 40 radiotherapy or brachytherapy units without knowing where they are required, ends up that many are [established] in major cities (P11, RO, Local).*

Identifying a funding model. Participants identified a viable funding model as crucial to ensure a country was able to commit to construction, equipment set-up and maintenance, and workforce development. Participants described multiple funding models, including public, private, public-private partnership and charitable. Regardless of the model, long-term funding was critical to consider from the outset to ensure a sustainable radiotherapy service:

> *You have to start looking at the long-term plan. The cost-effectiveness reflects in sustainability (P4, MP, International).*

Participants acknowledged that a well-framed business case that demonstrated radiotherapy benefit, financial, technical and operational viability was essential to securing financial commitment. Some countries have adopted public-private partnership strategies where the private sector finance, design, build, operate and maintain the facility for an agreed duration before handing over the responsibility to the public sector. Such partnerships were essential; however, it was a challenge when the country could not sustain the facility. While the private sector was recognised as an important source for financing a country's radiotherapy vision, it did not always promote equity of access and often created financial hardships for poor households without health insurance. Participants highlighted the vital role of charities and civil society organisations in mobilising funds through community engagement, philanthropic and political commitments to addressing barriers, such as financial risks associated with accessing radiotherapy. However, arriving at a subsidy agreement required lobbying:

> *…government is subsiding...diseases like cancer, kidney, and heart…$1000 (US) per patient…we lobbied with the Ministry of Health…met the Prime Minister (P14, Administrator, Local).*

2. **Making it happen and sustaining a safe service**

Establishing a radiotherapy service required project management inclusive of planning, construction, procurement, delivery, installation, commissioning and workforce development. International support at critical junctures, along with concurrent sustainability and contingency plans to manage unforeseen events which threatened the delivery of a fully function radiotherapy service on time and budget is also required.

Building the facility and purchasing the right machinery. Securing a suitable location with space for future expansion and constructing the facility was recognised as a challenging task because of the need for resources. The right balance of local knowledge and international expertise helped to meet the safety and operational requirements. Without a competent project management team, there was a risk of the building process being derailed due to poor stakeholder engagement and suboptimal decision-making, which contributed to cost overrun, project failure and damaged reputations. Participants also highlighted the power differential between local teams and powerful, for-profit vendors. They described how vulnerable many LMICs were when negotiating with larger vendors and how this vulnerability was amplified if there was a lack of tendering and contract management experience within the team:

> *In [HICs], when we decide we want to buy a new machine, we have these experienced physicists who lead the negotiations…But you can imagine that, if the country has no experience in that, the vendors will be dictating (P1, RO, International).*

Establishing collaborative relationships with centres of excellence and seeking technical assistance during the early planning stages was critical. Participants emphasised challenges in equipment licensing requirements at local regulatory levels, resulting in application processes being frustrating and hampered by long delays. Participants highlighted the important contribution that international experts, many of whom are volunteers. They ensured that radiotherapy machineries were correctly commissioned. Many of these experts, make a significant financial and/or time sacrifice to be based in an LMIC for anything up to a year:

> *… we've [international organisation] had…a medical physicist…there for 12 months…for their machine commissioning (P1, RO, International).*

Building the radiotherapy workforce. Building the radiotherapy workforce was essential to the operation and management of any radiotherapy facility. Providing radiotherapy safely required a core team of well-trained radiation oncologists, radiation therapists and medical physicists. This team needs to be in place before the radiotherapy service can commence. The absence of a suitably trained workforce has led some LMICs to resort to inappropriately substituting other health professionals into radiotherapy roles they were not qualified to perform, jeopardising patient and staff safety.

> *…often many departments are very keen to come on-board with new technology straight away when there has not necessarily [been any] training…the therapists are often…nurses…and told, "Okay, now you're the radiation therapist," with very little training (P1, RO, International).*

Overseas training for staff was perceived as unavoidable when establishing radiotherapy for the first time; but was criticised as being expensive with different disease pattern and technology compared to types of equipment and cases of patients treated in most LMICs. Also, overseas training risked the loss of local talent due to better standard of living, attractive incentives, stable political environment and access to advanced technology in HICs. As the length of workforce preparedness was lengthy, participants highlighted the need for workforce development to occur before installation of the equipment to prevent redundancy.

