5-1-2023

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advances
in radiation oncology

Scientific Article

Remote Global Radiation Oncology Education and Training: A Pathway to Increase Access to High-Quality Radiation Therapy Services in Low- and Middle-Income Countries

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Purpose: There is a vital need to train radiation therapy professionals in low- and middle-income countries (LMICs) to develop sustainable cancer treatment capacity and infrastructure. LMICs have started to introduce intensity modulated radiation therapy (IMRT), which is the standard of care in high-income countries, because of improved outcomes and reduced toxicities. This work reports the efficacy of a complementary asynchronous plus synchronous virtual-training approach on improving radiation therapy professions' self-confidence levels and evaluating participants' attitudes toward asynchronous and synchronous didactic hands-on learning in 3 LMICs.

Methods and Materials: Training was provided to 37 participants from Uganda, Guatemala, and Mongolia, which included 4 theoretical lectures, 4 hands-on sessions, and 8 self-guided online videos. The 36-day training focused on IMRT contouring, site-specific target/organ definition, planning/optimization, and quality assurance. Participants completed pre- and postsession confidence

Research data are available from the corresponding author upon reasonable request.

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surveys on a 0 to 10 scale, which was converted to a 5-point Likert rating scale to evaluate the training outcomes. The pros and cons of the 3 different training formats were compared.

Results: The participants included 15 (40.5%) radiation oncologists, 11 (29.7%) medical physicists, 6 (16.2%) radiation therapists, and 5 (13.5%) dosimetrists. Approximately 50% had more than 10 years of radiation therapy experience, 70.8% had no formal IMRT training, and only 25% had IMRT at their institutions. The average experience and confidence levels in using IMRT at baseline were 3.2 and 2.9, which increased to 5.2 and 4.9 ($P < .001$) after the theoretical training. After the hands-on training, the experience and confidence levels further improved to 5.4 and 5.5 ($P < .001$). After the self-guided training, the confidence levels increased further to 6.9 ($P < .01$). Among the 3 different training sessions, hands-on trainings (58.3%) were most helpful for the development of participants' IMRT skills, followed by theoretical sessions with 25%.

Conclusions: After completing the training sessions, Uganda and Mongolia started IMRT treatments. Remote training provides an excellent and feasible e-learning platform to train radiation therapy professionals in LMICs. The training program improved the IMRT confidence levels and treatment delivery. The hands-on trainings were most preferred.

Introduction

Globally, an estimated 19.3 million new cancer cases and nearly 10.0 million cancer deaths occurred in 2020.[1] The effect of cancer burden is worst felt in low- and middle-income countries (LMICs), where there are limited resources and infrastructure to provide prevention, early detection, diagnosis, and effective cancer treatment.

Although major strides have been undertaken to improve access to cancer chemotherapy, immunotherapy, and surgery, radiation therapy, one of the most cost-effective cancer therapies, remains an impediment as the result of few trained personnel, equipment, and infrastructure,[2,3] despite the high demand. According to the International Atomic Energy Agency (IAEA) Directory of Radiotherapy Centres,[4] the number of external beam radiation therapy units per million population is approximately 0.1 for Uganda, 0.4 for Guatemala, and 1.5 for Mongolia, compared with the United States with 11.6. The percentage of patients with cancer receiving radiation therapy is approximately 7.5% for Uganda and 13.0% for Mongolia, compared with >50% for the United States.[5] In Uganda, the infrastructure of radiation therapy was built through collaboration with the IAEA, with the initial aim limited to conventional radiation therapy techniques. The last few years have witnessed a slow transition from conventional radiation therapy techniques toward 3-dimensional (3D) and advanced techniques such as intensity modulated radiation therapy (IMRT), as observed in Guatemala[6] and Mongolia.[7] Education and training have been identified as a way to improve local capacity of health care in LMICs.[8] However, the best methods to perform training and scale this to meet the needs of different centers globally remains a challenge.

With international support, training, and education, cancer treatment in LMICs has gradually improved in the last few decades. For example, in Uganda, the first linear accelerator (Linac) was commissioned in March 2021, lagging behind Mongolia and Guatemala by 1 to 2 years. Radiation therapy departments in many LMICs are undergoing a transition from conventional 2-dimensional (2D) techniques to more advanced techniques, such as IMRT/volumetric modulated arc therapy (VMAT). Education and training are highly needed during this transition to adapt the new technologies. Virtual training has shown tremendous success in the past.[9,10] However, there are many formats of virtual training, and it remains to be explored which formats are most effective based on feedback from participating radiation therapy professions.

