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RADIATION ONCOLOGY QUALITY AND SAFETY CONSIDERATIONS IN LOW RESOURCE SETTINGS: A MEDICAL PHYSICS PERSPECTIVE

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Abstract

The last few years have seen a significant growth of interest in the global radiation therapy crisis. Various organizations have quantified the need and are providing aid in support of addressing the shortfalls existing in many low-to-middle income countries (LMICs). With the tremendous demand for new facilities, equipment and personnel, it is very important to recognize the quality and safety challenges and to address them directly. An examination of publications on quality and safety in radiation therapy indicates a consistency in a number of the recommendations; however, these authoritative reports were generally based on input from high-resourced contexts. Here we review these recommendations with a special emphasis on issues that are significant in LMICs. While multidimensional, training and staffing are top priorities; any support provided to lower resourced settings must address the numerous facets associated with quality and safety indicators. Strong partnerships between high-income and other countries will enhance the development of safe and resource-appropriate strategies for advancing the radiation treatment process. The real challenge is the engagement of a strong spirit of cooperation, collaboration and communication between the multiple organizations in support of reducing the cancer divide and improving the provision of safe and effective radiation therapy.
1. Introduction

There has been a recent increased recognition of the growing cancer crisis, especially in low-to-middle income countries (LMICs). This is clearly demonstrated by Figure 1(a) which shows a significant increase in the number of publications dealing with the global cancer problem of which nearly 30% were published in 2014 and 2015. What is noteworthy, however, is that a similar publications search on the global radiotherapy problem yielded about 3% of the global cancer papers and of those about 80% were published in 2014 and 2015 (Figure 1(b)). The most significant recent report is the Lancet Oncology Commission on global access to radiotherapy\textsuperscript{1}. This report indicates that radiation therapy (RT) is essential for effective cancer treatment, but the availability of RT in LMICs is unacceptably low. It quantifies the shortfall in access to RT by country and globally for 2015 to 2035 based on current and projected need, and it shows the substantial health and economic benefits to investing in RT in spite of the high up-front costs. The projections to 2035 indicate the need for very significant growth in RT facilities and personnel so that 22,000 additional medical physicists will be required in LMICs to meet the overall demand and recommends an action in human resource capacity building of at least 6,000 newly trained medical physicists by 2025. With this tremendous demand for new facilities, equipment and personnel, it is important to recognize the quality and safety considerations in the lower resourced settings and to address them directly as a means of maximizing treatment quality and minimizing potential patient mis-administrations.

As pointed out in a report by the International Atomic Energy Agency (IAEA) on inequity in cancer care\textsuperscript{2}, “quality” in health care is a multidimensional concept\textsuperscript{3} with components of ‘inequality’ (or disparity) encompassing all the other elements of ‘quality’. A program to improve quality must therefore include activities to address the inequality problem. While this paper does
not address the problems of solving basic inequalities, it does address quality issues related to societal contexts where RT infrastructure is just being developed.

2. The Radiation Treatment Process and Elements of Quality and Safety

The radiation treatment process is complex with multiple steps and involves various professional personnel. Elements of quality and safety occur at both the programmatic and individual patient level as shown in Figure 2.

3. Impact of Quality on Patient Outcome

There is growing quantitative evidence that the quality of radiation treatment has a direct impact on clinical outcomes. A recent review\(^4\) which specifically addressed the question “Does quality of radiotherapy predict outcomes of multicenter cooperative group trials?” found, through a thorough literature review, that in nearly half the trials, clinical failure rates were significantly higher after inadequate versus adequate RT and that significantly worse overall and progression-free survival occurred after poor quality RT. Peters \textit{et al}\(^5\) demonstrated significantly inferior outcomes for those patients with major deficiencies in their treatment plans from data submitted for review for a large international phase III trial of head and neck cancers comprised of 687 patients. They noted that centers treating only a few patients are the major source of quality problems. Analogous data regarding dosimetry audit pass rates have been presented by the Radiological Physics Center / Imaging and Radiation Oncology Core and demonstrated that the pass rates improved with the number of machines in the department, with a pass rate of about 78% for departments with 1 to 2 machines versus 86% for departments with 5 or more machines\(^6\).
The problem of treatment errors is a more extreme manifestation of poor treatment quality and has the potential for much more significant negative short term clinical consequences\textsuperscript{7-10}. New technologies provide new risks of treatment errors as indicated by the 2009 ICRP report\textsuperscript{8}, the articles from the New York Times\textsuperscript{11} and multiple other reports\textsuperscript{12-15}.

4. Overview of Quality and Safety Considerations

In 1988, the World Health Organization defined quality assurance (QA) as “all those procedures that ensure consistency of the medical prescription and the safe fulfillment of that prescription as regards to the target volume, together with minimal dose to normal tissue, minimal exposure of personnel, and adequate patient monitoring aimed at determining the end result of treatment”\textsuperscript{16}.