Creative approaches to workforce development were required, including a range of local and international solutions that addressed barriers like insufficient qualified teachers and lack of mentors. They mentioned initiatives such as : e-learning platforms like Virtual University for Cancer Control, Africa Radiation Oncology Network and Chartrounds; and 'train-the-trainers' initiatives by Radiating Hope and Royal Australian and New Zealand College of Radiologists (RANZCR):

> *Since the last one year or two through a partnership with American Society [of Radiation Oncology] International Outreach Program, Chartrounds, is available to us…It's a digital conferencing with weekly at least 30 to 40 radiation oncologists join in to promote education and training (P11, RO, Local).*

Availability of appropriate incentive systems, which included financial and non-financial incentives was described as crucial in attracting and retaining radiotherapy workforce.

Gaining and maintaining financial stability. After the initial investment in establishing the radiotherapy facility, gaining and maintaining financial stability was crucial for operational sustainability. Participants described out-of-pocket payments, prepaid payment plans, social security funds, sustained donor pipeline, public taxes, government revenues and subsidies as payment models adopted to generate funds to sustain facility operations:

> *…we open our hospitals to investors 24 hours a day. So, investors may come and have a tour in the hospital. We show them how we treat our patients…that encouraged the people to donate (P8, RO, Local).*

Regular maintenance. During contract negotiations, it was essential to include an equipment maintenance clause to ensure equipment was serviced regularly, and parts could be readily sourced to minimise downtime. Expensive spare parts, lack of dedicated funding, poor spare parts supply and distribution, as well as lack of qualified engineers were identified as major barriers to maintaining radiotherapy services. Establishing innovative infrastructure maintenance and replacement policies and building a critical mass of equipment from the same vendor were recommended to address most of the named maintenance challenges:

> *What typically happens is every country does its own thing and buys whatever they like…What I would recommend is if there was a cluster of countries…they all go with the same equipment vendor…so that you can have an engineer based in one of those countries that can swing around (P15, RT, International).*

Building research culture and infrastructure. Producing quality data about service performance and improvement was identified as key to further funding commitments from investors. Radiotherapy was thus best recognised as a valuable contribution to cancer control when there was a capability to finance long-term investment in collaborative research to produce innovative solutions:

> *…we have active groups in medical oncology and active groups in radiotherapy. We are investigating the ways of making better medicine with cheaper expenses (P12, RO, Local).*

Good governance and management. Critical to the successful provision of the broad range of clinical and non-clinical services was good governance and management team. Having an inclusive governance and management structure ensured there was a good representation when making decisions to provide quality care.

Participants suggested that to be sustainable, it was critical for the facility management team to have a high degree of accountability, transparency and a culture of continuous expansion:

> *…is a charity hospital…but…we are…continuously expanding...there are two linear accelerators…And we started with 120 beds, but now 303 (P8, RO, Local).*

Improving patient outcomes. An important consideration identified was how the facility sustains patient flows in an ever-growing competitive environment. Creating a reputable brand by having a high-quality infrastructure, adopting evidence-based practices and engaging patients were facilitators that impacted patients' outcomes; hence, were crucial in gaining patients and donors' trust, loyalty and commitment. A further success factor was ensuring that social support systems for patients addressed both medical and non-medical costs when accessing radiotherapy:

> *It's about the extra small things that they [patients] want…when they [patients] are lodging at the hospital, meals are provided, three meals a day for free (P16, CO, Local).*

3. Leveraging off radiotherapy to strengthen integrated cancer care

Establishing a radiotherapy service was suggested to be the foundation for developing integrated cancer services inclusive of a comprehensive care strategy, multi-disciplinary approach and information technologies to improve outcomes.

Catalysing comprehensive care and support service. Achievement of a radiotherapy facility can play a central role in catalysing the development of comprehensive cancer infrastructure to address all necessary aspects of cancer control. A stepwise approach with achievable roadmaps was vital:

> *It [radiotherapy] certainly can be a driver if you like to bring cancer services together…you do have to build custom infrastructure and facilities…it tends to be, well rather than just build a*

radiotherapy centre, let's build a cancer centre…I have seen it work like that (P15, RT, International).

