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CLINICAL INVESTIGATION

Leveling Up the Access to Radiation Therapy in Latin America: Economic Analysis of Investment, Equity, and Inclusion Opportunities Up to 2030

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Purpose: Latin America faces a shortage in radiation therapy (RT) units and qualified personnel for timely and high-quality treatment of patients with cancer. Investing in equitable and inclusive access to RT over the next decade would prevent thousands of deaths. Measuring the investment gap and payoff is necessary for stakeholder discussions and capacity planning efforts.

Methods and Materials: Data were collected from the International Atomic Energy Agency's Directory of Radiotherapy Centers, industry stakeholders, and individual surveys sent to national scientific societies. Nationwide data on available devices and personnel were compiled. The 10 most common cancers in 2020 with RT indication and their respective incidence rates were considered for gap calculations. The gross 2-year financial return on investment was calculated based on an average monthly salary across Latin America. A 10-year cost projection was calculated according to the estimated population dynamics for the period until 2030.

Results: Eleven countries were included in the study, accounting for 557,213,447 people in 2020 and 561 RT facilities. Approximately 1,065,684 new cancer cases were diagnosed, and a mean density of 768,469 (standard deviation ±392,778) people per available unit was found. By projecting the currently available treatment fractions to determine those required in 2030, it was

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found that 62.3% and 130.8% increases in external beam RT and brachytherapy units are needed from the baseline, respectively. An overall regional investment of approximately United States (US) $349,650,480 in 2020 would have covered the existing demand. An investment of US $872,889,949 will be necessary by 2030, with the expectation of a 2-year posttreatment gross return on investment of more than US $2.1 billion from patients treated in 2030 only.

Conclusions: Investment in RT services is lagging in Latin America in terms of the population's needs. An accelerated outlay could save additional lives during the next decade, create a self-sustaining system, and reduce region-wide inequities in cancer care access. Cash flow analyses are warranted to tailor precise national-level intervention strategies.

Introduction

Worldwide, increasing numbers of cancer cases have made cancer control a primary focus of health care providers.[1,2] Given that over 50% of patients with cancer require radiation therapy (RT) at some point in their treatment, its development is a critical fulcrum for the improvement of cancer control. Established accessible, timely, and high-quality RT is essential for effective cancer treatment; however, a global shortfall of RT infrastructure and investment is currently impeding the achievement of these aims.[3]

Because of well-known disparities in health care access and the structural capacities of individual countries, disproportionate challenges for RT development exist among different low- and middle-income countries (LMIC) and high-income countries (HICs). Access to RT facilities in LMICs is far from optimal. Latin America (Latam) and Africa, which account for 55% of all LMICs, do not have a single RT facility available in 30% and 54% of their countries, respectively, nor enough facilities to treat all patients who require it, even within countries with RT facilities.[4,5] Additionally, RT utilization rates are lower than recommended because of patient factors, including low health literacy, low income levels, geographic inaccessibility, and socioeconomic status, which strongly correlate with inequities in access to care. The availability of RT resources in countries is heterogenous and influenced by national factors, such as political will and stability, health care priorities, national health budgets, population growth, incident cancer rates, and national welfare. Because of the involved capital costs, economic considerations are pivotal during decision-making about acquiring and maintaining RT equipment. Although costs are seen as a traditional barrier for RT development, the return on investment (ROI) must also be determined and considered at the country level because it can vary with demographics of patients with cancer, patterns of practice, and reimbursement systems.

The situation in Latam requires special attention. Cancer is the second leading cause of death in Latam today, and if no major action is taken at the political or administrative level to develop RT facilities, death from cancer will pose an enormous risk to the currently estimated 650 million people by the end of this decade.[6] Although there have been some improvements recently,[7] heterogeneous cancer control and prevention strategies have not shown major changes in limiting cancer expansion.[8] This is further evidence of the need for immediate treatment after diagnosis and for increasing the number of RT units. Another substantial challenge faced in Latam is insufficient funding. A lack of adequate infrastructure and resources, along with weak primary health care systems, has contributed to the chronic worsening of an already fragile situation in tertiary or specialized centers, which struggle to provide comprehensive geographic coverage.[9,10] Furthermore, shortages of qualified personnel and information about RT needs and access across the region are contributing to the deepening crisis and obstacles to overcome.[11,12] As the patient volume continues to rise, so too does the urgency to address the demand−supply gap in RT services in Latam, which is not only necessary but also in the interests of all stakeholders.

Most of the studies in the literature have identified problems and proposed solutions for countries and regions other than Latam; limited studies have focused on Latam.[4,13] Given the variability in socioeconomic environments, it may not be appropriate to adapt solutions designed for other regions to address Latam's needs.[4,14,15] Therefore, in this study, we aimed to compile accurate regional data and perform a comprehensive and relevant analysis to generate information that can aid the development of interventional strategies designed to achieve better care over the next 10 years. This up-to-date regional report encompasses the 10 most frequent cancers by incidence and projects the expected issues to be faced in the forthcoming decade in one of the most socially and economically unequal regions worldwide (Latam, henceforth referred to as "the region" in this article).