Washington University in St. Louis (WUSTL), in collaboration with Guatemala, implemented a project to increase the delivery of radiation therapy to more patients, helping to bridge a major health care gap.[5] In Guatemala, through partnership with the US Agency for International Development's Office of American Schools and Hospitals Abroad, WUSTL, industry partner Varian Medical Systems, and the US National Nuclear Security Administration, a Linac was installed to replace the Cobalt-60 machine that provided access to IMRT/VMAT while increasing the treatment capability for the population. In Uganda and Mongolia, the 2 main cancer institutions with collaborators from WUSTL are implementing a quality-improvement project aimed at adapting the use of Rapid Linac Acceptance, Commissioning, and Periodic Quality Assurance (QA) using onboard electronic portal imaging devices in radiation therapy. Through these ongoing global, multicenter collaborations, teams from WUSTL conducted training in IMRT/VMAT, targeting radiation therapy professionals from Uganda, Guatemala, and Mongolia. Three different training modules, each lasting approximately 1 to 2 months, were designed with the main objective of supporting radiation therapy professions in LMICs to improve IMRT/VMAT usage. The purpose of this study is to investigate the efficacy of a complementary asynchronous plus synchronous virtual training approach by adopting the Project ECHO (Extension for Community Health care Outcomes) model[11] to improve radiation therapy professions' self-confidence levels and evaluate participants' feedback toward asynchronous, synchronous

didactic, and synchronous hands-on learning in 3 centers representing Latin American, African, and Asian LMICs.

Methods and Materials

Participants working and training sites

Uganda Cancer Institute, Kampala, Uganda

The Uganda Cancer Institute is the national cancer referral, receiving approximately 6000 new cases of 34,000 diagnosed annually. The only radiation therapy facility located at the Uganda Cancer Institute attends to approximately 2500 new cases annually. Since its establishment in 1995 (with support from IAEA), the radiation therapy department had offered conventional 2D radiation therapy until March 2021, when the only Linac was commissioned, paving the way for a transition toward 3D conformal radiation therapy and IMRT/VMAT. The center has 2 cobalt-60 units, 1 Linac, and 1 high-dose-rate brachytherapy unit. The department has 3 radiation oncologists, 10 radiation therapists, and 4 medical physicists. Before the training, the Uganda Cancer Institute had not started IMRT treatments.

Liga Nacional Contra el Cancer/Instituto de Cancerologia, Guatemala City, Guatemala

Liga Nacional Contra el Cancer/Instituto de Cancerologia is responsible for radiation therapy services for more than 30% of the population. The department has 5 radiation oncologists and 5 medical physicists. Before 2019, the department treated patients with conventional 2D and 3D. After the installation of a Varian Halcyon machine in 2019, they started IMRT/VMAT, treating approximately 40 to 50 cases per day.[6] In Guatemala, there are 7 radiation therapy centers, with 6 teletherapy units and 7 brachytherapy units (Directory of Radiotherapy Centres).[4]

National Cancer Center in Mongolia, Ulaanbaatar, Mongolia

The National Cancer Center in Mongolia is Mongolia's only radiation therapy facility, with 800 referrals of 6000 new cancer cases reported in 2020. Since 1995, IAEA implemented several projects to improve the quality, scope, and scale of radiation therapy services in Mongolia. The department has 2 Linacs, commissioned in 2019. There are 10 radiation oncologists and 4 medical physicists. Before the training, National Cancer Center in Mongolia had not started IMRT treatments. In Mongolia, there is 1 radiation therapy center, with 5 teletherapy units and 1 brachytherapy unit.[4]

Project ECHO model

Project ECHO was first developed in 2003 and successfully implemented as a strategy for improving health care by connecting medical experts in high-resource areas with clinicians in low-resource regions to improve capacity.[12-14] Project ECHO is a cost-effective, high-impact intervention using regularly scheduled video sessions, in which the specialists use videoconferencing to share expertise via mentoring, guidance, feedback, and didactic education. This approach has enabled clinicians in underserved areas to improve skills, confidence, and knowledge to treat patients in their communities, thereby reducing travel costs, wait times, and avoidable complications.