Multidisciplinary approach to care. Participants emphasised the importance of building a multidisciplinary team with a patient-centred comprehensive care goal. Two models of a multidisciplinary approach to care were identified, which included: multidisciplinary clinics; and multidisciplinary cancer conferences to discuss the diagnostic and treatment of cancer patients' care. They suggested that collegial relationships, commitment to regular meetings and availability of operational policies or protocols to standardise care were essential characteristics of a successful multidisciplinary team approach. However, some participants perceived differences between professional perspectives and lack of understanding of the role of radiotherapy created challenges committing to a multidisciplinary path:

Surgeons want to be the owners of the patient, so they want to…bill, they want to get more treatments to the patient, and will only refer to radiation in most of the cases when they cannot do anything else (P13, RO, Local).

Information and communication technologies (ICTs). Participants described how the availability of ICTs contributed to effective integration. The primary objective of implementing ICTs was to improve patient outcomes. Another critical objective was to promote the training of the radiotherapy workforce. Participants explained ICTs as electronic enabling tools for processing and disseminating clinical and non-clinical information to aid effectiveness:

…we have a hospital information system in which this referral is [documented]…every person in the hospital has access to this hospital information system (P8, RO, Local).

Discussion

This qualitative study provides novel exploratory insights into the barriers and facilitators to establishing and sustaining radiotherapy services in LMICs. It demonstrates that radiotherapy establishment is a complex large-scale initiative dependent on multiple critical success factors. These factors relate to a country's ability to: demonstrate commitment towards radiotherapy; capacity to

translate commitment into results; and capability to leverage off radiotherapy to strengthen integrated care.

There is an implication that integrating a costed radiotherapy development plan in a country-wide cancer control programme promotes collaborative and coordinated investment actions. Accurate local data is required for effective planning (20). However, the situation remains that most LMICs lack epidemiological data to inform cancer control actions (1). Developing high-quality radiotherapy requires investment in initiatives to strengthen research capacity (4, 21). Through partnerships at the international level, the Global Initiative for Cancer Registry Development is empowering countries to advance information systems for cancer control (22). While trends in cancer incidence and mortality are needed, it is essential to develop a cancer survival database to inform service design and continuous improvement.

Funding arrangements are critical to establish and sustain radiotherapy services. However, state-of-the-art radiotherapy facilities are established out of a sense of social service with limited focus on sustainability. Achieving universal health coverage for radiotherapy requires diverse funding sources, including public, private, philanthropic and partnership investments. Irrespective of the source, political commitment is integral to facilitate resource mobilisation and allocation. Governments must recognise radiotherapy as a critical driver of economic growth (4). A well-managed facility can function for almost 40years and the equipment can operate for about 20 years (23). However, equipment becomes less efficient after 10 years and spare parts are harder to obtain and more costly. Having strategic maintenance and replacement policy is critical to minimise downtime while prioritising equipment that needs to be replaced (7).

Consistent with several studies in health and non-health, the findings indicate that effective project management is crucial for achieving radiotherapy establishment (10, 24-26). Appointing a project manager with skills to coordinate activities is integral. In situations where a country is establishing radiotherapy for the first time and the right expertise is unavailable, recruiting external expertise is essential (8). The principles of stakeholder participation are also important to promote co-design and ownership.

Sustaining radiotherapy facilities in LMICs is achievable but requires a capable workforce. Tailored in-country education and training initiatives are emerging and have proven successful (27-29). Multiple opportunities for regional training, mentoring and network building have been created. They include Africa Radiation Oncology Network (AFRONET) and Virtual University for Cancer Control by IAEA and 'train-the-trainers' approach by Radiating Hope, RANZCR and Medical Physics for World Benefit (3, 30-32). Links with radiotherapy centres in HICs are vital in improving technical support (2). The findings confirmed those of previous evidence that depending on overseas training is unsustainable (30, 33).

