Advances in Radiation Oncology (2023) 8, 101165

advances in radiation oncology

www.advancesradonc.org

Scientific Article

Targeting Education as a Barrier to Implement Hypofractionation: Results of a Country-Wide Training Program

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Received 15 November 2022; accepted 22 December 2022

Abstract

Introduction: Access to radiation therapy in low- and middle-income countries (LMICs) could be improved with modern hypofractionated radiation therapy schedules, although their adoption remains limited. We aimed to evaluate perceptions regarding hypofractionation and the effect of a dedicated curriculum in an LMIC.

Methods and Materials: We developed a pilot e-learning hypofractionation curriculum focused on breast, prostate, rectal cancer, and high-grade glioma in Colombia. International educators taught 13 weekly, 90-minute sessions. Participants completed pre- and postcurriculum questionnaires regarding hypofractionation attitudes, 1 to 5 Likert-scale self-confidence, and practices for 12 clinical scenarios. Physicians' responses were categorically scored "1" (for hypofractionation or ultrahypofractionation) or "0" (for conventional fractionation). We used the paired *t* test to measure pre- versus postcurriculum differences in self-confidence and the McNemar test to detect differences in hypofractionation selection.

Results: Across 19 cities in Colombia, 147 clinicians enrolled: 61 radiation oncologists, 6 radiation oncology residents, 59 medical physicists, 18 physics residents, and 3 other staff. Among physicians, education was the greatest barrier to select hypofractionation, common in ultrahypofractionation for prostate (77.6%) and breast cancer (74.6%) and less common for moderate hypofractionation of prostate (61.2%) and breast cancer (52.2%). Additional perceived barriers included unfamiliarity with clinic protocols (7%-22%), clinical experience (5%-15%), personal preference (3%-16%), and lack of technology (3%-20%), with variation across different clinical settings. After the curriculum, paired (n = 38) physicians' selection of hypofractionation increased across all disease sites (mean aggregate score 6.2/12 vs 8.2/12, P <.001). Self-confidence among paired clinicians (n = 87) increased for prostate ultrahypofractionation (+0.45), rectal ultrahypofractionation (+0.43), breast hypofractionation (+0.38), and prostate hypofractionation (+0.23) ($P \leq .03$).

Conclusions: In an LMIC with a bundled payment system, lack of education and training was a perceived barrier for implementation of hypofractionation and ultrahypofractionation. A targeted e-learning hypofractionation curriculum increased participant confidence and selection of hypofractionated schedules.

Sources of support: This work had no specific funding.

Disclosures: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Research data are stored in an institutional repository owned by Rayos Contra Cancer and will be shared upon request to the corresponding author

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https://doi.org/10.1016/j.adro.2022.101165

Introduction

One of the greatest gaps in cancer care in low- and middle-income countries (LMICs) is the lack of adequate access to radiation therapy. An estimated 40% to 60% of patients with cancer cannot access radiation therapy services, and the linear accelerator-to-population ratio is below international recommendations.[1,2] Furthermore, the problem is growing, as most of the world's projected growth in cancer cases is expected in these countries.[2] One potential solution is to make more efficient use of existing equipment by employing hypofractionated radiation therapy schedules, which allow the adequate redistribution of insufficient resources and expands the centers' capacities.[3]

Hypofractionated radiation therapy schedules have proven equivalent oncologic outcomes compared with conventional fractionation schedules. Many hypofractionated regimens are now accepted as a standard of care by different professional medical societies and radiation oncology guidelines,[4-8] and their corollary could extend direct benefits to LMICs. Shortening treatment time in LMICs could translate to improving the capacity of radiation therapy centers to treat more patients, reducing patient waiting lines, and reducing socioeconomic burdens for patients to complete treatments.[3] However, our understanding of the barriers to employing hypofractionation is limited, and the methods to affect its use need to be investigated.[9]

Despite the advantages of hypofractionation, there is significant variation in the use of hypofractionation among the regions of the world, and the adoption of LMICs remains low compared with high-income countries. Recognized barriers to the use of hypofractionation may relate to professional culture, reimbursement, available technology, and/or concerns about the lack of long-term outcomes.[9] Educational approaches to targeting knowledge gaps may be helpful for its implementation; however, this is currently unknown.

This current study aims to assess perceptions regarding the implementation of hypofractionation and to evaluate the effect of an e-learning hypofractionation curriculum in a single LMIC with several established radiation therapy centers. With country-wide participation, this study also explored correlations between participant demographics and the likeliness to select a hypo fractionated schedule for a given clinical scenario. We hypothesized that a lack of targeted clinician education is an additional barrier to implementing hypofractionation and that an e-learning curriculum could influence the selection of hypofractionated schedules. This work may help leaders working to understand radiation therapy provider perspectives surrounding hypofractionation and to improve radiation therapy access for patients with cancer in LMICs.

Methods and Materials

Study design and participants

The nonprofit organization, Rayos Contra Cancer, developed a hypofractionation e-learning curriculum to pilot in Colombia, a country in South America (population 50 million), with a bundled payment system based on radiation therapy techniques (ie, the same payment amount regardless of the disease site or the number of treatment fractions).[10] The program's leadership felt this would eliminate the influence of perverse financial incentives toward implementing hypofractionation, which might otherwise confound the effect of medical education on practice. Rayos Contra Cancer opened the program free of charge to radiation oncologists, medical physicists, and radiation oncology and medical physics residents, with no restrictions on the type of clinical practice, including those unemployed. The Colombian Association of Radiation Oncology (ACRO, its Spanish acronym) publicized the program.