Methods and Materials

Data collection and evaluation

Information on Latam's RT facilities was collected from the International Atomic Energy Agency's (IAEA) Directory of Radiotherapy Centers.[16] To avoid duplication, it was matched to information extracted from vendors' databases, individual surveys sent to national scientific societies, and a recent publication on the specific case of Brazil.[17] National data on the availability of external beam RT (EBRT) units (^{60}Co and linear accelerators [LINACs]), brachytherapy (BT) units, 2-dimensional and computed tomography scan simulators, and on personnel features were compiled.

Demographic information was obtained from World Bank and United Nations (UN) databases.[18,19] The Global Cancer Incidence, Mortality and Prevalence (GLOBOCAN 2020)[2] database was used to retrieve epidemiologic data on the 10 most common cancers in Latam with EBRT and/or BT indication and their respective incidence rates. An overall >2-year median survival rate was required for disease inclusion in the ROI analysis. Brain malignancies were excluded from the assessment because of their high disability and mortality rates within the first 2 years after treatment.[20]

Modeling the scale-up of RT services

The requirement for radiation oncologists (ROs), medical physicists (MPs), and radiation therapists (RTTs) was calculated using the IAEA recommendation of 1 professional per new diagnosis, namely 1 for every 250, 400, and 100 new cases per year, respectively, as a more reliable measure than per-population rate. According to the current availability of EBRT and BT devices, an equivalent in available fractions was calculated and matched to the required number to cover the demand of the participating countries. The absolute numbers of new cancer cases were obtained from GLOBOCAN. RT utilization rates (RTUs) were estimated for the 10 most frequent malignancies employing the models developed by Barton et al[21] and the Global Task Force on Radiotherapy and Cancer Control (GTFRCC)[4,21] and supported by IAEA estimations.[5] Moreover, specific RTU estimates published from Spain for uterine corpus BT and from India for cervix EBRT and BT were considered because of similarities to the situation in Latam.[22,23] A prostate BT RTU was adopted from a recent United States (US)–based report, setting an EBRT–BT combination scenario for all cases.[24] In accordance with the aforementioned, the assumed EBRT RTUs per malignancy were 87% for breast, 58% for prostate (5% BT), 60% for colorectal, 85% for uterine cervix (75% BT), 77% for lung, 27% for stomach, 4% for thyroid, 38% for uterine body (27% BT), 71% for head and neck, and 73% for non-Hodgkin lymphoma. The number of EBRT fractions needed was based on an average 20-fraction schedule, emulating the calculations performed by the GTFRCC (18.4), effectively multiplying the total patients with an EBRT indication by 20 to calculate the total number of fractions required for each country. This slight difference between the GTFRCC and our method was considered because of the low adoption rates of hypofractionation in the region.[25] BT calculations were limited to high-dose-rate devices, assuming a 4-fraction prescription multiplied by the total number of patients for uterine cervix and corpus malignancies and a single boost application for prostate cancer.[22] Other baseline values used in the model calculations were 240 working days (working 5 days per week and accounting for annual holidays) and a daily 60-patient occupancy per EBRT unit and a daily 4-patient occupancy per BT unit.

Average costs of US $1704 per EBRT-only course and US $1426 per BT-only course per patient in 2020 were estimated. The costs for increasing RT availability were obtained using the IAEA's Time-Driven Activity-Based-Costing tool for each country.[26] Costs for planning, treatment delivery, construction, machinery, maintenance, salaries, training, migration from ^{60}Co to LINACs, and other items were included within the assessments. In addition, a 10-year cost projection was calculated according to the expected demographic changes and the World Bank's Time Value of Money (TVM) equation for each country for the next 10 years, encompassing a mean interest rate of 7% in Latam.

The regional gross 2-year financial return was calculated using an average patient monthly wage of US $572.62, according to the World Bank and different national open-data sources. Furthermore, a 50% therapeutic success ratio and a minimum of 2 years of gained working time were integrated into these calculations, including patients who would be saved if RT requirements were met. This was determined from published overall survival rates of patients undergoing RT in different settings, using historical and recent data.[4,27] These rates are rather conservative compared with 5-year survival rates associated with modern treatments.

Reporting

Cancer incidences per 100,000 people are reported for each country, while mean values are reported for the region. The absolute number of cases requiring both EBRT and BT, the overall numbers of professionals and RT units, the projected number of rescued lives, and the financial balance per country and for the region are detailed. Additionally, the density of EBRT devices per population is presented. The number of additional devices needed in 2030 (projected) compared with the number in use in 2020 (baseline) for both treatment modalities is graphically shown, according to arbitrarily predefined categories of 0%, <50%, 50 to 100%, and >100%.