Thus, the components of QA include:

- Dose delivered to the target according to the prescription
- Safe dose to normal tissues
- Minimal dose to personnel
- Patient monitoring

Over the years, multiple reports have been written on quality assurance programs and quality control procedures with the aim of safely delivering the prescribed dose to the patient. However, in spite of these reports, treatment errors have occurred, albeit in only a very small percentage (1-2\%) of all RT patients treated\textsuperscript{17,18}, with the rate of serious or adverse errors estimated to be around 0.2\% per patient\textsuperscript{18,19}. Over the last decade, various international and national organizations have provided recommendations on how RT can be made safer. Dunscombe\textsuperscript{20} performed a detailed review of seven authoritative reports\textsuperscript{8-10,21-24} published since 2008 which provided 117 recommendations. Through a mapping exercise, the 117 recommendations were
distilled to 61 unique recommendations with 12 topics being identified in three or more of the seven documents. These were, in order of most to least cited: training, staffing, documentation, incident learning, communication, checklists, quality control and preventive maintenance, dosimetric audit, accreditation, minimizing interruptions, prospective risk assessment, and safety culture. IAEA TRS430\textsuperscript{25} summarized common errors in treatment planning to be related to education, documentation, verification, and communication. Clearly these overlap directly with the 12 topics identified from the authoritative reports.

5. Issues in Low Resourced Settings

5.1 Planning and Integration of Radiotherapy in National Health Programs

The Lancet Oncology Commission\textsuperscript{1} on expanding global access to RT had five “Calls for Action” with the first being a target that 80% of countries should have national cancer plans that include RT by the year 2020. Clearly, if national plans are not in place, the likelihood of any RT occurring in the country is low. The access to RT problem is most acute in sub-Saharan Africa, where most countries almost completely lack radiation therapy facilities. The IAEA is working together with pre-eminent cancer-related health organizations to leverage the effectiveness of radiation medicine, particularly in LMICs, by integrating it into comprehensive national cancer programs\textsuperscript{26}. They, along with the World Health Organization (WHO), have developed a National Cancer Control Programme/Plan (NCCP) Core Capacity Self-Assessment Tool that has been used to obtain a simple and quick qualitative overview of national cancer control planning and on-going activities. The results from 50 member states highlight specific areas where WHO, IAEA and partners could strengthen collaboration with countries to leverage on-going interventions and improve availability of resources. Clearly, cancer plans are essential for RT to be reasonably organized in a national context.
5.2 Adequate Facilities

In a systematic review of the published literature, Grover et al\textsuperscript{27} found 49 articles that addressed RT capacity in LMICs. They concluded that: (1) there is a dearth of publications on RT therapy infrastructure in LMICs; (2) based on limited published data, availability of RT resources reflects the countries’ economic status; (3) the challenges of delivering radiation therapy in LMICs are multidimensional and include: (a) lack of physical resources, (b) lack of human personnel, and (c) lack of data. Furthermore, access to existing RT and affordability of care remain large problems.

The Lancet Oncology Commission report\textsuperscript{1} demonstrated that by the year 2035 the following resources would be needed in LMICs to provide equal access to RT globally: (1) 6,300 departments with two-megavoltage RT machines each; (2) 12,600 megavoltage RT machines; (3) 6,300 CT scanners; and (4) 30,000 Radiation Oncologists, 22,100 Medical Physicists and 78,300 Radiation Therapists, all to be trained. The second Call for Action in this report is a target of increasing RT capacity by 25% by 2025.

5.3 Funding for Up-to-Date Equipment

The most significant RT challenges in LMICs include the quality and quantity of physical resources, the scarceness of skilled human resources, and the unequal distribution of available resources\textsuperscript{1, 27, 28}. The number, age, and quality of machines contribute to suboptimal RT capacity with many countries relying on machines that are more than 20 years old, which brings their functionality and reliability into question\textsuperscript{27, 29}. These issues all relate to a lack of adequate funding, often based on the lack of appropriate NCCPs.
5.4 Trained Staff and Local Education and Training Programs for Clinically Qualified Medical Physicists

Most reports on the availability of radiation oncology personnel and training programs indicate that there are not enough qualified professional staff to treat the number of patients requiring RT. The insufficient number of personnel is in part due to the insufficient number of training programs available locally. In view of the recognized deficiencies in human resources and financing, the Lancet Oncology Commission’s Actions 3 and 4 aim for training 7,500 radiation oncologists, 6,000 Medical Physicists and 20,000 Radiation Therapists by 2025 and target a $46 billion investment by 2025 to establish RT and training infrastructure in LMICs.

5.5 Resources for Equipment Parts and Qualified Support Staff for Maintaining Complex RT Equipment

Efficient equipment service and maintenance are key components of continuous operation of an RT facility. Stories abound of how equipment in LMICs sits idle because of a lack of maintenance support or a lack of funding for such support.

