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Original Article

Radiotherapy prioritization in 143 national cancer control plans: Correlation with radiotherapy machine availability, geography and income level

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ABSTRACT

Background: In 2015, the Global Task Force on Radiotherapy for Cancer Control (GTFRCC) called for 80% of National Cancer Control Plans (NCCP) to include radiotherapy by 2020. As part of the ongoing ESTRO Global Impact of Radiotherapy in Oncology (GIRO) project, we assessed whether inclusion of radiotherapy in NCCPs correlates with radiotherapy machine availability, national income, and geographic region.
Methods: A previously validated checklist was used to determine whether radiotherapy was included in each country's NCCP. We applied the CCORE optimal radiotherapy utilisation model to the GLOBOCAN 2020 data to estimate the demand for radiotherapy and compared this to the International Atomic Energy Agency (IAEA) Directory of Radiotherapy Centres (DIRAC) supply data, stratifying by income level and world region. World regions were defined according to the IAEA.
Findings: Complete data (including GLOBOCAN 2020, DIRAC and NCCP) was available for 143 countries. Over half (55%, n = 79) included a radiotherapy-specific checklist item within the plan. Countries which included radiotherapy services planning in their NCCP had a higher median number of machines (1.68 vs 0.75 machines/1000 patients needing radiotherapy, $p < 0.001$). There was significant regional and income-level heterogeneity in the inclusion of radiotherapy-related items in NCCPs. Low-income and Asia-Pacific countries were least likely to include radiation oncology services planning in their NCCP ($p = 0.06$ and $p = 0.003$, respectively). Few countries in the Asia-Pacific (18.6%) had a plan to develop or maintain radiation services, compared to 57% of countries in Europe.
Interpretation: Only 55% of current NCCPs included any information regarding radiotherapy, below the GTFRCC's target of 80%. Prioritisation of radiotherapy in NCCPs was correlated with radiotherapy machine availability. There was regional and income-level heterogeneity regarding the inclusion of specific radiotherapy checklist items in the NCCPs. Ongoing efforts are needed to promote the inclusion of radiotherapy in future iterations of NCCPs in order to improve global access to radiation treatment.
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Cancer is a leading cause of death and disability worldwide [1]. It is anticipated that there will be more than 30 million cases of cancer diagnosed in 2040 with the number of deaths per year projected to rise to 16.3 million [2]. Effective cancer control programmes have been shown to improve population outcomes by

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implementing evidence based practices within available resources and financial capabilities [3,4].

In 2017, the 70th World Health Assembly supported a resolution recommending that countries develop National Cancer Control Plans (NCCPs) to improve global cancer control [5]. NCCPs are government documents that outline a country's national cancer program and that set strategic goals to support its implementation [6,7]. The development, implementation, financing and evaluation of NCCPs is a fundamental component of cancer control [8]. Since this World Health Assembly resolution was adopted in 2017, significant efforts have been directed to analysing existing country plans [7,9]. A checklist was previously developed to evaluate and critically appraise the core components of NCCPs [7]. However, there has been little research examining radiotherapy specific components of NCCPs.

Radiotherapy is a critical treatment modality for the management of cancer, but there are significant global inequities in access [10]. In 2015, the Global Task Force on Radiotherapy for Cancer Control (GTFRCC) was convened, bringing together radiotherapy professionals, industry partners, patient groups, economists, and cancer control agencies to quantify the gap in radiotherapy and to develop strategies to close the gap by 2035. The GTFRCC issued a call to action to promote the inclusion of radiotherapy in 80% of NCCPs by 2020 [11]. A previous global analysis found that the number of radiotherapy machines acquired by a country increased after the implementation of an NCD (Non-Communicable Disease) Plan or NCCP. However, this increase was independent of the inclusion of radiotherapy within the NCCP [9]. It remains unknown if specific components of radiotherapy provision and planning within an NCCP correlate with radiotherapy machine availability. Better understanding of these correlations between income groups and regions will inform the work of international and regional agencies supporting the development and expansion of radiotherapy access globally.

The ESTRO Global Impact of Radiotherapy in Oncology (GIRO) project uses a data-driven approach to pursue the optimal uptake of radiotherapy worldwide. The objectives of this GIRO study were to determine: i) whether NCCPs included radiotherapy specific planning items; and ii) whether the inclusion of radiotherapy specific planning items in the NCCP correlates with radiotherapy machine availability. We then examined the association between the radiotherapy items in the NCCP and income level and geographic region.

Methods

Checklist items

The methods used to develop an NCCP quality checklist have been described previously [7]. For this study, an expert panel reviewed all 111 checklist items from the NCCP quality tool and selected 14 items pertaining to radiotherapy and its provision (Table 1). Five questions pertained directly to radiotherapy services, one item related to care coordination, a core element of high quality cancer care [12], one item related to workforce, an essential part of a radiotherapy service, and two items related to guidelines [13]. Two questions related to governance and three related to finances and costs. These final items were included given the importance of ministry approval and investments in establishing a sustainable radiotherapy service.