The program curriculum consisted of 13 hypofractionation topics, including a practical overview of health system implications, radiobiology considerations and calculation tools, physics principles, and guidance on implementation in clinical practice for breast, prostate, rectal cancer, and central nervous system (CNS) high-grade glioma. Topics were selected based on guidance from the ACRO based on disease sites where phase 3 clinical evidence was available and disease sites with included recommendations for use of hypofractionation in clinical guidelines. The topics were finally approved by the ACRO and tailored to meet further needs identified in the enrollment form.

An international team of 15 faculty members with expertise in radiobiology, physics, and clinical and technical aspects of hypofractionation volunteered to prepare and deliver once-per-week 75- to 90-minute educational sessions that covered these topics. Before the education session, group or personnel meetings were held to instruct educators to focus on practical concepts for implementing hypofractionation. Educators delivered each section via live video conferencing in Spanish (7 sessions) or English with a real-time Spanish translator (6 sessions). All sessions included a moderator who volunteered to promote engagement, field questions, and support the educator.

The methods have previously been described.[11-13] The curriculum and links to the recorded sessions are detailed in Appendix E1.

We asked interested participants to complete 2 online questionnaires with branching logic depending on their role (42 questions for physicians and 18 for all other roles), one before and one after completing the course. Authors BL and AGM developed the questions shared with 4 educators for refinement and testing before distribution. The survey was divided into sections for breast, prostate, rectal, and high-grade gliomas and asked all participants to rate on a 1- to 5-point Likert scale their self-confidence regarding their ability to perform their role in hypofractionation protocols and their team's ability to correctly implement hypofractionation.

In addition, the survey presented physicians with 3 disease site−specific scenarios per section (12 vignettes total) and asked detailed questions regarding their clinical practice, attitudes, and perceived barriers to select hypofractionation. Vignettes included early-stage breast cancer (ESBC) in a younger and older patient, postmastectomy breast cancer, favorable intermediate-risk (FIR) prostate cancer, unfavorable intermediate-risk (UIR) prostate cancer, high-risk prostate cancer, American Joint Committee on Cancer 8th edition stage T3N1 and T4N1 middle-rectal cancer, T3N1 low-rectal cancer, and high-grade glioma in a younger patient with poor performance status, an older patient with good performance status, and an older patient with poor performance status. We used consistent definitions in question stems about conventional fractionation (1.8-2 Gy per fraction), hypofractionation (defined as 2-5 Gy per fraction), and ultrahypofractionation (≥5 Gy per fraction). We built upon the previous work of Rodin et al[9] for multiselect questions regarding hypofractionation attitudes and barriers. In addition, we independently evaluated whether a lack of education and proper training was a perceived barrier for each clinical scenario. Google Forms was used to collect and store information. The detailed survey and examination items are in English in Appendix E2. Finally, after all forms were collected, an anonymous satisfaction survey was sent with the question, "How likely are you to recommend a Rayos Contra Cancer program to someone considering to participate?" The respondent was asked to rate this question on a scale of 1 to 10.

Statistical analysis

For the whole group of participants, we reported the frequencies and modes for categorical data. We used the Shapiro-Wilk test and the kurtosis measure to analyze the normality of continuous data. We reported the means and SDs for normal continuous variables and the median and IQRs for nonnormal continuous variables.

For the group of radiation oncologists who responded to the precourse survey, univariate and multivariate logistic regression analyses measured the association between hypofractionation selection in multiple clinical scenarios and radiation oncologist characteristics using odds ratios and 95% CIs. All significant factors or factors associated with hypofractionation selection in the different clinical scenarios ($P \leq .10$) were included in the multivariable model for each clinical scenario to develop a final model for each scenario using a probability of significance of $P < .05$ to identify variables associated with the selection of hypofractionation or ultrahypofractionation according to the clinical case. As hypofractionation is a widespread treatment in ESBC in Colombia, we focused our course on the selection of ultrahypofractionation. For early-stage intact breast cancer and rectal cancer, self-reported ultrahypofractionation use was defined as a dichotomous variable: "1" indicated a response using ultrahypofractionation and "0" indicated a response using other fractionation. For postmastectomy breast cancer and high-grade glioma, hypofractionation use was defined as a dichotomous variable: "1" indicated a response using hypofractionation and "0" indicated a response using conventional fractionation. For prostate cancer, ultrahypofractionation or hypofractionation use was defined as a dichotomous variable: "1" indicated a response using either ultrahypofractionation or hypofractionation and "0" indicated a response using conventional fractionation. Independent variables evaluated in the univariable model included sex, city of practice, country of training during residency, and years since graduation.

For self-reported physician practice patterns given each clinical vignette, "1" indicated a response using hypofractionation (in postmastectomy breast, prostate cancer, and high-grade glioma) or ultrahypofractionation (in early-stage intact breast, prostate cancer, and rectal cancer), and "0" indicated a response using conventional fractionation for that clinical case or standard of care moderate hypofractionation in early-stage intact breast. To measure the effect of the curriculum, we categorized physicians' selection of hypofractionation with a numerical score from 0 to 12 (0 = more conventional fractionation, and 12 = more hypofractionation). For the group of radiation oncologists who responded to both the pre- and postcurriculum survey, we performed a McNemar χ^2 test using Excel, version 16.54 (Microsoft Corp, Redmond, WA) to test differences selecting ultrahypofractionation or hypofractionation in the 12 clinical scenarios before and after the course with a $P < .05$ for statistical significance.