5.6 New Departments Often Start de novo in LMICs

When a new radiation therapy facility is developed in a high income country, basic infrastructure for planning and architectural design is readily available and education and training programs are in place to train radiation oncology-related professionals. Furthermore, continuing education programs and certification procedures are available through professional organizations and certifying bodies. In many LMICs such support is often not available nor can they get much support from colleagues from nearby centers because often there are no nearby centers. Thus, training and education is a very significant challenge in these settings. Furthermore, the planning of new departments is frequently performed by non-radiation oncology specialists who often do
not understand that radiation oncology-related professional staff should be part of the planning discussions in developing a new RT facility and should be available before the new center opens (see Programmatic QA in Figure 2). In addition, decisions on equipment specifications are often taken without input from a medical physicist, leading to the purchase of inadequate equipment or lack of connectivity to existing systems. Whatever education and training mechanisms are developed, they should be as close to home as possible to match the training with the nearby medical/technological environment and to minimize the “brain drain”.

6. Considerations for New Facilities or Upgrade of Existing Facilities

In planning for new departments or additional machines in existing departments, the IAEA has developed some excellent resources. Crucial to describing the operation of a new radiation oncology facility are five principal components: (1) facility design and development, (2) equipment, (3) consumable materials, (4) human resources and (5) procedures. A clear chain of authority and communication needs to be established early. One of the general concerns in developing a new cancer program is that decisions are made from the “top down” sometimes without consultation with the appropriate radiation oncology-related professionals. This has resulted in significant cost over-runs and time delays. Once the project to commission a RT facility has been approved, a team of professionals needs to be constituted to manage the project. If expertise is not available locally, external experts should be consulted. At a minimum, the team should include qualified: architect, structural engineer, mechanical engineer, electrical engineer, cost consultant, clinical medical physicist, and radiation oncologist. Ideally, key individuals will be available as part of the planning process, but the full staffing complement should be available when the center starts patient treatments.
6.1 Donated Equipment

Resource constraints in LMICs often encourage the consideration of donated medical equipment. Such donations allow for the surplus from high resource settings to be passed on to low resource settings; however, if poorly executed, donations could turn into a burden for the recipient, wasting money, human resources, and with long term implications on the healthcare systems.

Furthermore, the lack of appropriately trained staff could have significant implications for safety and quality. These issues are of particular significance for the high technology, complex and expensive equipment used in RT.

The WHO has developed resources on donated equipment including a guidance manual. The following main barriers to effective donation of medical equipment have been identified:

- Lack of genuine partnership between donor and recipient
- Insufficient appreciation for the challenges of the recipient’s context
- Limited standardized inventory of medical equipment in resource constrained settings to identify needs
- Insufficient support for the long term integration of new equipment
- Insufficient connectivity between activities of various organizations working on donations
- Lack of accountability - no tracking and monitoring of donations and no existing quantification framework for impact of donations
- Insufficient capacity and capacity building programs for recipients

The IOMP working with the AAPM has a joint equipment donation program specifically focused on equipment associated with radiation medicine. The bottom line, however, is that equipment
donations are often more of a hindrance than help to LMICs; thus, there needs to be well thought out plans before embarking on the donation of expensive and complex equipment.

7. Lessons Learned from Past Experience

The seven authoritative reports referred to in the Dunscombe paper provide guidance on delivering safe RT, based on lessons learned from past experience – experience which is primarily based on high income contexts. The question is what the corresponding risks are in lower income settings. Table 1 lists the topics of the 12 top most cited recommendations made in these papers. Based on our national and international experience, our interactions with medical physicists in both low and high income settings, and published reports, we have estimated a level of risk in LMIC contexts. While not a precise science, it is a way of raising concerns which we hope will be useful to the development of RT programs. Brief comments are made on several of the recommendation categories.

7.1 Training

Insufficient numbers of radiation therapy professionals and inadequate training of existing staff members are one of the main causes of radiation therapy mis-administrations and inferior quality treatments. “Education” provides the theoretical knowledge and is usually given through university programs. “Training” provides the skills to perform specialized tasks. For Medical Physics activities, training is the “on-the-job” learning usually given through a clinical residency program. In addition to learning how to perform specific tasks, the prime purposes of education and training of Medical Physicists is to be able to solve unexpected and unique problems, combined with providing safe, competent, independent and effective service in the clinical environment. The specialized training for specific technologies can be quickly outdated with the evolution of new technologies. Both the IOMP and the IAEA recommend a postgraduate
degree in Medical Physics, generally an MSc or equivalent, and clinical training for a period not less than two years. European and IAEA surveys indicate that the minimum academic education and clinical training time frame for employment as a hospital medical physicist varies between three and nine years, with an average of six years\textsuperscript{39}.