This study highlights the importance of readiness assessment prior to establishing a radiotherapy service. To achieve an objective assessment of a country's readiness often proves to be challenging due to the lack of indicators. Providing a relevant tool for readiness assessment is imperative. The factors identified in this study provide a promising starting point. It will also be important to strengthen the various innovation programmes for researching and developing innovative technologies to address most of the identified radiotherapy challenges. Thus, LMICs have opportunities to invest in potentially 'leapfrog' radiotherapy technologies. Like mobile diagnostic units, mobile radiotherapy service delivery models can make a significant impact on access to radiotherapy service in LMICs. There is value in sharing lessons learned from radiotherapy implementation in a global context.

Strengths and limitations

The strengths of this study are: participants had varied experiences in establishing, strengthening, sustaining and/or delivering radiotherapy across LMICs; we involved the views multiple disciplines within radiotherapy, thus increasing our confidence in the data. The sample size of this study was enough to capture and understand broad themes related to radiotherapy service implementation, which will enable us to develop item indicators for a future survey with a large sample size. A few limitations are important to mention. First, participants were required to recount their experiences and may have created recall bias. Additionally, while telephone interviews enabled us to gain insight into the various implementation barriers and facilitators, we were unable to take account of facial expression and body language.

Conclusion

This study identified several barriers and facilitators to establishing high-quality sustainable radiotherapy services in LMICs. We identified examples of successful radiotherapy services in LMICs that were largely achieved through strong political support, advocacy activities of vision champions, diversified sources of funding, strategic partnerships, costed cancer control plan, adoption of evidence-based practice, prepared workforce, technical assistance from IAEA and other expert volunteers, well-negotiated service contract and international and/or regional research collaborations. Assessing the level of readiness to establish and sustain a radiotherapy service is highly recommended. Future research is recommended to develop a readiness assessment tool for radiotherapy services implementation at LMICs.

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Availability of data and materials

De-identified datasets analysed in the current study are available from the corresponding author on reasonable request.

Authors contributions

All authors contributed to manuscript writing, editing and final approval, including table design. AD, TL, SA and JP conceived the study. AD, SA and JP facilitated recruitment. AD, TL and JP led the data collection. Data analysis was performed by AD with consensus discussions with all authors. VV assisted with interpretation of the findings. All authors reviewed the draft manuscript and provided approval to the final manuscript.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

Figure and table legends

Fig. 1 Innovative Care for Chronic Conditions framework adapted with permission granted by World Health Organisation

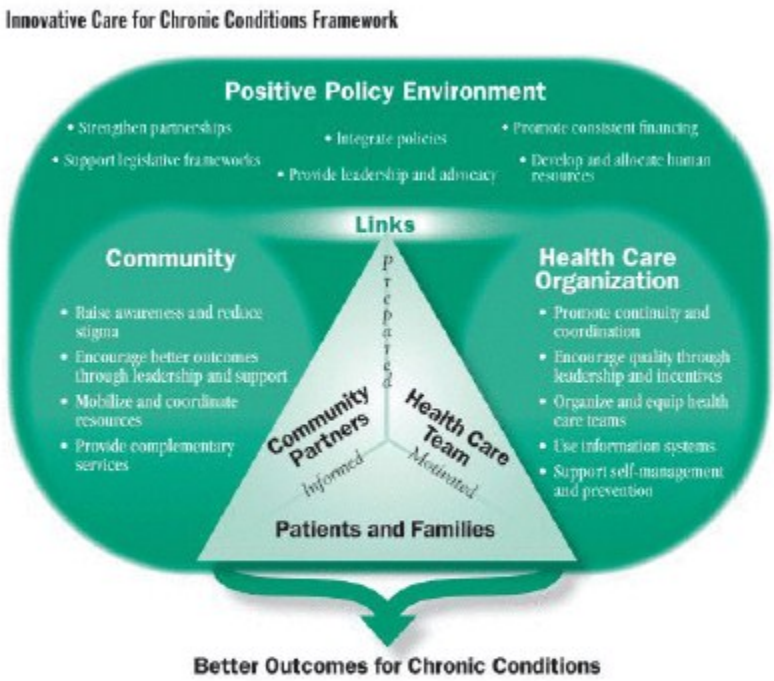

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Table 1: Barriers and facilitators to establishing and sustaining radiotherapy services in LMICs, with sample comments