Results

Demographics, epidemiology, and RT services in 2020

Eleven Latam countries and a total population of 557,213,447 people were included in the analysis, encompassing Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay, and Venezuela, representing approximately 85% of the estimated regional population in 2020, according to the World Bank database. Of the 11 countries, 7 were classified as upper middle–income countries, 2 as HICs (Chile and Uruguay), and 2 as LMICs (Bolivia and Venezuela).

According to GLOBOCAN 2020 estimates for Latam, the 10 most frequent malignancies requiring RT were breast, prostate, colorectal, uterine cervix, lung, stomach, thyroid,

Table 1 Regional incidence rates and device density

Country	Breast	Prostate	Colorectal	Cervical	Lung	Stomach	Thyroid	Uterine corpus	H&N	Non-Hodgkin lymphoma	Inhabitants per EBRT device in 2020
Brazil	61.9	78.0	19.4	12.7	14.3	7.1	11.9	8.1	12.7	4.3	778,514
Mexico	40.5	42.2	10.6	12.6	5.3	6.2	8.1	7.6	2.9	5.0	865,320
Argentina	73.1	42.0	25.1	16.7	19.2	6.3	8.0	7.6	8.0	6.2	383,015
Colombia	48.3	49.8	16.9	14.9	10.5	12.8	9.1	8.1	6.2	7.0	716,660
Peru	35.9	44.3	11.4	22.2	7.2	15.2	7.1	6.5	4.6	8.3	1,030,370
Venezuela	52.6	49.8	14.2	22.2	16.2	6.8	4.2	9.7	7.5	4.7	334,541
Chile	37.4	56.7	19.9	11.1	12.2	13.1	4.8	6.5	4.3	5.3	424,805
Ecuador	38.2	35.7	12.9	16.0	6.0	12.5	9.2	8.4	3.3	8.0	767,090
Uruguay	65.1	60.2	32.0	11.7	30.7	8.0	9.3	7.8	13.2	9.9	267,210
Bolivia	25.5	32.4	5.7	36.6	7.6	7.8	2.1	11.5	3.0	2.2	1,459,129
Paraguay	61.9	55.9	24.9	24.8	21.4	7.3	7.5	8.5	5.7	7.2	1,426,506
Regional mean	49.1	49.7	17.5	18.3	13.7	9.4	7.4	8.2	6.5	6.2	768,469
SD	14.2	12.2	7.3	7.3	7.4	3.2	2.6	1.3	3.8	2.1	392,778

Incidence rates for 100,000 inhabitants per disease group in each assessed country and regional mean and inhabitants per megavoltage device.
Abbreviations: EBRT = external beam radiation therapy; H&N = head and neck; SD = standard deviation.

uterine corpus, head and neck, and non-Hodgkin lymphoma. In 2020, approximately 1,065,684 new cancer cases of these malignancies were diagnosed. The current cancer incidence rates per 100,000 people, the mean regional incidence, and the EBRT unit density per population are detailed in Table 1. The current and projected absolute numbers of new patients requiring EBRT per country for each malignancy and the relative increases from 2020 to 2030 are described in Table 2.

A total of 561 RT facilities, 821 teletherapy units (685 LINACS and 136 Co^{60}), 335 simulation scanners (189 computed tomography scanners and 146 2-dimensional scanners), 624 planning stations, 316 BT units (67 low-dose-rate and 249 high-dose-rate), and 20 intraoperative RT machines were found to be distributed among the analyzed countries. Regarding EBRT units, the mean density was found to be 768,469 (standard deviation ±392,778) people per unit. In terms of personnel, 1965 ROs, 1175 MPs, and 3800 RTTs were identified, and regional means of 542, 907, and 280 new patients per year per professional, respectively, were calculated. Hence, in 2020, estimated professional deficits of 41% (RO), 40% (MP), and 73% (RTT) existed in the number of professionals required to cover the baseline regional demands. The current professional gaps per newly diagnosed cases, detailed by country, absolute numbers, and proportions, are displayed in Table 3.

Projected demographic and epidemiologic status in 2030

In 2030, about 1,467,673 new cancer cases will be diagnosed in the evaluated countries, representing an increase of 38.3% compared with 2020. The details of the increase per country are given in Table 2. Regarding the regional professional gaps, an additional 1860 ROs, 1143 MPs, and 5292 RTTs above current numbers will be required by 2030 to appropriately treat new RT cases. This represents a need to increase current staffing by 95%, 97%, and 139%, respectively, for each current professional group compared with current availability. Detailed projections for each country are provided in Table 3.

Current and projected RT supply and demand

Across the 11 countries, 694,198 new cases required EBRT and 90,428 required BT in 2020. These figures are projected to increase by 38.2% and 38.4%, respectively, in 2030. The available treatment fractions were found to be 11,822,400 (EBRT) and 216,960 (BT). When the fractions are equated to radiation devices, the gaps are 17.4% (EBRT) and 66.7% (BT) in 2020. Hence, a projected increase from the baseline of 62.3% (EBRT) and 130.8% (BT) until 2030 will be needed to cover the growing demand.

Notably, a strong positive correlation was observed between average income level and device availability at both assessed time points for HIC and middle-income countries. A detailed description of the actual and projected RT unit requirements is provided in Table 4 and Fig. 1.