According to Datta \textit{et al}\textsuperscript{28}, 55 LMICs, representing 358 million people, have no access to RT. Clearly, these 55 countries have no Medical Physics training programs. Even in some countries with RT, education and training are non-existent or at an embryonic stage. Thus, there is a “bootstrapping” problem of how to provide education and training without existing experienced university and clinical staff to lead the necessary education and training programs. There are several considerations in this context. For development of new facilities or expansion of existing facilities in LMICs, a multidimensional approach can be used whereby the national government, international government or non-government agencies, not-for-profit volunteer organizations as well as foreign hospitals and universities work in partnership to establish or expand existing programs. Organizations like the IAEA are heavily involved in support of infrastructure enhancement in low income settings\textsuperscript{29,40-42}. Member states of the IAEA can apply for assistance through their country projects since development of RT programs usually include human resource improvement components of expert missions, scientific visits, fellowships, and national courses or workshops\textsuperscript{40}. Regional and interregional training courses and projects are also available. In addition, there are multiple volunteer and non-profit organizations in support of infrastructure and educational development both at the broader and grassroots levels. Examples include International Cancer Experts Corps (ICEC) (www.ICECcancer.org) and Medical Physicists Without Borders (MPWB) (www.mpwb.org). A link in the latter website (http://www.mpwb.org/page-18070) provides further hyperlinks to multiple organizations in support of radiation therapy activities in low-to-middle income settings. Novel solutions to
education and training issues are possible through collaboration between international organizations, local governments, and regional organizations\(^\text{29}\).

### 7.2 Staffing

Inadequate resources mean that multiple facets of healthcare are underfinanced including equipment and staff. Staffing recommendations have been provided by various organizations. Many of the original staffing recommendations were based primarily on patient numbers\(^\text{35}\). A European survey indicated that the guidelines across Europe are far from uniform and the metrics used for capital and human resources are variable\(^\text{43}\). Recent, more advanced staffing algorithms are activity-based and account for patient workload, technology, techniques, procedures and infrastructure so that they are more relevant for the reality in local circumstances\(^\text{44-46}\) and are applicable to environments that range from 2-D RT to intensity modulation with image guidance, motion management and 4-D considerations. The IAEA algorithm is accompanied by a spreadsheet calculator so that it can be used as a practical tool for determining staffing levels\(^\text{46}\).

### 7.3 Documentation/Standard Operating Procedures

The literature shows that 70\%-80\% of incidents (defined as “an unwanted or unexpected change from a normal system behavior that causes or has the potential to cause an adverse effect to persons or equipment”) are primarily caused by either lack of, inadequate, or failure to follow standard procedures\(^\text{18, 47}\). Thorough documentation is essential along with the mandate to follow procedures as documented. Unfortunately, when staffing levels are constrained, documentation is one of the first things to be compromised. Considerations for reducing treatment uncertainties include the implementation of clear policies, guidelines and procedures, good documentation of the policies and procedures as well as the results of acceptance, commissioning and QC tests\(^\text{6}\). If the acceptance, commissioning and QC procedures are not documented, then it is effectively
equivalent to not having performed them at all. If there is staff turnover, the new incoming staff member will not know what procedures have occurred to commission the equipment. If there are no protocols for patient procedures, it will be difficult to maintain consistency from one patient to the next. Stringent QA review can have a positive impact on every day clinical practice\textsuperscript{48}. A policies and procedures manual should be available in every department and should be reviewed and updated annually.

### 7.4 Incident Learning

The Institute of Medicine’s report on “To Err is Human: Building a Safer Health System”\textsuperscript{49} was one of the first reports to overtly emphasize that we should learn from our (or others’) mistakes. Since the year 2000, much activity and publicity has been given on the development of incident learning systems and various examples have shown how the error rate has been reduced as a result of openly disclosing errors and learning from past mistakes\textsuperscript{18, 47, 50}. However, open disclosure of errors and a well-documented incident learning process requires a working environment of trust and agreement that patient treatment errors are not the problem of individuals but they are a result of an inadequate quality management system. Unfortunately, in the past and in some cultural environments, there is a tendency to want to blame individuals for patient-related treatment errors. In some cultural contexts, the “no blame” concepts are very difficult to accept and implement. However, without an overt acceptance of an incident learning mentality, the error rates are not likely to decrease.

The IAEA has developed a web based user system, SAFety in Radiation ONcology (SAFRON) for improving the safety and quality of patient care in radiation therapy by sharing knowledge about incidents and near incidents. SAFRON allows radiotherapy centers to contribute incidents and near misses to an international learning system, allowing the participating centers to share
and receive information on incidents and near misses. By pooling information on the incidents, causality and corrective actions, radiotherapy facilities can develop a safety system that can prevent or reduce the likelihood of an incident occurring at their facility.

7.5 Communication/Questioning

A well-developed safety culture includes an atmosphere of open and non-threatening communication. The emphasis should be on “no question is a dumb question” so that all staff will readily ask questions of their peers, superiors and subordinates without feeling intimidated. One study performed a cross-cultural survey of medical residents to determine perceived barriers in questioning and challenging authority\textsuperscript{51}. The conclusion was that organizational and professional culture may be as important, if not more so, than national culture to encourage "speaking up". Residents (and staff) should be encouraged to overcome barriers to challenging their colleagues, and training programs should foster improved relationships and communication between trainers and trainees.