For all participants, paired *t* tests were performed to determine differences between participants' pre- versus postcurriculum confidence in ultrahypofractionation or hypofractionation use. Analyses were performed using STATA software, Version 17 (StataCorp LLC, College

Station, TX) and 2-sided statistical testing with 95% CIs.

Results

Across 19 cities in Colombia, 147 participants enrolled in the program. The baseline characteristics of the participants are presented in Table 1. Overall, 61 (41.5%) of the participants were radiation oncologists, 6 (4.1%) were radiation oncology residents, 59 (40.1%) were medical physicists, and 18 (12.2%) were medical physics residents. Among the participants, 54 (36.5%) were female. Forty-five (30.6%) of the participants had been in practice for less than 5 years. Participants joined from 46 centers of 49 radiation oncology centers in the country at the time enrollment in the curriculum.[10] Among the 67 physicians, 38 (57%) responded to both surveys. All 38 respondents were in practice, representing 30.6% of the current workforce of radiation oncologists in the country.[14]

General barriers and rationales for the selection or not of ultra- or moderate hypofractionation schedules are presented in Fig. 1. Of physicians who did not select hypofractionation, the main self-reported barriers included (in descending order, averaged across all disease sites) unfamiliarity with clinic protocols, clinical experience, personal preference, lack of technology, colleague preference, clinical evidence, and patient preference. Varying perceptions were recorded across divergent clinical settings. Being unfamiliar with the clinical protocols was the main barrier to select prostate cancer ultrahypofractionation (32.8%). The lack of proper technology was a more relevant barrier for prostate cancer cases, both for ultra- (29.9%) and moderate hypofractionation (14.9%) than for the other clinical settings. Lack of clinical experience was the main barrier to select breast cancer ultrahypofractionation (22.4%) and a common barrier to select prostate cancer ultrahypofractionation (28.4%). A lack of convincing clinical evidence was a greater barrier for the CNS high-grade glioma case (10.4%). Resource optimization and reimbursement were only identified as barriers by 1 participant (1.5%) in 2 of the settings.

Self-reported rationales for the selection of ultra- and moderate hypofractionation are presented in Fig. 2. The main rationales were (in descending order, averaged across all disease sites) convincing clinical evidence, having available technology, and being familiar with the clinical protocols. Following these, the reported rationales included personal preference, clinical experience, patient preference, and resource optimization. Reimbursement was identified only as a rationale by one participant (1.5%) in 2 of the settings.

Univariate and multivariate analyses for predictors of the selection of hypofractionation are presented in Table 2. Multivariate analysis showed that the physicians' city of practice was associated with ultrahypofractionation selection in patients with rectal cancer (Bogotá, $P = .009$) and the selection of ultrahypofractionation in patients with ESBC. A physician's male sex was a predictor of the selection of hypofractionation for high-grade gliomas ($P = .02$), FIR ($P = .025$), and UIR prostate cancer ($P = .018$) and ultrahypofractionation for rectal cancer

Table 1 Baseline characteristics of the participants

Characteristic	Participants (n = 147)
Sex, n (%)	
Female	54 (36.5)
Male	93 (62.8)
Profession, n (%)	
Radiation oncologists	61 (41.5)
Medical physicists	59 (40.1)
Radiation oncology residents	6 (4.1)
Physics residents	18 (12.2)
Technologist	1 (0.7)
Dosimetrist	1 (0.7)
Other	1 (0.7)
Time from graduation, n (%)	
≤5 y	45 (30.6)
6-10 y	41 (27.9)
11-15 y	12 (8.2)
16-20 y	9 (6.1)
>20 y	12 (8.2)
In training	24 (16.3)
NA	4 (2.7)
Geographic region, n (%)	
Andinean	93 (62.6)
Caribbean	24 (16.3)
Pacific	25 (17.0)
Orinoquia	1 (0.7)
Amazon	0 (0.0)
NA	5 (3.4)
Country of training, n (%)*	
Colombia	33 (48.5)
Argentina	10 (14.7)
Costa Rica	1 (1.5)
Spain	9 (13.2)
Mexico	2 (2.9)
Peru	1 (1.5)
Venezuela	2 (2.9)
Not available	10 (14.7)

Abbreviation: NA = not available.
* Only available for physicians.