Financial dynamics

An estimated regional investment of US $349,650,479 (85.5% in EBRT) in 2020 would have resulted in an

Table 2 New cases requiring radiation therapy in 2020 and 2030

Country	Year	Breast	Prostate		CR	Cervical		Lung	Stomach	Thyroid	UC		H&N	NHL	Total		Increase (%)
		EBRT	EBRT	BT	EBRT	EBRT	BT	EBRT	EBRT	EBRT	EBRT	BT	EBRT	EBRT	EBRT	BT	
Brazil	2020	111415	95798	8258	24648	22859	20170	23316	4059	1008	6518	4631	19901	6647	316170	33059	39.6
	2030	155495	133700	11526	34400	31903	28150	32541	5665	1407	9097	6463	27774	9277	441259	46139	
Mexico	2020	44385	31558	2720	8200	13809	12184	5262	2158	418	3724	2646	2767	4706	116986	17550	40.8
	2030	62515	44448	3832	11550	19449	17161	7411	3040	588	5245	3726	3897	6628	164770	24719	
Argentina	2020	28082	11010	949	6806	6416	5661	6682	769	145	1305	927	2676	2046	65936	7537	21.5
	2030	34127	13380	1153	8272	7797	6879	8120	934	176	1586	1127	3252	2486	80129	9160	
Colombia	2020	20890	14697	1267	5160	6444	5686	4114	1759	185	1566	1113	2335	2600	59749	8066	42.3
	2030	29734	20919	1803	7344	9173	8094	5856	2503	264	2229	1584	3323	3701	85045	11481	
Peru	2020	10061	8472	730	2255	6222	5490	1828	1353	94	814	579	1122	1998	34220	6799	38.0
	2030	13886	11692	1008	3113	8587	7577	2523	1868	129	1124	799	1549	2757	47227	9383	
Venezuela	2020	12714	8213	708	2423	5366	4735	3547	522	48	1048	745	1578	976	36435	6187	46.3
	2030	18600	12016	1036	3544	7850	6927	5189	764	70	1533	1090	2309	1427	53304	9052	
Chile	2020	6077	6287	542	2282	1804	1591	1796	676	37	472	335	608	740	20778	2469	37.6
	2030	8365	8653	746	3142	2483	2191	2472	931	51	650	462	837	1018	28601	3398	
Ecuador	2020	5729	3653	315	1366	2399	2117	815	595	65	563	400	431	1030	16647	2832	42.0
	2030	8133	5186	447	1939	3407	3006	1157	845	92	800	568	612	1463	23634	4021	
Uruguay	2020	1922	1213	105	667	345	305	821	75	13	103	73	339	251	5750	483	14.1
	2030	2193	1384	119	761	394	348	937	86	15	117	83	387	286	6561	551	
Bolivia	2020	2530	2194	189	399	3631	3204	683	246	10	510	362	259	187	10650	3756	33.2
	2030	3370	2921	252	532	4836	4267	910	327	13	679	483	345	250	14183	5002	
Paraguay	2020	3753	2313	199	1066	1504	1327	1175	141	21	230	164	301	375	10878	1690	34.3
	2030	5041	3106	268	1431	2020	1782	1579	189	29	309	220	404	504	14611	2270	

Absolute number and proportional increase of patients requiring radiation therapy per country and regionally in 2020 and 2030.
Abbreviations: BT = brachytherapy; CR = colorectal cancer; EBRT = external beam radiation therapy; H&N = head and neck; NHL = non-Hodgkin lymphoma; UC = uterine corpus.

Table 3 Status and projected requirement of professionals in radiation oncology

	Radiation oncologists					Physicists					Radiation therapists				
Country	N	Year	R	Gap	%	N	Year	R	Gap	%	N	Year	R	Gap	%
Brazil	734	2020	1265	531	72	450	2020	739	289	64	2000	2020	2956	956	48
		2030	1765	1031	140		2030	1031	581	129		2030	4125	2125	106
Mexico	413	2020	468	55	13	180	2020	283	103	57	250	2020	1133	883	353
		2030	659	246	60		2030	399	219	122		2030	1596	1346	539
Argentina	192	2020	264	72	37	137	2020	157	20	15	380	2020	630	250	66
		2030	321	129	67		2030	191	54	40		2030	766	386	101
Colombia	132	2020	239	107	81	104	2020	142	38	37	309	2020	570	261	84
		2030	340	208	158		2030	203	99	95		2030	811	502	163
Peru	104	2020	137	33	32	40	2020	81	41	102	112	2020	324	212	189
		2030	189	85	82		2030	112	72	179		2030	447	335	299
Venezuela	246	2020	146	-	-	172	2020	86	-	-	411	2020	343	-	-16
		2030	213	-	-		2030	126	-	-		2030	502	91	22
Chile	98	2020	83	-	-	51	2020	50	-	-	143	2020	201	58	40
		2030	114	16	17		2030	69	18	35		2030	276	133	93
Ecuador	45	2020	67	22	48	22	2020	40	18	82	72	2020	160	88	122
		2030	95	50	110		2030	57	35	158		2030	227	155	215
Uruguay	23	2020	23	-	-	6	2020	14	8	125	70	2020	54	-	
		2030	26	3	14		2030	15	9	157		2030	62	-	-12
Bolivia	14	2020	43	29	204	9	2020	25	16	174	38	2020	99	61	160
		2030	57	43	305		2030	33	24	265		2030	131	93	246
Paraguay	9	2020	44	35	383	4	2020	26	22	552	15	2020	104	89	596
		2030	58	49	549		2030	35	31	776		2030	140	125	835
Total	1965	2020	2777	882	41	1175	2020	1644	556	40	3800	2020	6574	2858	73
		2030	3837	1860	95		2030	2271	1143	93		2030	9084	5292	139