Themes	Sub-themes	Barriers	Facilitators	Exemplar comments from participants
1. Committing to a vision of improving cancer care	Policy environment	• Political impasses. • Bureaucratic corruption. • Lack of political leadership continuity. • Competing political demands on scarce resources. • Policymakers' negative misperception about radiotherapy.	• Political stability. • Political decision to invest in basic infrastructure. • Strong political support.	*"…with the support of the Ministry of Health…six centres and teaching hospitals were selected to start cancer care, including radiotherapy" (P10, CO, Local).* *"…the most challenging things are politics, our politicians…they change every three or four years depending on the country. So, it's very difficult to have continuity of investment" (P13, RO, Local).*
	Advocacy	• Feelings of powerless to influence decision • Lack of a coordinated advocacy effort.	• Vision champion. • Useful window of opportunity.	*"[You need] someone that has some sort of clout…that will listen to…a university professor, or physician, or a senior medical physicist, or even someone that works in the government already" (P4, MP, International).* *"I think that the coordination of different individuals and groups would be a really good thing…[and] the work we do should primarily be directed towards government" (P6, RT, International).*
	Radiation safety	• Non-member State of the IAEA. • Lack of legal and regulatory framework.	• Member State of IAEA. • Availability of a regulator. • Availability of legal and regulatory framework.	*"There is the Ministry of Health and there is the Ministry of Science and Technology, which are responsible for controlling all the radiation services and the radiation sources in the country" (P10, CO, Local).* *"We had to work with whatever radiation safety body within the country…and generate licenses…[because]…they're going to have a radiation-producing machine" (P4, MP, International).*

	Country-wide radiotherapy implementation plan	• Poor planning. • Lack of reliable epidemiological data.	• Availability of a costed cancer control plan. • Accurate epidemiological data at the institutional or LMIC-level. • Access to global cancer data (GLOBOCAN).	*"…you need radiotherapy to be installed within a comprehensive national cancer control program. So, you need the cancers that are preventable being prevented. You need early detection so that the cases that are coming into radiotherapy are maximised... Then you're palliating the ones that can be palliated" (P15, RT, International).* *"The starting point is the demographics, which again may or may not be available in some countries…in many cases, the data were extrapolated, especially in Africa because there are so few countries with good cancer registries" (P3, RO, International).*
	Identifying a funding model	• Lack of a comprehensive and reliable line-item budget. • Poor mobilisation and allocation of financial resources.	• Diversified sources of funding – public, private, partnerships and philanthropic investment. • Ability to develop a well-framed business case for investment in radiotherapy. • Ability to gain long-term financial commitment.	*"I approached a bank for a loan and when the bank financed the loan, now we bought a property to build a centre that houses everything under one roof ... they've [bank] been quite supportive in trying to make sure the facility is built... The process was first you have to give a business case and then they have to come and evaluate the feasibility of the plan." (P9, CO, Local).* *"…there is a little bit of a trend… where a company will come in with what they call a turn-key solution. So, they will come in [country] and they will build the building, put the equipment in, commission the equipment, get it ready to go, and in some cases put workforce in there for a period of time… Then they walk away… and…turn over to local people to run and operate" (P15, RT, International).*
2. Making it happen and sustaining a safe	Building the facility and purchasing the	• Lack of local radiotherapy expertise. • Poor stakeholder	• IAEA's technical cooperation programme. • Access to	*"…we had a local architect who could collaborate and share the drawings with an international person to critique and give*