Development, implementation, and assessment of training sessions

We applied Kern's 6-step-model[15-17] for curriculum development and a needs assessment by conducting informal interviews and electronic surveys of liaisons from each partner center. The trainings and assessment were virtual instructor-led sessions (the trainers and learners were in different locations), conducted in English, with the automatic real-time translation to Spanish. This was done either in synchronous mode (live sessions) or asynchronous mode (online access to recordings and supporting collateral prepared materials). The sessions, given by the radiation oncologists and medical physicists at WUSTL, focusing on normal tissue contouring, site-specific target delineation, IMRT planning/optimization, and IMRT QA, were offered to cancer centers mainly in Uganda, Guatemala, and Mongolia. To have a high-impact training, the participants proposed their main treatment cancer sites of interest be covered depending on their center's workloads. The training formats were identified according to reports in the literature on effective methodology for radiation oncology virtual training for LMICs.[18-20] Before the IMRT training, there were collaborative engagements and discussions between WUSTL and the 3 LMICs, for periods ranging between 6 and 12 months, during which the training gaps were identified. All the participants responded to a 21-question pre-IMRT online survey to establish baseline knowledge (Appendix E1). The training format included 3 different sessions, discussed to follow.

Synchronous didactics through theoretical sessions

Training sessions for each of the 4 different disease sites (prostate, head and neck, breast, and cervix), consisted of 20 to 30 minutes of overview on the contouring, treatment prescription, and so on, given by American Board of Radiology−certified WUSTL and UT—MD Anderson Cancer Center radiation oncologists with a

diverse background in different disease sites, followed by another 20 to 30 minutes on planning skills given by a medical physicist. A question-and-answer session followed the presentations. The trainings were weekly (approximately 1 hour) for each disease-site. A 22-question post-IMRT online-survey was done after each session (Appendix E2).

Synchronous hands-on training sessions

Patient cases of prostate, head and neck, breast, and cervical cancers, identified by the Uganda Cancer Institute radiation oncologist, were used for IMRT contouring, treatment planning, and plan evaluation sessions. The identities/details of the patient cases were anonymized before export to training platforms. A dedicated session on IMRT patient-specific QA using 2D Matrix and portal dosimetry was also conducted. A 28-question post-hands-on IMRT training online survey was done after sessions (Appendix E3).

Asynchronous self-guided sessions

Two online 1-hour video sessions each, developed by Rayos Contra Cancer, were sent to participants on a weekly basis. The weekly topics consisted of the following:

Week 1: Contouring for medical physicists
   IMRT treatment planning: The "Shulman" VMAT optimization method
Week 2: IMRT treatment planning—What is a good plan?
   Plan review
Week 3: How to develop the perfect VMAT plan for:
   Head and neck cases
   Pelvic cases
Week 4: Hidden red flags in IMRT treatment planning

   High-yield clinical applications of IMRT

At the end of each week, an online assessment was sent to the participants, and scores were provided immediately after submission. A 35-question self-guided IMRT online survey was done after all the sessions (Appendix E4). During the training sessions, participants posted questions through the online platform. Participants who completed the training sessions received "certificates of completion" from the Department of Radiation Oncology and Global Health Center at the Institute for Public Health, WUSTL.

Participant's assessment

All the surveys, including pre- and postsessions, were developed based on a review of previous telehealth educational programs[12,21,22] and were adapted for use in this study with input from radiation oncologists and medical physicists in both WUSTL and 3 partner institutions. Assessment of participants was based on their survey responses to specific questions on level of understanding,

experience, and confidence in treating with IMRT. In this study, the change in the participant's level of experience with using IMRT after each training session is defined as their self-assessed ease of using IMRT in the clinic. To evaluate the outcome of the training, participants responded to pre- and posttraining session surveys on a 0 to 10 scale, which was reduced to a 5-point Likert rating scale during analysis, according to the following:

○ 0-2: Strongly disagree, strongly dissatisfied, very low
○ 3-4: Disagree, dissatisfied, below average
○ 5-6: Neutral, neither agree nor disagree, average
○ 7-8: Agree, satisfied, above average
○ 9-10: Strongly agree, strongly satisfied, very high

Participants responded to questions regarding whether the training was informative, the content was beneficial to their work, the content was easy to understand, and the training format (each session with 2 presentations, 1 by a medical physicist and 1 by a radiation oncologist), were easy to follow, questions and answers time was sufficient, level of experience using IMRT, the confidence level in treating patients with IMRT, overall rating, et cetera. Experience and confidence levels were measured using the average of the participant's self-assessed ratings on a 0 to 10 scale before and after each training session. The experience and confidence level scores were averaged for each training session to obtain participants score.