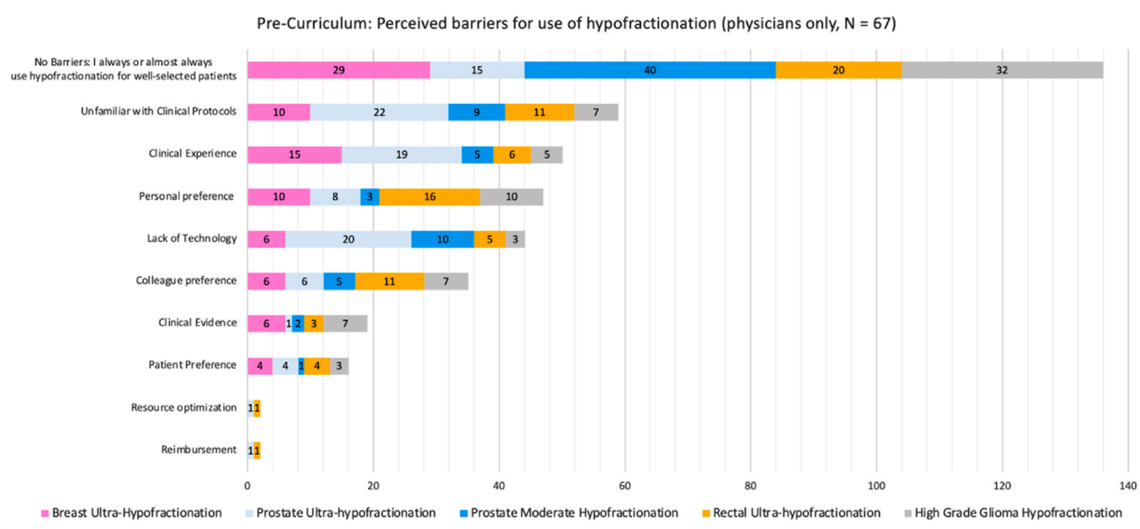


Figure 1 Perceived barriers to using hypofractionation.

(*P* = .025) and older patients with ESBC (*P* = .050). Multivariate analysis showed only years in practice associated with ultrahypofractionation in rectal cancer (*P* = .024). The country of training was not associated with hypofractionated regimens in any clinical scenarios presented.

At baseline, among all the physicians in practice (n = 67), ultrahypofractionation was the preferred regimen for elderly women with ESBC (49.3%). Moderate hypofractionation was preferred for younger women with ESBC (65.2%) as it was for the postmastectomy setting in elderly patients (62.7%), with only 31.8% and 10.4% of the respondents selecting ultrahypofractionation in these scenarios, respectively. Conventional fractionation was still widely selected in the postmastectomy scenario (58.2%). In prostate cancer, ultrahypofractionation was selected by 7.5% and only for FIR disease. As for moderate hypofractionation, the greatest selection rates were in low- and intermediate-risk diseases at 57.5% and 54.5%, respectively, compared with 41.9% in high-risk disease and 23.6% when treating pelvic nodes. For rectal cancer, 23.5% chose ultrahypofractionation for cT3-T4 node-positive patients. This was reduced to 15% in patients with comprised anal sphincter tone. For high-grade gliomas, performance status and age appeared to drive the selection of a hypofractionated schedule; 64.2% and 43.3% of the physicians chose hypofractionation for 72-year-old and 60-year-old patients with a poor performance status (European Collaborative Oncology Group [ECOG] Performance Status of 2), respectively. The selection of hypofractionation decreased to 26.9% for a 72-year-old patient with an ECOG performance status of 0 to 1.

At baseline, education was a perceived barrier across all clinical scenarios. Education as a barrier was most common for prostate (77.6%) and breast cancer (74.6%)

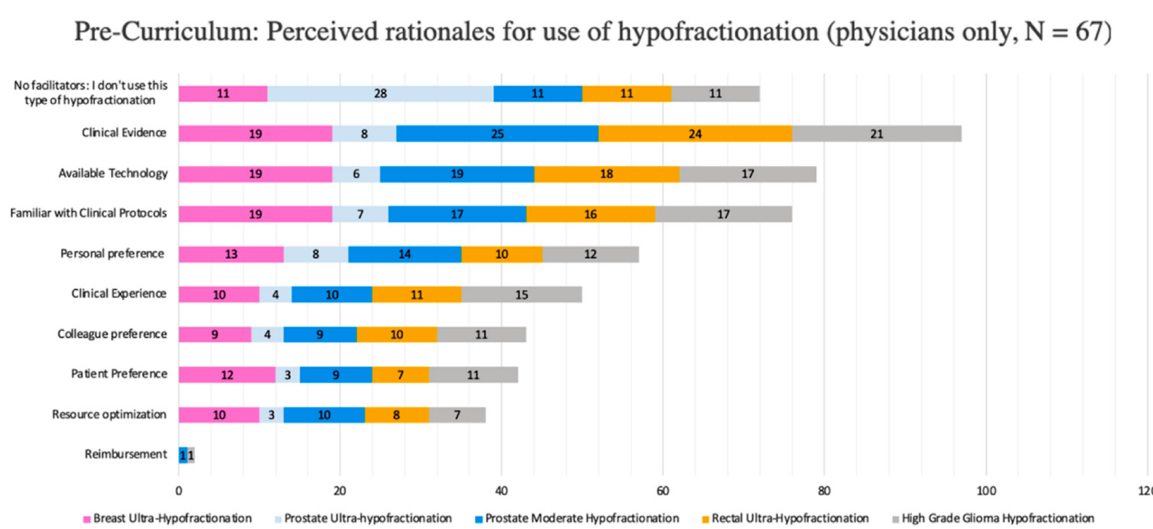


Figure 2 Perceived rationales for using hypofractionation.