Current availability of radiation oncologists, physicists, and radiation therapists. Qualified professional gaps are displayed in absolute and relative values for both 2020 and 2030 projections. Calculations were performed according to the IAEA recommendation: 1 radiation oncologist, physicist, and radiation therapist per 250, 400, and 100 new cancer cases, respectively.

Abbreviations: % = proportion of required personnel increase; Gap = absolute number of personnel deficit in 2020 and 2030; IAEA = International Atomic Energy Agency; N = absolute number of available professionals in 2020; R = 2020 and 2030 projected requirement of professionals.

additional 170,568 treated patients compared with the actually treated that year. If investment is only made in 2030 and after adjusting the TVM, US $872,889,949 (87.8% EBRT) will need to be spent to treat 399,610 additional patients, with each additional full RT course costing an average of US $2295. After taking into account all costs and assuming that 50% of patients reintegrate into the economically active population for at least 2 years, the expected 2-year posttreatment gross ROI from patients treated only in 2030 would be US $2,159,813,564. A detailed description of the investment and ROI per country can be found in Table 5.

The data file is located in Appendix E1. The variables can be adjusted to perform different analyses and assess various scenarios.

Discussion

This report addresses the current and projected gaps in human and logistic resources in RT that detrimentally affect achieving the UN's Agenda for Sustainable Development Goals related to the 10 most common cancers in Latam. Despite not explicitly being mentioned among the necessary means for fulfilling these objectives, RT is a vital element that must be strengthened to diminish the rate of premature mortality from noncommunicable diseases by one-third. In contrast, the updated World Health Organization recommendations for prioritizing cost-effective interventions against cancer, which were formulated during the 2017 World Health Assembly, include RT and its related resources under a main scope of interest. However, as previously

Table 4 Available and projected utilization and requirement of EBRT and BT units

Country	Year	n = EBRT	n = BT	Available EBRT Fx	Available BT Fx	Required EBRT Fx	Required BT Fx	Gap EBRT units	Gap BT units	Required + EBRT (%)	Required + BT (%)
Brazil	2020	295,558	31,984	3,916,800	95,040	6,323,406	132,237	167	39	61	39
	2030	412,492	44,637			8,825,179	184,555	341	93	125	94
Mexico	2020	113,340	16,901	2,145,600	28,800	2,339,717	70,201	13	43	9	144
	2030	159,635	23,804			3,295,409	98,876	80	73	54	243
Argentina	2020	62,996	7235	1,699,200	19,200	1,318,713	30,149	0	11	0	57
	2030	76,557	8793			1,602,577	36,639	0	18	0	91
Colombia	2020	56,997	7763	1,022,400	28,800	1,194,985	32,264	12	4	17	12
	2030	81,129	11,049			1,700,908	45,923	47	18	66	59
Peru	2020	32,397	6506	460,800	10,560	684,390	27,195	16	17	49	158
	2030	44,712	8979			944,533	37,532	34	28	105	255
Venezuela	2020	34,341	5935	1,224,000	9600	728,694	24,750	0	16	0	158
	2030	50,241	8683			1,066,078	36,209	0	28	0	277
Chile	2020	20,062	2384	648,000	9600	415,567	9875	0	0	0	0
	2030	27,614	3281			572,013	13,593	0	4	0	42
Ecuador	2020	15,996	2719	331,200	3840	332,935	11,329	0	8	0	195
	2030	22,710	3861			472,672	16,084	10	13	43	319
Uruguay	2020	5411	466	187,200	1920	114,998	1930	0	0	0	0
	2030	6174	532			131,226	2203	0	0	0	15
Bolivia	2020	9865	3585	115,200	3840	212,998	15,023	7	12	85	291
	2030	13,138	4774			283,664	20,007	12	17	146	421
Paraguay	2020	10,436	1619	72,000	5760	217,556	6759	10	1	202	17
	2030	14018	2175			292220	9078	15	3	306	58

The number of available treatment fractions of EBRT and BT in 2020 were calculated according to the existing units in each country. Calculations based on the number of new cases per country requiring either EBRT or BT were performed to obtain the needed 2020 and 2030 fractions. Gap results are expressed in absolute numbers, and recommended increases are in percentages for both delivery modalities.