Data collection and statistical analysis

Quantitative data are presented by numbers, percentages, and averages. P values were computed by comparing the participants' pre- and posttraining scores; $P < .05$ was considered statistically significant. Excel (Microsoft, Redmond, WA) was used for data collection, statistical analysis, and P value evaluation, assuming a t test of 2 samples of equal variances.

Administrative approval

The training materials (patients' anonymized data sets, etc) were approved by the participating centers administration for use during the training sessions.

Results

Thirty-seven participants attended the 36-day IMRT training sessions that included 4 lectures, 4 hands-on training, and 8 self-guided training videos on contouring, planning, and optimization of major sites, including prostate, cervical, breast, and head and neck cancers. Table 1 shows the participation rates for the 3 LMICs for the different training modalities. The participants included 15

Table 1   Participants and number of surveys for the 3 LMICs for different training modalities

Sessions	Uganda	Mongolia	Guatemala	Other countries	Total
Pre-IMRT response (baseline)	12 (32.4)	11 (29.7)	8 (21.6)	6 (16.2)	37
Theoretical sessions					
Prostate	9 (28.1)	12 (37.5)	6 (18.8)	5 (15.6)	32
Cervical	8 (24.2)	15 (45.5)	7 (21.2)	3 (9.1)	33
Breast	6 (26.1)	10 (43.5)	5 (21.7)	2 (8.7)	23
Head and neck	9 (32.1)	10 (35.7)	6 (21.4)	3 (10.7)	28
Post-IMRT responses	10 (35.7)	15 (53.6)	8 (28.6)	2 (7.1)	35
Hands-on training					
Prostate	7 (31.8)	8 (36.4)	5 (22.7)	2 (9.1)	22
Cervical	8 (40.0)	8 (40.0)	4 (20.0)	0 (0.0)	20
Breast	8 (32.0)	9 (36.0)	6 (24.0)	2 (8.0)	25
Head and neck	10 (29.4)	14 (41.2)	7 (20.6)	4 (11.8)	34
Post-hands-on responses	9 (31.0)	11 (37.9)	7 (24.1)	2 (6.9)	29
Post-IMRT self-guided responses	10 (27.8)	14 (38.9)	7 (19.4)	5 (13.9)	36

Abbreviations: IMRT = intensity modulated radiation therapy; LMICs = low- and middle-income countries.
There were 37 participants and responses for 3 different training sessions. The survey response rate was 100%, 94.5%, 78.3%, and 97.3% for the pre-training survey and each training session, respectively.

(40.5%) radiation oncologists, 11 (29.7%) medical physicists, 6 (16.2%) radiation therapists, and 5 (13.5%) dosimetrists. The participants working experiences were 0 to 5 years, 11 (29.7%); 5 to 10 years, 8 (21.6%); 10 to 15 years, 15 (40.5%); and >15 years, 3 (8.1%). Approximately 70.3% had no formal training in IMRT, and only 24.3% (mainly from Guatemala) had IMRT experience.

The daily attendance varied between sessions. The average of participants attending the theoretical sessions, hands-on training, and self-guided video training sessions was 29.8 ± 4.8, 25.3 ± 6.2, and 28.1 ± 6.8, respectively. Table 2 shows the theoretical training evaluation for the different sites (prostate, cervical, breast, and head and neck), indicating the participant's ranking of whether the training was informative, beneficial to their work, content was easily understandable, and overall rating. On average, 77.2%, 76.0%, and 59.9% agreed or strongly agreed that the training was respectively informative, beneficial to their work, and the content was easy to understand. Approximately 81% rated the overall training sessions as satisfactory or strongly satisfactory. Table 3 shows the evaluation summary for IMRT hands-on training survey for the different sites. On average, 70.1%, 66.9%, and 61.9% agreed or strongly agreed that the hands-on trainings were respectively informative, beneficial to their work, and the contents were easy to understand. Approximately 79.4% rated the IMRT hands-on training sessions as satisfactory or strongly satisfactory. Table 4 shows the evaluation summary for the self-guided training surveys. Approximately 68%, 74%, and 60% agreed or strongly agreed that the self-guided training was informative,

beneficial to their work, and the contents were easy to understand, respectively.

Results in Fig. 1 show clustered bar charts comparing the respondents' experience and confidence levels in treating patients with IMRT at baseline and after each training session. At baseline, approximately 55% and 58% of the participants had very low experience and confidence levels, respectively, which reduced to 44% and 43% after the theoretical training sessions, further reducing to 22% and 8% after the hands-on training sessions, and became 0 after the self-guided sessions. In comparison, 0% of the participants had very high experience and confidence levels at baseline, and these numbers increased to 20% and 14%, respectively.