Table 2 Univariate and multivariate logistic regression analysis of provider characteristics associated with hypofractionation use

	Univariate			Multivariate		
	OR	95% CI	*P*	OR	95% CI	*P*
Early breast cancer >50 y ultrahypofractionation						
Sex						
Female	–	–	–	–	–	–
Male	3.51	(1.23-9.97)	**.02**	4.25	(1.0-18)	**.05**
City						
Other	–	–	–	–	–	–
Bogotá	10.6	(2.05-54.9)	**.05**	5.020	(1.19-21-01)	**.03**
Cali	5.30	(0.93-30.2)	.06	25.17	(3.13-202.2)	**.00**
Medellin	0.50	(0.09-2.80)	.43	2.22	(0.32-15.3)	.42
Residency training						
Outside Colombia	–	–	–	–	–	–
In Colombia	2.19	(0.82-5.82)	.11			
Years in practice (continuous variable)	0.94	(0.88-0.99)	**.04**	0.97	(0.90-1.04)	.40
Early breast cancer <50 y ultrahypofractionation						
Sex						
Female	–	–	–	–	–	–
Male	3.51	(1.23-9.97)	**.02**	4.25	(1.0-18)	**.05**
City						
Other	–	–	–	–	–	–
Bogotá	10.6	(2.05-54.9)	**.05**	5.020	(1.19-21-01)	**.03**
Cali	5.30	(0.93-30.2)	.06	25.17	(3.13-202.2)	**.00**
Medellin	0.50	(0.09-2.80)	.43	2.22	(0.32-15.3)	.42
Residency training						
Outside Colombia	–	–	–	–	–	–
In Colombia	2.19	(0.82-5.82)	.11			
Years in practice (continuous variable)	0.94	(0.88-0.99)	**.04**	0.97	(0.90-1.04)	.40
Favorable intermediate prostate cancer hypofractionation						
Sex						
Female	–	–	–	–	–	–
Male	3.56	(1.15-10.97)	**.03**	3.82	(1.18-12.3)	**.02**
City						
Other	–	–	–	–	–	–
Bogotá	1.22	(0.27-5.38)	.79			
Cali	2.33	(0.25-21.63)	.46			
Medellin	0.26	(0.05-1.21)	.09			
Residency training						
Outside Colombia	–	–	–	–	–	–
In Colombia	0.65	(0.21-1.93)	.44			
Years in practice (continuous variable)	0.94	(0.89-1.0)	.07	0.94	(0.89-1.0)	.06
Unfavorable intermediate prostate cancer hypofractionation						
Sex						
Female	–	–	–	–	–	–
Male	3.17	(1.31-10.5)	**.01**	3.60	(1.24-10.4)	**.02**
City						
Other	–	–	–	–	–	–
Bogotá	0.56	(0.16-1.97)	.37			

(*continued on next page*)

Table 2 (*Continued*)

	Univariate			Multivariate		
	OR	95% CI	*P*	OR	95% CI	*P*
Cali	3.95	(0.43-35.8)	.22			
Medellin	0.45	(0.10-1.98)	.29			
Residency training						
Outside Colombia	–	–	–	–	–	–
In Colombia	0.4	(0.14-1.09)	.07	0.41	(0.14-1.19)	.11
Years in practice (continuous variable)	0.97	(0.92-1.02)	.28	–	–	–
CNS high-grade glioma hypofractionation						
Sex						
Female	–	–	–	–	–	–
Male	4.84	(1.65-14.18)	**.00**	6.74	(1.98-22.9)	**.02**
City						
Other	–	–	–	–	–	–
Bogotá	3.28	(0.78-13.7)	.10	3.53	(0.73-17.07)	.12
Cali	6.26	(0.69-56.24)	.10	11.4	(1.07-121)	.04
Medellin	1.78	(0.38-8.28)	.45	3.09	(0.54-17.7)	.20
Residency training						
Outside Colombia	–	–	–	–	–	–
In Colombia	1.12	(0.813.0.414)	.24			
Years in practice (continuous variable)	1.012	(0.95-1.069)	.45	–	–	–

Abbreviations: OR = odds ratio.[a]
[a] Bolded p values ≤ 0.05 are statistically significant.