7.6 Checklists

The fourth most effective risk mitigation strategy proposed by the Institute for Safe Medication Practices (ISMP) is the use of reminders, double checks and checklists\textsuperscript{52}. In WHO’s \textit{Radiotherapy Risk Profile}\textsuperscript{9} one of the suggested risk reduction interventions for all stages of the radiation therapy process includes information transfer with redundancy. However, the challenge of checklists is the potential for automaticity\textsuperscript{20} whereby procedures are repeated by rote without careful thought. This results in the risk of copying errors. This automaticity is a significant concern in busy understaffed departments as might occur in lower resourced environments. Thus, an emphasis should be placed on developing policies and procedures that are simultaneously effective and efficient with appropriate redundancies and checklists.
7.7 Quality Control/Preventative Maintenance

Numerous reports have been written by national and international organizations on QC protocols for RT-related technologies and procedures, many of which are available on-line\textsuperscript{53}. Vendors provide detailed documentation on preventative maintenance procedures. The trend is towards facility-unique QC programs through the use of failure modes and effects analysis (FMEA) whereby risk assessment is made on a local basis; however, this is still an evolving process and has not yet been practically implemented in a low resourced RT environment\textsuperscript{22}.

7.8 Dosimetric Audit

Dosimetric audits for low income settings have been in use since 1969 by the IAEA/WHO and have proven to be an invaluable guide for identifying errors and reducing uncertainties\textsuperscript{54}. These audits have improved the practice and accuracy of dosimetry in a wide range of RT centers and have helped in maintaining these levels over time\textsuperscript{6}. Over the years the audits have evolved from mailed thermoluminescent dosimetry (TLD) measurements under reference conditions to non-reference conditions\textsuperscript{55} and then to on-site end-to-end tests\textsuperscript{56}. These audits have been found so useful that the IAEA, in its report on *Accuracy Requirements and Uncertainties in Radiotherapy*\textsuperscript{6} made the recommendation that “An independent dosimetry audit should be performed for every new installation that is about to embark on radiation treatments. In addition, regular (e.g. annual) audits should be performed using remote services or on-site visits (or equivalent).”

The IAEA audit program has been extended to include a review of the total RT care process including observations concerning buildings, human resources, treatment and dosimetry equipment, comprehensive patient care, adherence to standards of radiation protection and establishment of quality assurance program, education and research\textsuperscript{57}. The quality assurance team for radiation oncology (QUATRO) program includes an on-site team visit with a radiation oncologist, medical physicist, radiation therapist, and a fourth member with special competencies
such as a radiation protection officer from the visited country\textsuperscript{58}. The QUATRO audits have proved to be a valuable tool for identifying weaknesses in infrastructure, human resources and procedures in RT centers and have been applied primarily to LMICs.

7.10 Minimizing Interruptions

Interruptions and distractions have been shown to result in significant treatment safety concerns in different clinical contexts\textsuperscript{59,60}. General recommendations include “no interruption zones” and educational programs on risks associated with untimely interruptions. Other factors that were identified as contributing to errors included cluttered therapy workstations containing multiple computer monitors as components of various aspects of treatment, and staff traffic patterns that do not shield the radiation therapist from extraneous conversations and interruptions\textsuperscript{21}. These issues could be of additional concern in low income environments with non-optimum ergonomic settings and understaffed conditions.

7.12 Safety Culture

A patient safety culture is referred to as the employees' shared beliefs, values and attitudes regarding patient safety in an organization, all of which are reflected in the daily operational clinical practice. A recent survey\textsuperscript{61} identified 7 subcultures of a patient safety culture: (a) leadership, (b) teamwork, (c) evidence-based, (d) communication, (e) learning, (f) just, and (g) patient-centered. Successful patient error reporting programs are dependent on the level of importance given by management and it is this level of importance that determines the organizational culture\textsuperscript{62}. An organizational culture that seeks to prevent patient harm is characterized by effective communication, shared values about the importance of safety, and the presence of systems that help the organization learn from errors and prevent them from occurring. Reason\textsuperscript{63} took lessons from industry to make sense of the high number of adverse events in health
care. He indicated that only a systems approach (as opposed to the “person” approach of blaming an individual) will create a safer health-care culture because it is easier to change the conditions people work in than change human actions. When a system fails, the immediate question should be why it failed rather than who caused it to fail, e.g., which safeguards failed? Reason created the “Swiss cheese” model\textsuperscript{64} to explain how faults in the different layers of the system can lead to accidents/mistakes/incidents. According to the Institute of Medicine\textsuperscript{49}, “the biggest challenge to moving toward a safer health system is changing the culture from one of blaming individuals for errors to one in which errors are not treated as personal failures, but as opportunities to improve the system and prevent harm.”

One manifestation of a patient safety culture is the implementation of a dedicated formal quality assurance committee consisting of a multidisciplinary team (e.g., radiation oncologists, medical physicists, medical dosimetrists, and radiation therapists) that meets regularly and serves as liaison with leadership and hospital-wide safety committees\textsuperscript{45}.