The average experience and confidence levels in using IMRT at baseline were 3.2 and 2.9, which increased to 5.2 and 4.9 (P < .001), respectively, after the theoretical sessions. After the hands-on training, the level of experience and confidence levels of using IMRT further improved to 5.4 and 5.5 (P < .001), respectively, compared with baseline. After the self-guided training, the confidence levels of using IMRT raised further to 6.9 (P < .01). On evaluating which training sessions were most preferred, 59.3% indicated that the hands-on training was most helpful, followed by theoretical sessions at 25%.

Discussion

LMICs are faced with numerous obstacles, including high volumes of patients with cancer, limited numbers of

Table 2   *Site*-specific theoretical posttraining evaluation

Category		Strongly disagree No. (%)	Disagree No. (%)	Neutral No. (%)	Agree No. (%)	Strongly agree No. (%)
Training was informative	Prostate	0 (0.0)	4 (12.5)	11 (34.4)	4 (12.5)	13 (40.6)
	Cervical	0 (0.0)	0 (0.0)	5 (15.2)	5 (15.2)	23 (69.7)
	Breast	0 (0.0)	0 (0.0)	2 (8.7)	12 (52.2)	9 (39.1)
	Head and neck	0 (0.0)	0 (0.0)	6 (21.4)	11 (39.3)	11 (39.3)
Content was beneficial to my work	Prostate	5 (15.6)	2 (6.3)	5 (15.6)	9 (28.1)	11 (34.4)
	Cervical	0 (0.0)	2 (6.1)	3 (9.1)	8 (24.2)	20 (60.6)
	Breast	0 (0.0)	2 (8.7)	3 (13.0)	7 (30.4)	11 (47.8)
	Head and neck	0 (0.0)	0 (0.0)	6 (21.4)	8 (28.6)	14 (50.0)
Content was easy to understand	Prostate	2 (6.7)	3 (10.0)	14 (46.7)	0 (0.0)	11 (36.7)
	Cervical	0 (0.0)	0 (0.0)	7 (21.2)	7 (21.2)	19 (57.6)
	Breast	0 (0.0)	0 (0.0)	9 (39.1)	5 (21.7)	9 (39.1)
	Head and neck	0 (0.0)	2 (7.1)	8 (28.6)	9 (32.1)	9 (32.1)
Training format works well	Prostate	0 (0.0)	0 (0.0)	5 (16.1)	8 (25.8)	18 (58.1)
	Cervical	0 (0.0)	2 (7.1)	12 (35.7)	7 (21.4)	12 (35.7)
	Breast	0 (0.0)	2 (8.7)	3 (13.0)	7 (30.4)	11 (47.8)
	Head and neck	0 (0.0)	1 (4.6)	11 (40.9)	8 (27.3)	8 (27.3)
Session times sufficient	Prostate	0 (0.0)	0 (0.0)	5 (16.7)	8 (25.8)	18 (58.1)
	Cervical	0 (0.0)	0 (0.0)	12 (35.7)	12 (35.7)	9 (28.6)
	Breast	0 (0.0)	0 (0.0)	9 (39.1)	5 (21.7)	9 (39.1)
	Head and neck	0 (0.0)	1 (4.6)	10 (36.4)	9 (31.8)	8 (27.3)
Overall rating	Prostate	0 (0.0)	5 (16.1)	6 (19.4)	5 (16.1)	15 (48.4)
	Cervical	0 (0.0)	0 (0.0)	3 (9.4)	6 (18.8)	23 (71.9)
	Breast	0 (0.0)	0 (0.0)	3 (13.0)	11 (47.8)	9 (39.1)
	Head and neck	0 (0.0)	0 (0.0)	5 (17.9)	11 (39.3)	12 (42.9)