service	right machinery	engagement. • Lack of a competent project manager. • Lack of negotiating power of LMICs. • Lack of coordination and communication among relevant stakeholders. • Lack of synchronisation of different activities.	suitable land, with space for future expansion. • Ability to create a multidisciplinary implementation team. • Appointment of a responsible project manager. • Creation of a technical assistance plan. • Appropriate arrangements for commissioning and licensing of the new radiotherapy service prior to the start of patient treatment. • Access to experienced contractors. • Engagement of expert volunteers.	*input" (P9, CO, Local).* *"…the medical physicists were not involved, right from the beginning…when the companies came to evaluate the status of the bunkers, they found some design problems" (P10, CO, Local).*
	Building the radiotherapy workforce	• Absence of a suitably trained workforce. • Lack of sufficiently qualified teachers and mentors. • Lack of appropriate incentives. • High degree of brain drain after overseas education and training. • Lack of staff succession plan.	• Availability of a workforce development plan. • Timely arrangement to ensure staff education and training is undertaken in centres with patient population and equipment relevant to the needs of the LMIC. • Availability of innovative educational programmes such as Virtual University for Cancer Control and Africa Radiation	*"I always make it very clear that professionals at a minimum you need radiation oncologist, medical physicist and radiation therapist. It's a three-legged stool, if one of the legs do not work, the stool doesn't work. For at least those three professions, and then you can also put in oncology nursing and dietitian and so on" (P2, MP, International).* *"In one case…the facility was ready, the equipment was installed, but the trainees were not ready…and what happened during that time, rats and mice basically ate up the wiring" (P3, RO, International).* *"…the biggest challenge…of the educational program is the residency part, because the residency part is extended, you need experienced people, you*

			Oncology Network. • Arrangement to establish a country-based accredited training programme. • Appropriate incentive strategies to attract and retain workforce.	*need technology to be able to give proper residency training" (P2, MP, International).*
	Gaining and maintaining financial stability	• Lack of financial resources to support service operation. • Financial hardship to patients and their families.	• Clear financial mechanism for operational sustainability.	*"…there is government and private cooperation resources that have gone into setting up the facility…however, patients end up paying for their radiotherapy services" (P6, RT, International)* *"We have insurances paying for them, but majority…do not really have medical insurance" (P9, CO, Local).*
	Regular maintenance	• Lack of a long-term service contract. • Poor spare parts supply and distribution. • Expensive spare parts • Lack of qualified engineers.	• Build a critical mass of equipment. • A well-negotiated service contract to minimise downtime. • Favourable trade and border legislation that eliminates procedural barriers to medical goods across the border.	*According to our [service] agreement, the uptime of our machines must exceed 95%.…For example, one linear accelerator stops working for some or other reason; we make a call out, the engineer is supposed to be on-site, according to the agreement, within one hour (P17, MP, Local).* *"…all these machines are coded in American dollars…our currency is not very good right now...So, they say, 'Okay, we don't want the machine anymore because you're giving the machine you are not giving money for the next five years to maintain the machine' (P13, RO, Local).*
	Building research culture and infrastructure	• Lack of research capacity in radiotherapy.	• International and/or regional research collaborations. • Allocation of funds for research.	*"Building research capacity is the only way…because being a researcher generates the data that then supports that it's worth it, to make more investment… People don't care about opinions, they care about statistics and evidence" (P16, CO, Local).*

				"…they should really link with some very good regional and international cancer centres to learn" (P7, RO, Local).
	Good governance and management	• Lack of clear roles and responsibilities.	• Availability of an inclusive governance and management board • Leadership that fosters continuous expansion.	*"The cancer hospital is run by 9-member management committee…These board members are responsible for the development… and all the financial aspect…of the hospital… they have a certain time frame" (P14, Administrator, Local).* *"The machines will be sold, but there's not any kind of responsibility…to see it through to the end. It's just like, "Okay. we've sold it. That's it". (P1, RO, International).*
	Improving patient outcomes	• Lack of trust based on information and communication processes. • Lack of needed social support services. • Limited access to evidence-based clinical guidelines.	• Adoption of evidence-based practice. • Availability of social services for patients, such as transport and accommodation assistance schemes. • Involvement of patients and their families. • Development of trust based on quality service.	*"…with good service…we received the trust of the people…it's very important…they don't trust the government hospital; they don't trust other NGO hospitals. When they have money, they choose the private hospital" (P14, Administrator, Local).* *"We use guidelines and sit every year to review these guidelines. We put the guidelines under discussions… we agree on international guidelines, which is there in our system" (P7, RO, Local).*
3. Leveraging off radiotherapy to strengthen integrated cancer care	Catalysing comprehensive care and support service	• Inability to plan and prioritise the integration sufficiently. • Expensive process for governments.	• Vision and milestones to develop a comprehensive cancer centre. • Strong clinical and political leadership support. • Long-term financial commitment. • Development of strategic partnerships.	*"They implemented radiotherapy in a fantastically staged fashion. So, stage one was to build that radiotherapy centre; stage two was to build extra buildings next door to create dedicated cancer wards. Stage three was to start their own training programmes and start to undertake cancer research…it's a clinician that led this implementation approach. He was very, very strategic… That really helped in terms of getting funding through, getting decisions taken, all of that high-level support" (P15, RT,*