In summary, a safety culture consists of an environment where patient safety is addressed as (1) a priority from top management and down, (2) no blame is assigned to (patient) errors - errors are a systems problem, (3) open communication at all levels is encouraged including an attitude of no question is too dumb, (4) an error reporting system is in place so that lessons can be learned from errors, and (5) team work is encouraged, with all team members having equal and important roles. Unfortunately, different societal/cultural contexts may make a safety culture difficult to implement; however, it is lessons from transformative organizations that have encouraged the patient safety culture as being a significant approach to minimizing patient adverse events.
8. Broad Quality and Safety Matters for Low-Resourced Settings

The specific issues for low resourced settings are not all that different from issues that existed within high resourced settings a number of years ago, with high resourced settings having moved forward in the meantime. Hopefully the high-resourced contexts can provide guidance and a higher rate of implementation for lower-resourced circumstances. The broad issues of significant concern include: (1) support from upper level management and encouragement for quality and safety considerations along with the development of a QA culture, (2) concern about the lack of professional recognition of medical physicists, (3) lack of educational infrastructure to educate and train locally, (4) appropriate budgets especially for radiation technology service and maintenance, (5) development and recording of quality metrics, and (6) support through national and international initiatives.

8.1 Administrative Support

Quality and safety will receive much greater emphasis in an environment where they are actively supported and promoted by senior management. The first general conclusion from a meeting entitled “Safety in Radiation Therapy: A Call to Action” held in Miami, Florida in June 2010, which was sponsored by the AAPM and ASTRO and hosted by 13 North American related organizations, was that “policies and procedures to improve patient safety are successful only if senior management emphasizes their importance. At the institutional level, safety must be supported and encouraged by the institution’s board of directors and senior management. At the level of individual services, such as radiation oncology, the physician director, departmental administrator, chief physicist, and chief therapist must emphasize the importance of patient safety.” In some contexts this requires significant cultural shifts. However, the first step to
transformation is recognition of the issue, the second step is open discussion and the third step is implementation.

8.2 Professional Recognition of Medical Physicists

The profession of medical physicist is often not understood, primarily as a result its highly specialized nature as well as its minimal presence in low-income countries\textsuperscript{65,66}. High income countries have about 15 to 20 medical physicists per million population while in developing countries there may be 1 to 5 per million and in many low-income countries there are none. In numerous countries, where the profession is not formally recognized, medical physicists are often recruited and employed under other designations such as technician, biomedical engineer, or research assistant. Such inappropriate recognition has a direct impact on their socio-economic and professional status in health-care teams\textsuperscript{65}. The Bonn Call-for-Action Joint Position Statement by the IAEA and WHO concluded that recognizing medical physics as a skilled, independent health care profession, is a key step to strengthening radiation safety culture in health care\textsuperscript{67}.

8.3 Educational Infrastructure

The Lancet Oncology Commission report\textsuperscript{1} called for new approaches to train RT professionals globally, with the creation of new core curricula, innovative learning methods, and international credentialing to expand the RT workforce. Training should become part of the mandate of each national RT center to self-propagate the required skills, enabling national expansion of cancer therapies and providing the ability to replace staff as they leave or are recruited out of country. Potential tools, techniques and procedures that can aid education and training in resource limited environments include: (1) e-learning\textsuperscript{68-71}, (2) e-mentoring/e-rounds\textsuperscript{72} (e.g., http://chartrounds.com/), (3) collaborative course development/education/training\textsuperscript{39,73}, and (4) courses provided by national/international organizations\textsuperscript{74}. 
8.4 Partnerships and Peer-to-Peer Collaborations

While the growing cancer divide is becoming increasingly recognized\textsuperscript{1, 26, 28, 30, 40, 75} the solution in support of reducing the divide is very complex since it involves multiple social, economic, cultural and political facets. Approaches to improving the availability of safe and effective RT in LMICs, will require collaboration between multiple organizations including local governments, regional, international as well as non-government organizations\textsuperscript{40, 41}. Advanced and coordinated planning by governments, professional and other not-for-profit volunteer organizations will be essential to the success of these initiatives. The number of organizations involved is significant as indicated by the 34 examples listed in Table 2. Thus, coordination will be crucial.

Regarding the involvement of professionals in LMIC contexts, the International Cancer Experts Corps (ICEC) proposes an altruistic service along with a philosophy that global health becomes an integral part of the spectrum of academic and professional careers with a goal that 20% of time be devoted to this activity. Students and residents can also consider this part of their community service and altruistic efforts\textsuperscript{76}.

9. Summary and Conclusions

The radiation treatment process is complex involving sophisticated high technology equipment and multiple professionals including radiation oncologists, medical physicists and radiation therapists. The complexity, sophistication, high up-front costs and a lack of trained professional staff have been a deterrent for implementation of RT in many LMICs. However, with appropriate political and organizational will these barriers can be overcome and indeed are beneficial to both the healthcare of individuals as well as to a nation’s economic status. The quality, safety and benefits of radiation treatment are strongly dependent on the quality and safety culture. Strong
Partnerships between multiple organizations and countries will enhance the development of safe and resource-appropriate strategies for advancing the radiation treatment process.
References


Figure Captions

Figure 1. Number of publications from PubMed search done in January 2016: (a) with the words “global” and “cancer” in the title; (b) with the words “global” and (“radiotherapy” or “radiation therapy” or “radiation oncology”) in the title.