NCCP document evaluation

The data on the inclusion of these checklist items within the NCCP or Non-communicable disease (NCD) Plan of each member state was obtained from a larger global analysis performed in 2018 [9], combined with additional data for countries which developed or updated NCCPs between 2018 and December 2020. For three countries, an alternative cancer care document was available for review (Uganda, Iceland and Democratic Republic of Congo) from which service planning information was drawn. For the remainder of this paper, we refer to alternative cancer care documents, NCCPs and NCDs collectively as NCCPs. Responses to each checklist item were categorised as either Yes (signifying checklist item was included in NCCP) or No/No consensus (signifying checklist item was not included in NCCP or unable to reach consensus whether checklist item was included).

Radiotherapy demand and availability

Based on the most recent GLOBOCAN estimates from the International Agency for Research on Cancer (IARC) [1], we extracted the number of new cancer cases in 2020, stratified by cancer type for 185 countries and territories. One region (Micronesia) was included in the country data, as an NCCP for this small group of island nations was available. Guam, the only country within Micronesia for which country-level data was available, was therefore excluded. We used previously published estimates of optimal radiotherapy utilisation and machine needs [14], estimated as 409 new patients/machine/year for low income (LIC), lower-middle income (L-MIC), upper-middle income (U-MIC) and 288 for high income countries (HIC). We then estimated the number of patients requiring radiotherapy in 2020 by tumour type for each country, and the optimal number of machines (Cobalt and MV Linac) needed to meet these demands (calculated as [Number of patients with indication for radiotherapy per year / 409] for LMICs and [Number of patients with indication for radiotherapy per year / 288] for high income countries). The estimated demand for radiotherapy machines was then compared with the current number of available radiotherapy centres and radiotherapy machines (Cobalt and MV Linac) per country, as sourced from DIRAC in February 2020 [15]. For any country where DIRAC data was not provided, we assumed machine availability was zero. Finally, for each member state, we calculated the number of available radiotherapy machines per 1000 patients needing radiotherapy as [(Number of available Machines)]/(number of patients with indication for radiotherapy)]*1000.

Geographical location and income level

Using established World Bank classifications for income levels from 2020, all members states were categorised as LIC, L-MIC, U-MIC and HIC [16]. Territories and overseas departments without an income classification (eg. La Reunion) were assigned the income group of their associated country. Member states were categorised into one of five geographical regions (Africa, North America, Latin America and Caribbean, Europe, and Asia-Pacific) in keeping with the regional definitions used by the IAEA Technical Cooperation Department. As only one country in North America had a unified NCCP, this region was excluded from statistical comparisons. The USA has state and territory based NCCPs which are the subject of ongoing research but were excluded from this current study.

Statistical analysis

We correlated responses to the 14 NCCP checklist items with radiotherapy machine availability per 1000 patients needing radiotherapy. We also examined whether countries had included any of the five radiotherapy specific items in the NCCP and correlated this with radiotherapy machine availability per 1000 patients needing radiotherapy. We then examined the responses to the 14 checklist items, stratified by country income level and geographic location.

Table 1
Checklist items pertaining to radiotherapy machines, planning and provision within NCCP checklist, finances, workforce, and governance.

Radiotherapy Planning Questions
1. Does the NCCP acknowledge device and machine needs and maintenance?
2. Is there any strategy/mechanism for review of new technology and mechanisms for purchasing and procurement?
3. Is there any radiation oncology service planned or in place?
4. Is there any assessment of radiation oncology machines and safety?
5. Is there any plan to develop/maintain radiation oncology service?
Care Coordination
1. Is there any coordination between centres or coordination of care for individuals?
Workforce Planning Questions
1. Is there any health workforce strategy or plan linked to general workforce?
Financial Planning Questions
1. Are financial resources for NCCP activities specified?
2. Are costs mentioned?
3. Is there a breakdown of resources or tracking of health accounts versus total cancer expenditure?
Governance and Guideline Questions
1. Endorsement of the plan approved by the Ministry of Health and other government?
2. Is there a reference to cancer treatment guidelines/protocols?
3. Are there national guidelines for specified cancers or plans to develop them?
4. Are there cancer targets and indicators stated?

Categorical data were compared using a Chi squared test. Continuous data with 2 groups were compared using a Student's t-test for parametric data and using Mann-Whitney U for non-parametric data. Where indicated, log transformation was used to normalise the data prior to statistical comparisons, using half-integer correction for zero-inflated data. A test for linear trend was used to examine the association between the ordinal variable income group and the mean number of radiotherapy related items included in the NCCP. All analyses were performed using STATA version 12.0 (StataCorps LP, College Station, TX, USA). Statistical significance was defined as $p < 0.05$.

Missing data

Only countries with complete data from GLOBOCAN, DIRAC and NCCP were included in our final analysis.