Abbreviations: BT = brachytherapy; EBRT = external beam radiation therapy; Fx = fractions; n = number of patients requiring EBRT and BT.

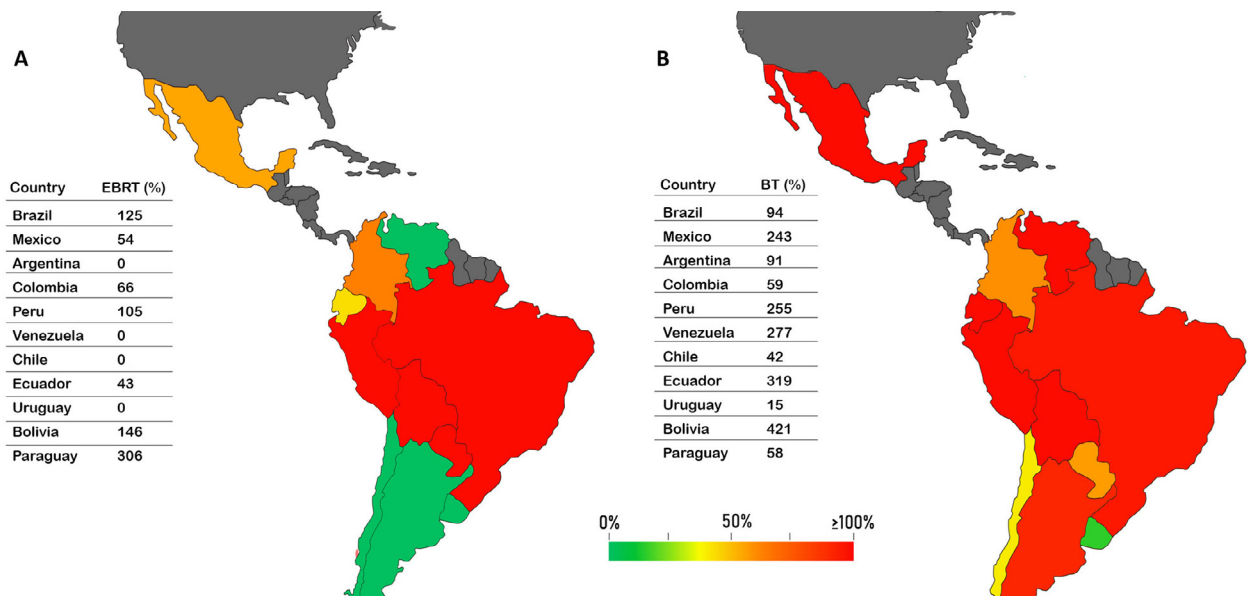

Fig. 1. Projected requirements for external beam radiation therapy (A) and brachytherapy (B) devices in 2030 per country. The increase in the requirement is displayed using a color scale denoting 0% to ≥100% from the baseline (existing devices).

Table 5 Required investment and expected 2-year financial balance

Country	Year	Value EBRT needed (US$)	Value BT needed (US$)	Additionally rescued patients	RT cost per additionally treated patient	Final 2-y balance (US$)
Brazil	2020	221,913,151	13,030,177	60,165	1952	604,929,328
	2030	485,300,624	33,622,595	122,709	2114	1,322,916,553
Mexico	2020	17,899,518	14,502,877	4853	3338	48,793,608
	2030	113,683,797	26,321,138	28,745	2435	309,898,998
Argentina	2020	-	3,835,504	1369	1401	14,973,686
	2030	-	6,550,251	2180	1502	25,571,972
Colombia	2020	15,914,020	1,213,376	4315	1985	43,381,193
	2030	67,085,383	6,431,701	16,963	2167	182,872,964
Peru	2020	20,617,235	5,827,303	5590	2365	56,202,033
	2030	47,827,618	10,131,024	12093	2396	130,376,810
Venezuela	2020	-	5,306,872	1894	1401	20,717,860
	2030	-	9,994,367	3326	1502	39,017,691
Chile	2020	-	96,484	34	1389	376,671
	2030	-	1,499,870	499	1503	5,855,446
Ecuador	2020	159,996	2,623,383	936	1487	436,145
	2030	13,987,644	4,598,899	3537	2627	38,129,944
Uruguay	2020	-	3553	1	1777	13,869
	2030	-	106,110	35	1516	414,251
Bolivia	2020	9,017,930	3,917,470	2445	2645	24,582,636
	2030	16,656,324	6,072,609	4212	2698	45,404,695
Paraguay	2020	13,421,756	349,874	3639	1892	36,587,348
	2030	21,773,595	1,246,401	5506	2090	59,354,239
Total	2020	349,650,480	50,706,875	85,284	2222	850,994,378
	2030	872,889,949	106,574,965	190,142	2295	2,159,813,564

Total value of additional EBRT and BT required for 2020 and 2030. The number of rescued patients is assumed after a 50% success rate of the global additionally treated patients. The financial balance is calculated after a 2-year working period and an average US $572.62 income.