Figure 2. Elements of quality assurance (QA) activities occur at both the programmatic and individual patient levels. (Adapted from an unpublished figure from M. Milosevic.)

Tables

Table 1. Top cited recommendations20 for patient safety and estimated level of concern in low-to-middle income countries.

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Estimated risk level in LMICs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>* Very low risk</td>
</tr>
<tr>
<td></td>
<td>*****</td>
</tr>
<tr>
<td>Training</td>
<td></td>
</tr>
<tr>
<td>Staffing</td>
<td>***</td>
</tr>
<tr>
<td>Documentation/SOP</td>
<td>***</td>
</tr>
<tr>
<td>Incident learning</td>
<td>***</td>
</tr>
<tr>
<td>Communication/questioning</td>
<td>***</td>
</tr>
<tr>
<td>Check lists</td>
<td>***</td>
</tr>
<tr>
<td>QC/PM</td>
<td>****</td>
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<tr>
<td>Dosimetric audit</td>
<td>****</td>
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<tr>
<td>Accreditation</td>
<td>***</td>
</tr>
<tr>
<td>Minimizing interruptions</td>
<td>****</td>
</tr>
<tr>
<td>Prospective risk assessment</td>
<td>**</td>
</tr>
<tr>
<td>Safety culture</td>
<td>***</td>
</tr>
</tbody>
</table>
Table 2. Organizations in support of enriching RT capabilities in LMICs.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Web Link</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Above and Beyond Cancer</td>
<td><a href="https://aboveandbeyondcancer.org/">https://aboveandbeyondcancer.org/</a></td>
<td>A public charity with a mission to elevate the lives of those touched by cancer. Along with getting to mountaintops, they are devoted to advocacy and leading an example for healthy living and cancer prevention in their communities.</td>
</tr>
<tr>
<td>3 African Organization for Research and Training in Cancer (AORTC)</td>
<td><a href="http://www.aortic-africa.org">www.aortic-africa.org</a></td>
<td>AORTC is dedicated to the promotion of cancer control in Africa.</td>
</tr>
<tr>
<td>4 Alliance des Ligues Francophones Africaines &amp; Mediterraneennes (ALIAM)</td>
<td><a href="http://www.aliam.org">www.aliam.org</a></td>
<td>ALIAM was founded by common agreement between the representatives of multiple associations from multiple Francophone countries to fight against cancer.</td>
</tr>
<tr>
<td>5 American Association of Physicists in Medicine (AAPM)</td>
<td><a href="http://www.AAPM.org">www.AAPM.org</a></td>
<td>Through various international committees and on-line educational resources for developing countries.</td>
</tr>
<tr>
<td>6 American Society for Radiation Oncology (ASTRO)</td>
<td><a href="http://www.ASTRO.org">www.ASTRO.org</a></td>
<td>Through its International Education Subcommittee (IES)</td>
</tr>
<tr>
<td>7 American Society of Radiological Technologists Foundation</td>
<td><a href="http://foundation.asrt.org/">http://foundation.asrt.org/</a></td>
<td>It invests money raised in medical imaging technologists and radiation therapists who want to deliver the safest and highest-quality patient care possible around the world and more.</td>
</tr>
<tr>
<td>8 Association Cancérologues sans Frontières (“Oncologists Without Borders”)</td>
<td><a href="http://www.cancerologuesansfrontieres.com">www.cancerologuesansfrontieres.com</a></td>
<td>&quot;Oncologists Without Borders&quot; was created in 1998 to promote oncology in developing countries. It is a non-profit organization.</td>
</tr>
<tr>
<td>9 BOTSwana Oncology Global Outreach Program (BOTSOGO)</td>
<td><a href="http://www.botsogo.org">www.botsogo.org</a></td>
<td>Works to improve access to quality cancer care in Botswana.</td>
</tr>
<tr>
<td>#</td>
<td>Organization</td>
<td>Website</td>
</tr>
<tr>
<td>---</td>
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<td>--------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>ChartRounds</td>
<td><a href="http://www.chartrounds.com">www.chartrounds.com</a></td>
</tr>
<tr>
<td>2</td>
<td>European Society for Radiotherapy and Oncology</td>
<td><a href="http://www.estro.org">www.estro.org</a></td>
</tr>
<tr>
<td>3</td>
<td>Foundation for Cancer Care in Tanzania</td>
<td><a href="http://www.tanzaniacancercare.org">www.tanzaniacancercare.org</a></td>
</tr>
<tr>
<td>4</td>
<td>Global Oncology</td>
<td><a href="http://www.globalonc.org">www.globalonc.org</a></td>
</tr>
<tr>
<td>5</td>
<td>Global RT</td>
<td><a href="http://globalrt.org">http://globalrt.org</a></td>
</tr>
<tr>
<td>6</td>
<td>International Agency for Research on Cancer (IARC)</td>
<td><a href="http://www.iarc.fr">www.iarc.fr</a></td>
</tr>
</tbody>
</table>