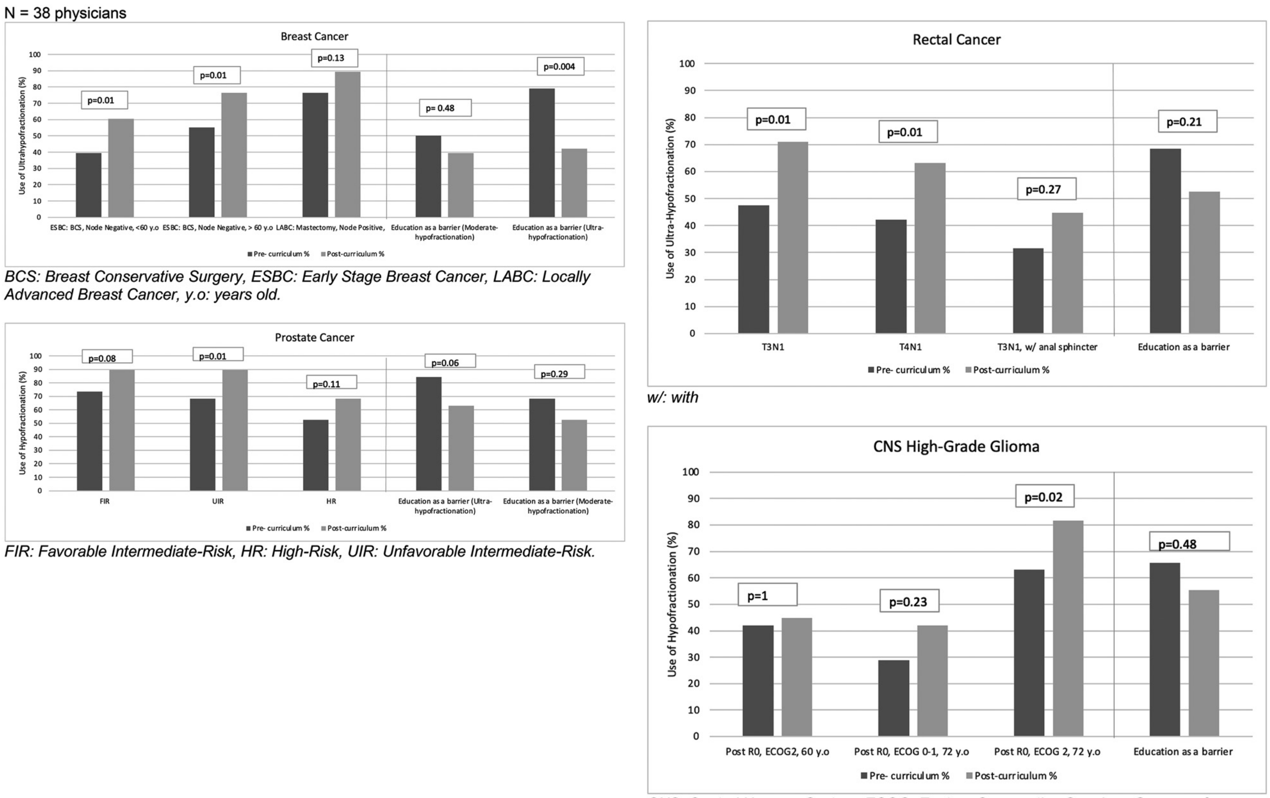
ultrahypofractionation, followed by rectal cancer (67.2%) ultrahypofractionation and high-grade glioma (64.2%) hypofractionation, and the least commonly for prostate (61.2%) and breast cancer (52.2%) moderate hypofractionation.

Measuring the curricular effect: paired respondents pre- versus postcurriculum

Available paired physician responses (N = 38) for each clinical scenario before and after the course are depicted in Fig. 3. More respondents selected hypofractionation after the curriculum for all scenarios (mean precurriculum score 5.8/12 vs postcurriculum score 3.8/12, $P <$ .001). For breast cancer, hypofractionation selection after node-negative lumpectomy increased by 21% for younger patients (39% vs 60%, $P = .01$) and 21% for older patients (55% vs 76%, $P = .01$), and for locally advanced postmastectomy increased by 13% (76% vs 89%, $P = .13$). For prostate cancer, hypofractionation selection for unfavorable intermediate-risk patients increased by 21% (68% vs 89%, $P = .01$), for favorable intermediate-risk by 15% (74% vs 89%, $P = .08$), and for high-risk by 16% (52% vs 68%, $P = .11$). For rectal cancer, ultrahypofractionation selection for cT3N1 and cT4N1 midrectal patients increased by 24% (47% vs 71%, $P = .02$) and 21% (42% vs 63%, $P = .01$), respectively. For low-rectal cancer patients, ultrahypofractionation selection increased by 13% (32% vs 45%, $P = .13$). For CNS high-grade gliomas, hypofractionation selection for older patients with poor performance status (ECOG 2) increased by 18% (63% vs 81%, $P = .02$). There was no change in hypofractionation selection for younger patients with ECOG 2 performance status (42% vs 45%, $P = 1$) or older patients with ECOG 0 to 1 performance status (29% vs 42%, $P = .23$). Overall, there was a decrease in the perception of education as a barrier after the curriculum, which was only statistically significant for breast cancer ultrahypofractionation (from 78.9%-42.1%, $P = .003$).

Participant confidence and satisfaction

Aggregate pre- versus postcurriculum confidence scores about oneself and one's team to correctly perform their role in hypofractionation increased across all the clinical settings (Table 3). For paired responses, confidence scores in oneself were significantly greater ($P \leq .03$) for all clinical scenarios except for breast ultrahypofractionation and high-grade glioma hypofractionation. Confidence scores about the physician's team were significantly greater in all of the breast, prostate, and rectal cancer



BCS: Breast Conservative Surgery, ESBC: Early Stage Breast Cancer, LABC: Locally Advanced Breast Cancer, y.o: years old.

FIR: Favorable Intermediate-Risk, HR: High-Risk, UIR: Unfavorable Intermediate-Risk.

w/: with

CNS: Central Nervous System, ECOG: Eastern Cooperative Oncology Group performance status, R0: Complete Resection, y.o: years old.

Figure 3 Hypofractionation practices and education as a perceived barrier by clinical scenario before and after the course. *Abbreviations:* BCS = breast conservative surgery; CNS = central nervous system; ECOG = Eastern Cooperative Oncology Group performance status; ESBC = early-stage breast cancer; FIR = favorable intermediate-risk; HR = high-risk; LABC = locally advanced breast cancer, R0 = complete resection UIR = unfavorable intermediate-risk; w/ = with; y. o. = years old.

clinical scenarios. After the course, 34 participants (23.1%) completed an additional anonymous feedback survey and rated the program 9.88/10.