Table 3   IMRT hands-on training survey summary

Category		Strongly disagree No. (%)	Disagree No. (%)	Neutral No. (%)	Agree No. (%)	Strongly agree No. (%)
Training was informative	Head and neck	2 (5.9)	0 (0.0)	9 (26.5)	12 (35.3)	11 (32.4)
	Prostate	0 (0.0)	0 (0.0)	9 (40.9)	2 (9.1)	11 (50.0)
	Cervical	0 (0.0)	0 (0.0)	4 (20.0)	4 (20)	12 (60.0)
Content was easy to understand	Head and neck	0 (0)	2 (5.9)	12 (35.3)	12 (35.3)	8 (23.5)
	Prostate	0 (0.0)	2 (9.1)	9 (40.9)	5 (22.7)	6 (27.3)
	Cervical	0 (0.0)	2 (10.0)	2 (10.0)	8 (40.0)	8 (40.0)
Content was beneficial to my work	Head and neck	0 (0.0)	0 (0.0)	12 (36.4)	6 (18.2)	15 (45.5)
	Prostate	0 (0.0)	0 (0.0)	8 (36.4)	3 (13.6)	11 (50.0)
	Cervical	0 (0.0)	0 (0.0)	3 (16.7)	3 (16.7)	12 (66.7)
Training format works well	Head and neck	0 (0.0)	2 (5.9)	14 (41.2)	9 (26.5)	9 (26.5)
	Prostate	0 (0.0)	2 (9.1)	7 (31.8)	5 (22.7)	8 (36.4)
	Cervical	0 (0.0)	0 (0.0)	3 (16.7)	5 (25.0)	11 (58.3)
Question-and-answer time was sufficient	Head and neck	0 (0.0)	2 (5.9)	12 (35.3)	11 (32.4)	9 (26.5)
	Prostate	0 (0.0)	0 (0.0)	8 (36.4)	8 (36.4)	6 (27.3)
	Cervical	0 (0.0)	0 (0.0)	3 (15.8)	5 (26.3)	11 (57.9)
Overall rating	Head and neck	0 (0.0)	0 0.0)	5 (14.7)	17 (50.0)	12 (35.3)
	Prostate	0 (0.0)	0 (0.0)	8 (36.4)	3 (13.6)	11 (50.0)
	Cervical	0 (0.0)	0 (0.0)	2 (10.5)	6 (31.6)	11 (57.9)

Abbreviation: IMRT = intensity modulated radiation therapy.

Table 4   Self-guided IMRT training survey summary

Category	Strongly disagree No. (%)	Disagree No. (%)	Neutral No. (%)	Agree No. (%)	Strongly agree No. (%)
Training was informative	0 (0.0)	3 (8.6)	8 (22.9)	15 (42.9)	9 (25.7)
Content was easy to understand	0 (0.0)	3 (8.6)	11 (31.4)	12 (34.3)	9 (25.7)
Content was beneficial to my work	0 (0.0)	3 (8.6)	6 (17.1)	11 (31.4)	15 (42.9)
Training format works well	0 (0.0)	3 (9.4)	9 (28.1)	12 (37.5)	8 (25.0)
Overall rating	0 (0.0)	2 (5.7)	8 (22.9)	14 (40.0)	11 (31.4)
Abbreviation: IMRT = intensity modulated radiation therapy.					

well-trained staff, busy departments, resource constraints, and travel encumbrances/restrictions due to COVID-19. In such situations, virtual sessions were the most desirable solutions for remote training. The objective of the virtual training was to increase access to high-quality radiation therapy services for participants from LMICs with minimal interruption to their clinical workflow while providing training-sessions and evaluation on participants' levels of experience and confidence levels in treating patients with IMRT. The training wasn't aimed at providing general knowledge of radiation therapy but to focus on meeting the specific needs of the LMICs that are in the transition from 3D to IMRT or to enhance the clinical experience in IMRT for Guatemala. Baseline results show that before the virtual sessions, both the IMRT training levels and usage by the participating centers were very low. Among the targeted LMICs, Uganda and Mongolia had not started using IMRT, despite the huge numbers of cancer patients. Guatemala was treating 30 to 40 patients undergoing IMRT per day, and the numbers quickly ramped up to 90 patients a day after the training. It is a known fact that IMRT/VMAT offers better tumor coverage and reduced toxicity to normal tissues/organs at risk and improves clinical outcomes, and it is the standard of care in developed countries.[23,24] With the experience gained from the remote training sessions, both Uganda and Mongolia started IMRT treatments after the self-guided virtual training session.