| 7 | International Atomic Energy Agency (IAEA) (a) Programme of Action for Cancer Therapy (PACT) | http://cancer.iaea.org/mission.asp | PACT strives for global partnerships to confront the cancer crisis in developing countries, with }
<p>| 1 | International Campaign for Establishment and Development of Oncology Centers (ICEDOC) | <a href="http://www.icedoc.org">www.icedoc.org</a> | A non-governmental organization which aims to lessen the human suffering from cancer all over the world. |
| 2 | International Cancer Research Partnership (ICRP) | <a href="https://www.icrpartnership.org/">https://www.icrpartnership.org/</a> | ICRP is a unique alliance of cancer organizations working together to enhance global collaboration and strategic coordination of research. |
| 2 | International Network for Cancer Treatment and Research (INCTR) | <a href="http://www.inctr.org">www.inctr.org</a> | A not-for-profit organization dedicated to helping build capacity for cancer research and treatment in developing countries. |
| 3 | International Organization for Medical Physics (IOMP) | <a href="http://www.iomp.org">www.iomp.org</a> | Advances medical physics practice worldwide by disseminating scientific and technical information, fostering educational and professional development of medical physics and promoting the highest quality medical services for patients. |
| 4 | Medical Physicists Without Borders (MPWB) | <a href="http://www.mpwb.org">www.mpwb.org</a> | MPWB is a not-for-profit, membership-based volunteer organization to support the effective and safe use of physics and technologies in medicine through advising, training, demonstrating and/or participating in medical physics-related activities, especially in LMICs. |
| 5 | Mephida | <a href="http://www.okonmedphys.com">www.okonmedphys.com</a> | Mephida is an independent NGO with a novel approach to improve cancer care in Africa through medical physics services. |
| 6 | Physicien Médical Sans Frontière | <a href="http://www.pmsf.asso.fr">www.pmsf.asso.fr</a> | French-based non-government organization with expertise in Medical Physics and devoted to |</p>
<table>
<thead>
<tr>
<th>2</th>
<th>Pink Ribbon Red Ribbon</th>
<th><a href="http://pinkribbonredribbon.org">http://pinkribbonredribbon.org</a></th>
<th>A global organization powered by partnerships, Pink Ribbon Red Ribbon saves lives from cancer in countries where the need is greatest.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Rad-Aid</td>
<td><a href="http://www.rad-aid.org">www.rad-aid.org</a></td>
<td>Its mission is to improve and optimize access to medical imaging and radiology in poor and developing regions of the world for increasing radiology’s contribution to global public health initiatives and patient care.</td>
</tr>
<tr>
<td>2</td>
<td>Radiating Hope</td>
<td><a href="http://www.radiatinghope.org">www.radiatinghope.org</a></td>
<td>Volunteer-run, mountain climbing, cancer-care focused, non-profit organization with the mission of improving cancer care, specifically radiation oncology care, around the globe.</td>
</tr>
<tr>
<td>2</td>
<td>Radiation Safety Without Borders</td>
<td><a href="https://hps.org/documents/rswb_flyer.pdf">https://hps.org/documents/rswb_flyer.pdf</a></td>
<td>An initiative of the Health Physics Society to provide peer support to radiation safety professionals in developing countries.</td>
</tr>
<tr>
<td>3</td>
<td>TreatSafely Foundation</td>
<td><a href="http://www.treatsafely.org">www.treatsafely.org</a></td>
<td>A free, peer-to-peer training and sharing site that hosts clinically practical, very useful videos and documents.</td>
</tr>
<tr>
<td>3</td>
<td>Union for International Control of Cancer (UICC)</td>
<td><a href="http://www.uicc.org">www.uicc.org</a></td>
<td>The UICC is a membership-based organization which unites the cancer community to reduce the global cancer burden, to promote greater equity, and to integrate cancer control into the world health and development agenda.</td>
</tr>
<tr>
<td>3</td>
<td>World Cancer Research Fund International (WCRF)</td>
<td><a href="http://www.wcrf.org">www.wcrf.org</a></td>
<td>WCRF is the world’s leading authority on the link between diet, weight, physical activity and cancer. It is a not-for-profit organization that leads and unifies a network of cancer prevention charities with a global reach.</td>
</tr>
<tr>
<td>3</td>
<td>World Health Organization (WHO) - Cancer</td>
<td><a href="http://www.who.int/cancer/en/">www.who.int/cancer/en/</a></td>
<td>This is the component of the WHO website devoted to cancer.</td>
</tr>
<tr>
<td>3</td>
<td>Worldwide Cancer Research (WCR)</td>
<td><a href="http://www.worldwidecancerresearch.org">www.worldwidecancerresearch.org</a></td>
<td>WCR is a charity which funds research anywhere in the world.</td>
</tr>
</tbody>
</table>