Discussion

Our study explored the perceptions surrounding hypofractionation in Colombia, an LMIC with a bundled payment system. It revealed a lack of education as an addressable barrier to using hypofractionation through a novel education and training e-learning curriculum. Among physicians, the program significantly increased the radiation oncologists' selection of hypofractionation schedules, and among combined radiation oncologists and medical physicist staff, it improved confidence across breast, prostate, and rectal cancer clinical settings. These results coincide with the participants' barriers perceived precurriculum to using hypofractionation and ultrahypofractionation.

The appropriate use of hypofractionation can increase global access to radiation therapy where there is a documented shortage of radiation oncology centers, machines, and personnel.[3] However, its implementation has been limited, particularly and paradoxically in LMICs, where potentially a much greater effect exists.[9] Some have hypothesized a lack of education is a barrier to hypofractionation use in selected clinical settings such as prostate cancer.[9,15,16] Indeed, knowledge and education gaps are historical barriers to implementing new radiation oncology technologies with high-quality care.[1] In a recent study, Rodin et al[9] explored several barriers to the use of hypofractionation on a global scale; in Latin America, the most common barriers were related to the lack of long-term data (36.3%), followed by concerns about late toxicity (29.1%), lack of adequate technology (24.2%), and reimbursement, listed as a barrier by 14.3% of the participants. However, studies have not evaluated targeted clinical education or knowledge gaps for hypofractionation.

Our work provides new information on how education and training may be another unexplored barrier to using hypofractionated radiation therapy. We show that

Table 3 Paired pre- and postcurriculum confidence scores

Domains and topics assessed	All-comer data (n = 147)		Paired participants (n = 87)			
	Mean Precurriculum confidence, 1-5 (SD)	Mean Postcurriculum confidence, 1-5 (SD)	Mean Precurriculum confidence, 1-5 (SD)	Mean Postcurriculum confidence, 1-5 (SD)	Mean change (SD)	*P*
What is your confidence in yourself to correctly perform your role in. . .						
Breast hypofractionation	3.33 (1.07)	3.79 (0.90)	3.41 (1.02)	3.79 (0.90)	+0.38 (0.84)	<.01
Breast ultrahypofractionation	3.87 (0.98)	4.07 (0.85)	3.99 (0.93)	4.07 (0.85)	+0.08 (0.72)	**.30**
Prostate hypofractionation	2.95 (1.17)	3.25 (1.04)	3.02 (1.17)	3.25 (1.04)	+0.23 (1.00)	.03
Prostate ultrahypofractionation	3.48 (1.14)	3.90 (1.02)	3.45 (1.17)	3.90 (1.02)	+0.45 (0.95)	<.01
Rectal ultrahypofractionation	3.27 (1.14)	3.74 (0.93)	3.31 (1.13)	3.74 (0.93)	+0.43 (0.95)	<.01
CNS high-grade glioma hypofractionation	3.35 (1.13)	3.62 (1.07)	3.41 (1.17)	3.62 (1.07)	+0.21 (1.01)	**.06**
What is your confidence that your team can correctly perform treatments in. . .						
Breast hypofractionation	3.53 (0.98)	3.89 (0.87)	3.61 (0.96)	3.89 (0.87)	+0.28 (0.92)	<.01
Breast ultrahypofractionation	3.88 (0.88)	4.17 (0.80)	3.87 (0.87)	4.17 (0.80)	+0.30 (0.81)	<.01
Prostate hypofractionation	3.01 (1.19)	3.38 (1.06)	3.05 (1.21)	3.38 (1.06)	+0.33 (1.03)	<.01
Prostate ultrahypofractionation	3.55 (1.08)	4.03 (0.96)	3.52 (1.16)	4.03 (0.96)	+0.52 (0.94)	<.01
Rectal ultrahypofractionation	3.45 (1.06)	3.86 (0.92)	3.44 (1.05)	3.86 (0.92)	+0.43 (0.91)	<.01
CNS high-grade glioma hypofractionation	3.51 (1.07)	3.76 (1.00)	3.60 (1.05)	3.76 (1.00)	+0.16 (0.94)	**.11**
		(same as paired)		(same as all-comer)		

Abbreviations: CNS = central nervous system.

radiation oncologists perceive education as a barrier to using hypofractionation schedules. This can be as high as 77.6%, 74.6%, and 67.2% for ultrahypofractionation in selected clinical scenarios for breast, prostate, and rectal cancer, respectively. Our findings add a detailed, single-country perspective, exploring both barriers and rationale for the use of hypofractionation in an LMIC setting with 46 of 49 radiation therapy centers participating.