Abbreviations: BT = brachytherapy; EBRT = external beam radiation therapy; RT = radiation therapy; US$ = United States dollars.

reported, developing countries might be facing a greater challenge. Socioeconomic inequities and insufficient health funding in Latam have resulted in the emergence of overwhelmed, underequipped, and understaffed facilities across the region. As developed countries continue to thrive in terms of RT technological development, only a few exceptions in Latam have managed to keep pace.[13]

This study was performed to provide updated information on the status of RT services and access across the region and to estimate the current and projected health care costs if needs are not met. In addition to the IAEA's Directory of Radiotherapy Centers, firsthand comprehensive data were obtained from regional societies, key opinion leaders, and manufacturers, allowing an accurate assessment of the actual situation in Latam. This study is also unique because its calculations are based on numbers of newly diagnosed cases instead of a population-based approach. This improves the quality of predictions as they are based on real-world situations and demands.

To close the existing supply−demand gap, a substantial increase in both public and private investment in RT is required. If the existing gap is not closed, the current disparities in health care access will relentlessly increase and prevent achievement of the UN's proposed 2030 goal. Furthermore, any delay in action will inevitably result in more deaths and higher economic costs over time.

The estimate of the investment required to scale up RT services in the 11 analyzed countries (US $873 million) aligns with those calculated in previous studies for the entire region.[13] This investment in RT services could help save additional patients who could potentially be reintroduced into the national workforce and deliver a financial surplus of over US $2.1 billion in 2030 alone. Hence, sustainability is a key outcome of adopting these measures. Other groups have presented comparable results using similar methodologies, in terms of additional saved patients and a 2-year ROI.[4,14] Although it should be noted that our calculations were based on an estimated average wage, simulating the

real-world situation, it must also be noted that the high rates of informal labor in Latam might limit any precise analysis and modeling. If gross domestic product per capita calculations were to be applied, the actual financial return would be substantially higher in most of the assessed countries. It is also relevant to remark that, based on the TVM concept, it is more worthwhile to invest today than in the future. As such, health care expenditure should be viewed as an investment opportunity that may generate mid- and long-term interest. Nevertheless, these calculations should be considered preliminary, as detailed per-country assessments are required to establish actual ROIs. Furthermore, urgent unmet population needs must be addressed, regardless of the financial implications.

The case of Uruguay is particularly noteworthy. Its present-day available technology might cover the projected demand for the next 10 years. Chile is following closely behind; if it can hold its current momentum, it could progressively reach the desired BT coverage in 2030. Most of the other countries must increase the number of BT units, and some must renew older teletherapy units (Co^{60}) and address human resources disparities. Another relevant point worth addressing is the migration from conventional fractionation to hypofractionation or extreme hypofractionation techniques, which might help increase the number of patients treated per machine per year by 30%.[17,25] Additionally, an uneven distribution of devices—they are mostly located in urban areas—could be masking the real needs of the rural population.

Several areas of concern were identified in our study. First, there is a shortage of specialized personnel. It has been observed that there is relatively low interest in the RT field in academic terms, and this is not only affecting RT services in Latam but also worldwide. Recent studies have found that medical students in the US are less interested in RT and that this has led to unfilled radiation oncology residency positions, which has resulted in encouraging new graduates with other primary interests to fill these positions.[28,29] The shortage and the imbalance in the distribution of human resources may also be attributed to the uneven (centralized) distribution of RT centers and secondary facilities being located in unappealing areas, which is a common scenario in LMICs.[30,31] It is likely that similar situations are occurring in the MP and radiation technologist academic fields. A possible solution could involve integrating RT-related curricula into undergraduate programs with the aim of increasing interest in RT.

Another area of concern identified in this study is the neglect of the needs of native and ethnic minorities. This neglect is not restricted to their oncology-related needs but spans all their medical needs. Contributing factors include challenging geography and political inattention. For example, in Peru, approximately two-thirds of all units are in Lima, the capital city, where one-third of the population resides, and patients from outside the city must travel long distances to access an RT facility.[32] In a system where about 85% should be granted coverage by the public health care system, approximately 33% of the available technology belongs to private stakeholders. Those mostly affected are usually members of Amazonian native communities. With over 1- or 2-day long traveling times, reaching the nearest oncology facility might be virtually impossible.[33] Literacy in health and socioeconomic status play additional roles against their welfare.[32,34] The situation of rural Andean inhabitants is not much better, based on the same factors previously mentioned. Similar circumstances have been reported in other Latam countries, such as Brazil.[17,33] The latter, with over 70% of the population depending on a public insurance, has experienced a 17% increase in their RT units, in contrast to the 32% increase of cancer cases during the last 10 years.[35] This mostly affects individuals of African descent and the native population, who are more exposed to social determinants of health in both rural and urban areas.[36,37] The addition of several other factors, including geographic, gender, and socioeconomic condition, contribute to worse oncologic outcomes. For instance, those patients living in northern and northwestern Brazil report worse outcomes in cervical cancer, with about 2.5 higher mortality rates in comparison to those receiving treatment in Sao Paulo.[38] Long travel distances and racial characteristics just raise the hurdle, not only in RT, but in oncology as well.[39,40] Even in the main urban areas, structural violence contributes to inequality in breast cancer treatment.[41] A repeated pattern of inequity and lack of inclusion is visible across the region because of political and economic reasons, affecting mostly those belonging to ethnic minorities of less-favored social groups.[42-44] To begin addressing the issues, inclusion and equity strategies should be developed and implemented to decentralize RT access.