The 3 different training sessions provided different pros and cons. Table 5 compares the strength and limitations of these training formats, arising from the study surveys, question-and-answer periods during the training session, and coupled with the tutor's experiences. The survey included questions on which training sessions were most helpful for their IMRT skills and why, and some open-ended questions to provide additional feedback on the training sessions. The combination of these 3 training sessions complemented each other to provide an effective outcome in a very short time.
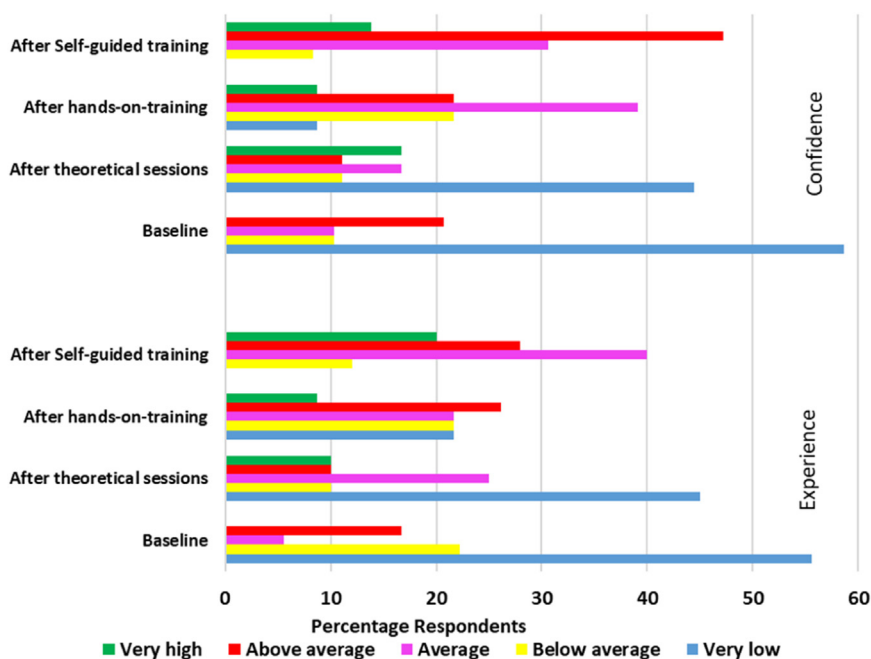

Figure 1 Clustered bar charts are shown comparing the respondents' confidence levels and experience in treating patients with intensity modulated radiation therapy at baseline and after each training session.

Table 5 Comparison of the pros and cons on the 3 different training formats

Training method	Pros	Cons
Theoretical lecture sessions	More opportunities for interactions Design for specific training needs	More effort to prepare lectures Not easy to scale up for many LMICs Time zone difference
Hands-on training sessions	More opportunities for interactions Design for specific training needs Real examples and practical tips meeting specific LMICs' needs	More effort to prepare lectures Not easy to scale up for many LMICs Time zone difference
Self-guided online training sessions	The prepared materials can be reused Easy to scale up No time zone difference	No interaction between the lecturers and trainees Participants not actively posting questions

Abbreviation: LMICs = low- and middle-income countries.

Results from Tables 2 and 3 indicate that the virtual hands-on training sessions were more easily understood than the theoretical training sessions based on the proportion of participants who agreed and strongly agreed. This fact was highlighted further with the post-IMRT self-guided survey, where participants responded that among the 3 different training sessions, 59.3% believed that the hands-on training was most helpful for their IMRT skills, followed by theoretical sessions. As shown in Fig. 1, the proportion of participants with very low experience and confidence in treating IMRT was approximately 60% at baseline and gradually decreased as the training was ongoing, such that by the post self-guided training review, none had very low confidence. In contrast, the percentage with above average or high confidence jumped from 21% to 61% after the training. The overall confidence level of treating patients using IMRT increased from 2.8 at baseline to 6.9 after the self-guided training.

Several e-learning training initiatives have been done to improve the quality of radiation therapy practice and treatment delivery in LMICs. Sarria et al[18] reported on remote/cloud-based SBRT/SRS training of radiation therapy professionals in Latin America, where they conducted 16 weekly 1-hour, interactive, and case-based sessions. The training effectively improved knowledge and confidence on SBRT/SRS among the participants; in agreement with this study. Mitchell et al[19] reported on an IMRT course for radiation therapists in Latin American Countries. Before the course, it had been established that topics fundamental to IMRT were lacking in these countries. The remote curriculum closed the gap and created accessibility, sustainability, and high-quality education. Hatcher et al[20] reported on the effect of a 12-week training course on high-dose-rate brachytherapy, via telehealth, in 10 participating LMICs. Competencies focused on high-dose-rate commissioning, shielding, treatment planning, radiobiology, and applicators. The course improved the participants' overall confidence in treatment delivery from 3.1 to 3.8, which is lower compared with 2.8 (baseline) to 6.9 (after self-guided training) in this study.

