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Is there a role for 3D dosimetry in low- and middle-income countries?

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Abstract. Low- and middle-income countries face significant challenges in developing comprehensive cancer programs. In some cases this involves opening radiation therapy centres in countries where patients have had almost no access to radiotherapy. In additiona to many political and administrative hurdles, staff and equipment shortages are significant. It is these shortages, perhaps, that researchers in high-income countries can have an impact. Perhaps we can adapt our technologies or processes to improve simplicity, robustness and efficiency, or perhaps we can redesign them to reduce cost. The purpose of this paper is to highlight some of the challenges to the 3D dosimetry community, and to promote discussion on whether 3D dosimetry systems can be redesigned or newly developed to help address some of these.

1. Introduction

In the United States and many other countries, much effort is spent researching new technologies that have significant scientific and clinical interest, but often provide only incremental therapeutic benefit [1]. This is likely also true for the last 17 years of the International Conference on 3D Radiation Dosimetry. There are, however, enormous opportunities for the development of technologies for low- and middle-income countries (LMICs) that have the potential to make significant changes to people's lives. More than half the cases of cancer in the world are found in LMICs, but many of these countries have no radiotherapy access at all [2]. In Africa the actual supply of teletherapy machines is around 20% of the actual need. There are, of course, major challenges to improving the situation in these regions, but the potential benefits could be enormous. This is not an area of research/development that will result in incremental therapeutic benefit, but an area that could have a dramatic impact on the lives of the populous in these regions. The purpose of this paper is to highlight some of the challenges and opportunities to the 3D dosimetry community, and promoting discussion on whether 3D dosimetry [3] can be used or adapted to help address some of these.

2. Background to some of the challenges faced in LMICs

Radiation therapy has been shown to be cost-effective for both palliative and curative cancer treatment in LMICs [2, 4]. For example, the cost of an entire course of radiation therapy is $300 in Senegal (independent of the durations or number of fractions) [5]. Reasons for the low cost include the fact that most people undergo treatment as outpatients, equipment and buildings have long lifespans, and equipment can be used for large numbers of patients (high throughput). Also, for many cancers (e.g., locoregionally cervical cancer), radiation is the only effective treatment choice, making for extremely

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poor prognoses for these cancers if radiation therapy is not available [2]. In high-income countries, 52% of new cancer patients should receive radiation therapy at least once [2]. In LMICs, the epidemiology of cancer cases is different from that in high-income countries, and most patients present with much more advanced disease in the former; in many of these cases, surgical resection is not feasible. For this reason, access to radiation therapy is even more important for these patients. However, access to radiation therapy in LMICs is extremely limited due to deficiencies in equipment, and insufficient skilled personnel.

2.1. Staffing shortages

It is estimated that by 2020, LMICs will have deficits of about 12,000 radiation oncologists, 10,000 medical physicists, and 29,000 radiation therapy technologists [6]. These estimates are based on data from various data sets in the public domain (e.g., IAEA), with staffing levels based on recommendations from the European Society for Radiotherapy & Oncology and IAEA. Hence, there is a crucial need for radiation therapy staff at all levels, in addition to the need for corresponding training for these individuals. For medical physicists, most guidelines recommend a 2- to 3-year internship or residency, often after completion of medical physics graduate school [7-9] - so the training burden is enormous. Various educational initiatives bring young radiation oncologists and medical physicists from LMICs to academic cancer centers in high-income countries, but they are insufficient in addressing the current and future staffing deficits [10]. Furthermore, the failure of professionals who receive training in a high-income country to return home after training in the high-income countries is a historical challenge in radiation oncology and other fields [11-13]. Thus projects that can reduce the number of staff, improve their efficiency, or can accelerate their training, could significantly impact cancer care in LMICs. An example of this from outside the 3D dosimetry world is the automation of treatment planning [14] - this has the potential to make a significant impact because around 50% of physicists time in LMICs is spent doing treatment plans. We should find other solutions, and perhaps there is something in 3D dosimetry?

It should be noted that, in some cases, institutions in LMICs may have the appropriate equipment to treat patients with treatments such as IMRT or VMAT, but lack the staff to perform the additional tasks that this entails, including contouring, treatment planning, machine QA, and patient-specific QA. The author has visited institutions in Africa that have a strong desire to increase their number of VMAT treatments, and have the necessary treatment machines, but do not have all the other resources (particularly staff/time) to make this move. He has also visited an institution where one of the treatment machines was mothballed because of insufficient staff to use it. There are many papers in this and previous conferences on 3D dosimetry which look at patient-specific QA, including potential advantages of 3D dosimetry. Could some of this research be adapted to make patient-specific dose measurements simpler to perform and more efficient? Such a development could help improve the throughput of QA, or all it to be carried out by staff with less training. For example, could a 3D dosimetry system be developed that was relatively insensitive to positioning (and therefore quicker to setup and use), or the control software developed to minimize user interaction?

Similarly, is there a way that 3D dosimetry systems could be developed to facilitate machine QA? The goal would not be to add sophistication to our current techniques, but to allow them to be carried out more efficiently?

Cost is also a significant factor - can current 3D dosimetry systems to be either cheaper, or more robust, than current systems? Often, once equipment breaks, it is difficult to get it serviced - so robustness is of particular importance.

The lack of a significant peer-base can also be a challenge to physicists and other staff in LMICs. They often do not have many experienced peers with whom to discuss their daily challenges. For this reason, links with established institutions is of particular importance in regions where there are limited local experts [2]. One way to establish these links is through research collaborations. Are there opportunities in 3D dosimetry to establish these connections?

Finally, although challenged by insufficient resources, medical physicists in LMICs are involved in research - is there an opportunity for 3D dosimetry here? Perhaps dosimetry systems or readers can be designed at the appropriate price-point to be useful for researchers in LMCs to investigate interesting research topics?

2.2. Equipment shortages

It has been reported that only 4 LMIC countries (Jordan, Lebanon, Suriname and Venezuela) have sufficient teletherapy equipment for their populations, with a median of 37% of patients having access to radiotherapy in the remaining countries (range: 2.3% to 98.8%). In LMICs, there is 0.7 teletherapy units/million population, compared to more than 10 times that number in high-income countries [6]. Patients often have to travel hundreds of kilometres for treatment [15]. The teletherapy equipment available in LMICs varies widely, with much wider use of Cobalt units than we see in the United States. Advantages of Cobalt units include dependability, simplicity and reduced electrical power requirements. This is important, given that in addition to equipment availability, there are many related challenges, such as power shortages and inadequate engineering support [16].

Independent auditing of new treatment equipment is an important part of care in any part of the world. The use of phantoms such as those used extensively by IROC Houston can be a challenge in many LMICs because of the challenge of getting the phantom in and out of the country. Purchasing their own anthropomorphic phantom for end-to-end tests and treatment planning system testing (e.g. as suggested by the IAEA [17, 18]) can also difficult because of the cost. Is there a role for 3D dosimetry here? Perhaps in making the extensive end-to-end testing simpler or more comprehensive? Is there a 3D dosimetry system that could be adapted to make simple measurements of beam characteristics (PDD or profiles) that could then be send to a central location for analysis? Perhaps, if the treatment planning system comes pre-commissioned, the entire acceptance and local commissioning could be performed using a 3D dosimeter - perhaps analysed locally or at a central location?

3. Conclusions

There are many challenges to radiotherapy in LMICs. This paper has highlighted some of them, indicating some of the possible ways in which researchers in the 3D dosimetry community could perhaps change the direction of their research to potentially address these challenges.

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