BT use has been declining over the last couple of decades, despite being a cost-effective alternative to radical and adjuvant treatments for a variety of entities. This decline raises serious concerns, mostly because BT is an important treatment modality for cervical and endometrial cancer, which are main indications for BT in Latam.[45,46] In fact, BT units are the most scarce resource, across both human and technological resources for RT, in Latam.[47] The fraction-based reimbursement model has also been detrimental to the use of BT.[48] Interestingly, according to our results, designating about 17% of the total investment to BT could enhance its availability, and, as implied previously, this could have a considerable effect on women in terms of BT-related rescued lives. Therefore, investing in BT is also an investment in equity in access to cancer care. Moreover, there is a correlation between human development and cervical cancer incidence; thus, the incidence reflects inequalities in a determinate territory. Even in thriving macroeconomies, a high rate of cervical cancer is a sign of an uneven distribution of resources, which is also linked to higher mortality rates, gender inequities, and overall low health expenditure.[49,50]

This study includes important limitations. Although the 11 evaluated countries comprise roughly 85% of Latam's population and socioeconomic similarities may exist regionally, the results cannot necessarily be generalized to a subregion or country level, such as Central American and Caribbean

countries.[51,52] Heterogeneity across the region, in terms of income and logistic capacities, does not allow a general regional assessment or recommendation; therefore, each individual country should be evaluated according to its own characteristics. Furthermore, this analysis simulated a financial return after investment in RT and assumed a certain ratio of therapeutic success; however, the latter must not be interpreted as a factor related only to RT, but as the result of a multidisciplinary approach. A larger analysis that includes other treatment modalities, such as that by Hanna et al,[53] is warranted to accurately attribute the individual weight that each has on the financial return. In addition, we included elements from both private and public practices, which might not be representative of real health care access in some countries. The centralized distribution of many facilities in capital or larger cities impairs the interpretation of the actual need in subnational or rural areas.[54] Furthermore, this study did not collect the functional status of RT units because of logistical complexity, which may have resulted in an overestimation of current RT resources when the total RT-unit distribution was determined. For instance, in the case of Venezuela, according to local sources, approximately 70% of the units detailed in this report are currently inoperative, which is consistent with the scarce literature available on this topic.[55] Lastly, our analysis includes only the 10 most common malignancies treated with irradiation, thus underestimates the actual RT needs for treating all malignancies.

Despite these limitations, the findings of this report raise awareness of the relevance of RT at a regional level and provide critical evidence for investing in RT over the next 10 years. Even with our conservative estimations, the findings indicate that there would be a considerable positive gross ROI for the entire region. This report should be interpreted as a benchmark model for future deeper analyses, adjusted to each country's characteristics.

Plans are in place to deliver in-depth reports with support from the IAEA to local governmental actors soon to tackle distinct scenarios in each country in Latam. National and international scientific societies could play a fundamental role in this process, augmenting visibility to local authorities. New collaborations between public and private stakeholders remain to be explored and could help close the gap in RT access in areas where no public coverage is available. Local analyses are required to identify the needs of underserved populations. Given that mostly rural and native populations lack access to timely and quality health care in Latam, considering and promoting equity and inclusion in implementation strategies is mandatory. Some tools, such as the American Society for Clinical Oncology statement on this matter, could be referenced and replicated in Latam to address the shortcomings.[56] As per their recommendations, ensuring equitable access to high-quality care and research, addressing structural barriers (workforce diversity, community partnership, and institutional discrimination), increasing awareness, and taking action are of utmost importance when seeking to fulfill these objectives in the short and long term. Furthermore, the role of artificial intelligence and telemedicine in RT services has not yet been defined; they could potentially be used to facilitate communication and to interconnect all providers and distant communities, helping to reduce these gaps.

Conclusions

In Latam, investment in RT treatment modalities is required to close the supply−demand gap and to ensure that societal needs are met. Currently, large proportions of the population, mostly native or ethnic minorities, are excluded from health care, and their medical needs are unattended. Inclusion and equity strategies should be integrated to deliver high-quality health care to those who are underserved. An accelerated investment in the region is necessary to treat patients and save additional lives during the next decade, with a decentralized approach to the distribution of RT services. Investing in RT could translate into social benefits and be economically self-sustaining. Cash flow analyses are warranted to tailor precise national-level intervention strategies.

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