Lewis et al[25] reported on a needs assessment and feasibility study of cloud-based technology to enable remote peer review and training in 3 Sub-Saharan African countries (Ghana, Tanzania, and Botswana). They reviewed the existing radiation therapy treatment facilities, including treatment machines, treatment planning systems, simulators, treatment capability (ie, 2D, 3D conformal, IMRT, and brachytherapy), and informatics infrastructure. Radiation therapy structure data sets were transferred to cloud-based software after installation at all sites. The study concluded that improved information technology infrastructure, particularly Internet capability, and the incorporation of clinical QA into day-to-day practice could allow radiation therapy centers in LMICs to benefit from the educational and quality improvement opportunities provided by cloud-based remote peer review. The IAEA developed an online 5-hour e-learning course designed to provide continuing education for radiation therapy professionals regarding safety and quality in radiation therapy.[26] The participants are expected to improve their understanding of safety, learn techniques to minimize incidents, understand the value and use of incident learning systems, learn about useful sources of information to enhance safety, and gain insight into improving safety culture in radiation therapy clinics/facilities. After the completion of the course, the participants receive an IAEA certificate. In our study, we adopted the Project ECHO model to provide virtual training to resource-limited countries in 3 different continents, focusing on IMRT implementation. The complementary approach with Project ECHO model and Kern's 6-step model via expert-led videoconferencing and assessment provides an effective method to improve IMRT skills and knowledge of clinicians in LMICs. The virtual training sessions provided by WUSTL, and Rayos Contra Cancer, offered a comprehensive, in-depth training on how to use IMRT. However, there were some challenges, including:

1. The different time zones: The sessions were conducted from 8:00 AM to 9:00 AM, US central time,

which was early mornings in Guatemala, late evenings in Uganda, and late nights in Mongolia. It's challenging to keep team spirit high and motivate the collaboration with 1 team leaving the office just as another is starting their workday.

2. The language used was English. Only Uganda uses English as the official language, whereas Guatemala and Mongolia use Spanish and Mongolian, respectively. We used Zoom's live auto-transcription function; however, this was not sufficient for Guatemala participants. Per the request of Guatemala, a Spanish translator was added for the training sessions. The participants' language articulacy could be a potential source of misinterpretation in the survey responses.

3. The training program was attended by the entire radiation oncology team, whereas medical physicists, radiation oncologists, and radiation therapists have very different needs. Ideally, the training sessions should be more specific to the individual discipline.

On-site training at cancer institutions in LMICs is an important complementary component to assess the needs, improve awareness, and build trust between collaborators. It is not practical to only perform on-site training in a busy clinic. Remote training is a critical and viable approach to training the radiation therapy professionals in LMICs. For radiation oncologists, treatment protocols with simultaneous integrated boost, hypofractionations, and guidelines for target contouring and margins from gross total volume to clinical target volume or planning target volume should be the focus. For many disease sites, there is need to increase the daily dose and reduce the number of fractions. For example, prostate cancer can be treated with 28 fractions with 2.5-Gy daily dose instead of treating 40+ fractions with 1.8 Gy. Hypofractionated treatments will increase the capacity in LMICs by 20% to 40% if performed correctly. This will also reduce the waiting time for patients to receive radiation therapy treatments.

IMRT is still relatively new to radiation oncology specialists and follows the 3D treatment protocols. For example, treatment of the prostate and nodes with different phases (phase 1: 50 Gy, phase 2: 60 Gy, and phase 3: 74 Gy). Medical physicists or radiation therapists need to create 3 different plans and perform QA verification 3 times. This is the same case for the head and neck. IMRT has the capability to deliver different dose levels through simultaneous integrated boost to different targets in a single plan, which can reduce staff workload. For medical physicists and radiation therapists, there is a need to focus more on hands-on training with simplified planning and QA procedures, as complicated procedures used in high-income countries are not practical or easy to implement. There is also a need to explore and encourage more usage of portal dosimetry for patient-specific QA, as it's faster than other verification methods.

Conclusion

Remote training provides an excellent and feasible e-learning platform to train radiation therapy professionals in LMICs. The training program improved the confidence levels and experience and treatment delivery using IMRT. The hands-on training session was the most preferred method to improve IMRT clinical skills. Approximately 1 month after the end of the self-guided training, Uganda and Mongolia successfully started IMRT treatments.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j. adro.2023.101180.

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