				International). *"…it is very difficult because we are depending on government grants...For now, we have been depending on partners who are interested...I think the frame-work with development...is very large and it has very long-term funding. It's about achieving milestones, and we are kind of still working through that funding" (P16, CO, Local).*
	A multidisciplinary approach to care	• Differences between professional perspectives. • Lack of understanding of the role of radiotherapy.	• Service providers motivated to provide patient-centred care. • Availability of a multidisciplinary cancer conference operational policy. • Respectful collegial relationships. • Motivation to provide evidence-based and coordinated cancer treatment and care. • Commitment to regular attendance.	*"…we work under one scientific umbrella without having this problem of junior or senior, or different school, British school or American, or local. We faced that problem in the past…with differences of views… but then we created our internal law here that no patient can be treated without having a decision by the multidisciplinary team" (P7, RO, Local).* *"Some departments are easier to collaborate with surgeons and others are not…For instance, in prostate, the patient should be offered radiation or surgery…the surgeons will treat the majority of the patient without even offering radiation…sometimes most of these surgeons they have no idea what radiation is, and they think, "Okay, this is gonna burn the patient, I don't want them to have that…we are now trying to educate the surgeons… and also educate the patient" (P13, RO, Local).*
	Information and communication technologies (ICTs)	• Inadequate training and assistance for users.	• Supportive technology and information access. • Electronic platform for training and multidisciplinary conference. • Adequate training for information technologists. • Access to the	*"We are connecting everybody digitally so that people can network, conference and move ahead… we do weekly Tumour Boards using the ECHO platform…specialists can connect with each other, present their cases and do things" (P11, RO, Local).* *"With information technology… we have a program available on the internet, which is*

			internet.	*educating regularly" (P12, RO, Local).*

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	Advocacy	• Feelings of powerless to influence decision • Lack of a coordinated advocacy effort.	• Vision champion. • Useful window of opportunity.	*"[You need] someone that has some sort of clout…that will listen to…a university professor, or physician, or a senior medical physicist, or even someone that works in the government already" (P4, MP, International).* *"I think that the coordination of different individuals and groups would be a really good thing…[and] the work we do should primarily be directed towards government" (P6, RT, International).*
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				(P15, RT, International).
5. Making it happen and sustaining a safe service	Building the facility and purchasing the right machinery	• Lack of local radiotherapy expertise. • Poor stakeholder engagement. • Lack of a competent project manager. • Lack of negotiating power of LMICs. • Lack of coordination and communication among relevant stakeholders. • Lack of synchronisation of different activities.	• IAEA's technical cooperation programme. • Access to suitable land, with space for future expansion. • Ability to create a multidisciplinary implementation team. • Appointment of a responsible project manager. • Creation of a technical assistance plan. • Appropriate arrangements for commissioning and licensing of the new radiotherapy service prior to the start of patient treatment. • Access to experienced contractors. • Engagement of expert volunteers.	*"…we had a local architect who could collaborate and share the drawings with an international person to critique and give input" (P9, CO, Local).* *"…the medical physicists were not involved, right from the beginning…when the companies came to evaluate the status of the bunkers, they found some design problems" (P10, CO, Local).*
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			such as Virtual University for Cancer Control and Africa Radiation Oncology Network. • Arrangement to establish a country-based accredited training programme. • Appropriate incentive strategies to attract and retain workforce.	*RO, International).* *"…the biggest challenge…of the educational program is the residency part, because the residency part is extended, you need experienced people, you need technology to be able to give proper residency training" (P2, MP, International).*
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