The noneducational barriers reported by our participants correlate with those reported in the aforementioned global hypofractionation survey; however, among our participants, reimbursement was listed as a barrier by only 1% of the participants and only for 2 of our selected clinical scenarios, which is much lower than in the global report average.[9] This difference from the international survey might be related to Colombia's current national bundled payment system for radiation services,[10] which may be distinctive among Latin American countries. In choosing Colombia to pilot this program, we considered a bundled payment system ideal for this kind of work, as it reduces financial disincentives as a barrier against hypofractionation and allows a cleaner analysis of nonfinancial barriers regarding its implementation.[15]

To explore the potential influence of hypofractionation education on physician practice patterns, we evaluated multiple clinical scenarios within each disease site (ie, breast, prostate, rectal, and CNS high-grade glioma). Questions were designed with different parameters within each disease site (eg, patient age, primary tumor information, etc) to evaluate possible thresholds for adopting hypofractionated schedules. For ESBC, after the curriculum, the respondents were more confident and adopted ultrahypofractionation protocols for older and younger women. For locally advanced rectal cancer, respondents were more confident and increased adoption of ultrahypofractionation for middle-rectal cancer but not low-rectal cancer cases. For prostate cancer, respondents were more confident and increased adoption of hypofractionation or ultrahypofractionation for FIR and UIR, but not for high-risk patients. For high-grade glioma, respondents increased adoption of hypofractionation for elderly patients with poor performance status but not for younger patients or patients with favorable performance status. These results suggest clinically appropriate adaptations to practice.[16-21]

In the LMIC setting, we observed that a lack of technology came into play as a barrier mainly for prostate cancer, with 20% of participants listing technology as a barrier for prostate ultrahypofractionation. This is probably due to the need for image guided radiation therapy to accurately deliver high dose per fraction while sparing dose to the adjacent bladder and rectum.[22] Interestingly, familiarity with clinical protocols was also a relatively highly reported barrier in this scenario, where we believe there is uncertainty about the details and specifics of treatment and treatment planning. In a longitudinal remote stereotactic body radiation therapy (SBRT)/stereotactic radiosurgery (SRS) training program that included physicians from Colombia and Peru, only 11% to 15% of participants had received previous web-based training on stereotactic radiosurgery/SBRT.[11] Furthermore, in a cross-sectional analysis of universities and training centers for radiation oncologists in Latin America, as of 2020, only 50% of training programs in Latin America include specific SBRT training for residents.[23] Consequently, a gap between SBRT training and education could contribute to its relatively low use in LMICs.[11,24-26]

The dynamics and use of hypofractionation may vary across regions of the same country. We observed that the physician's city of practice, mostly in Bogotá and Cali, was correlated with the greater selection of ultrahypofractionation schedules. This may be due to available technology; however, limited data exists besides the number and location of machines about the use of image-guided radiotherapy and advanced radiation therapy techniques. According to ACRO's 2020 data, Colombia has 92 linear accelerators that are concentrated more in Bogotá (n = 10), Medellin (n = 6), and Cali (n = 4).[10,27] Women were less likely to select hypofractionation, which correlates with the results from an international survey that found that 25% of women were less likely to use hypofractionation.[9] Our understanding of the country's practice and factors that may influence the use of more hypofractionation schedules remains to be improved.

The results from our program suggest that education is an effective approach to addressing the perceived barriers to implementing hypofractionation. An important component of success was sharing knowledge in a protected learning environment among developed and developing countries in an accessible way to address the shortage of radiation therapy training opportunities. This e-learning modality is a low-cost and scalable solution previously shown to be successful for other radiation therapy techniques.[11,13] Based on local observations and in-person interactions with centers that participated in the hypofractionation program, we believe that during or shortly after finishing the curriculum, these educational results do translate into tangible changes in radiation therapy practice that can better serve patients.

The expansion of radiation therapy in countries with a shortage of radiation oncology machines and personnel, such as Colombia,[10,27] requires further commitment from professional associations. Our curriculum was supported by local in-country leadership and the main professional association for radiation oncology in the country (that is, ACRO), with reminders and encouragement, and a commitment to the procurement of live translators to reduce language barriers. Strengthening leadership and accountability to expand access to radiation therapy through education and training by professional radiation therapy associations is a strategy that we encourage⍰and not just for other LMIC countries. The study was offered in English and Spanish with live translators, which might have contributed to the good participation and high satisfaction rates (9.88/10) throughout the course. This combined approach can enhance the expansion of this model in environments other than English. In the future, further translation into other languages could expand its audiences.

One study's limitations include the difficulty that not all precurriculum respondents completed the postcurriculum survey, resulting in a small size for paired respondent analysis and a chance of selection bias. Furthermore, there is no way to verify the true hypofractionation use rates outside of the survey responses and reported likeliness to select a hypofractionated schedule. According to ACRO, there have been past limitations in obtaining results from survey and practice patterns in the country. Even though we believe the results may be helpful in other bundled payment systems or resource-limited settings, results from a single country's experience may not be generalizable to all clinicians in other LMIC settings, for instance, countries with postgraduate Continuing Medical Education or board examination requirements, which to date are not implemented in the country.

Conclusions

In an LMIC with a bundled payment system, a lack of education and training was a perceived barrier for the implementation of hypofractionation and ultrahypofractionation in breast, prostate, rectal, and CNS disease sites. A targeted e-learning hypofractionation curriculum offered to all in-country radiation oncology clinicians addressed barriers and increased physician's likeliness to select hypofractionation. Education continues to remain a barrier to adoption, and further work in this domain is needed to address the global shortage of radiation therapy availability.

Acknowledgments

We acknowledge all the curriculum educators and participants, and the board of directors of the Association of Colombian Radiation Oncology for their support and for provision of live-translation services.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.adro.2022.101165.

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