Results

Complete GLOBOCAN, DIRAC and NCCP data was available for 143 countries. Countries with incomplete data across any of these three databases were excluded, as indicated in Supplemental Table 1. Among the 143 included countries, 55.2% (n = 79) included information for at least one of the five radiotherapy related questions. The number of radiotherapy related items included in the NCCP for each individual country is illustrated in Fig. 1. Based on the available data, over 2.5 billion people reside in countries with either no NCCP or where radiotherapy is not mentioned within the existing NCCP.

Countries in which the NCCP acknowledged device/machinery needs and maintenance had a higher median number of machines per 1000 patients with an indication for radiotherapy in 2020 (1.48 vs 1.02 machines/1000 patients needing radiotherapy, $p = 0.02$). Countries that discussed radiation oncology services planned or in place within their NCCP also had a higher median number of machines per 1000 patients with an indication for radiotherapy in 2020 (1.68 vs 0.75 machines/1000 patients needing radiotherapy, $p < 0.001$). Countries that included at least one of the five radiotherapy related questions in their NCCP had higher machine availability (median 1.61 vs 0.71 machines/1000 patients needing radiotherapy, $p < 0.001$). Countries which included national guidelines or cancer specific guidelines in their NCCP also had higher machine availability (1.61 vs 0.53 machines/1000 patients needing radiotherapy, $p<=0.001$, 1.45 vs 0.64 $p = 0.007$). Finally, countries that acknowledged coordination between centres or coordination of care for individuals also had higher machine availability (1.69 vs 0.75 machines/1000 patients needing radiotherapy, $p < 0.001$). In contrast, there were no associations between machine availability and questions regarding workforce, financial planning, or governance (Table 1).

The proportion of countries with an NCCP differed by income group, with 58.6% of HICs having an NCCP as compared to only 25.7% of LICs ($p = 0.02$). (Table 2). There was no linear association between the mean number of reported radiotherapy related items and increasing country income level ($p = 0.31$ for test for linear trend) (Table 2). HICs were more likely to include a strategy for review of new technology (25%) than LICs (4%) ($p = 0.05$) (Table 2). HICs were also more likely to include coordination of care between centres in their NCCP (59.1%), compared to LICs (20%) ($p = 0.017$). HIC and L-MICs were more likely to have a clear health workforce strategy or plan linked to the general workforce within their cancer care plans (56.8% of HICs, 74.3% of L-MICs, 44% of LIC and 33.3% of U-MIC, $p = 0.004$). Most cancer plans were endorsed or approved by the Ministry of Health or other government organizations, regardless of income group (range 94.9–97.1%). However, cancer plans in HICs were more likely to reference cancer treatment guidelines or protocols (70.4% in HICs vs 28% in LICs, $p = 0.007$). (Table 2).

The proportion of countries with an NCCP varied by geographic location, with 80% of countries in Europe having an NCCP as compared to only 38.6% of countries in Asia-Pacific, 40.6% of countries in Latin America, and 40.7% of countries in Africa ($p < 0.001$). (Table 3) (see Table 4).

There were several differences between provisions for radiotherapy planning in NCCP when stratified by geographic region (Table 3). Countries in Europe were more likely to include device and machinery needs and maintenance in their NCCPs (59.5%) as compared to other regions ($p = 0.023$). A higher proportion of countries in Europe (70.3%) included radiation oncology services planned or in place in their NCCPs, as compared to Asia-Pacific (27.9%), African (52.5%) and Latin American countries (54.6%) ($p = 0.002$). The proportion of countries with a plan to develop or maintain radiation services ranged from only 18.6% in countries in the Asia-Pacific, to 56.8% of countries in Europe ($p = 0.004$). Approximately 76% of European countries included at least one radiotherapy related item in their NCCP, as compared to only 34.9% of countries in Asia-Pacific, 55% in Africa, and 63.4% in Latin America (Table 2). European countries were also more likely to describe coordination between centres or coordination of care for individuals in their NCCP (75.7%) compared to countries from Asia-Pacific (27.9%) or Latin America (22.7%) ($p < 0.001$). The mean number of radiotherapy related questions included in the NCCP was highest in Europe (2.4) and lowest in the Asia-Pacific region (0.88) ($p < 0.0001$) (Table 2).

The proportion of countries with a clear health workforce strategy or plan linked to the general workforce within their cancer care plans was similar in all geographic regions. NCCP from Africa (55%) were most likely to reference costs, as compared to Europe (43%), Asia-Pacific (30.2%) and Latin America (27.3%), although this finding was not statistically significant ($p = 0.07$). Most cancer plans were endorsed or approved by the Ministry of Health or other government organizations, regardless of geographic location (range 93% to 100%). However, cancer plans in Europe (73%) and Latin America (77.3%) were more likely to reference cancer treatment guidelines or protocols compared to Africa (45%) or Asia-Pacific

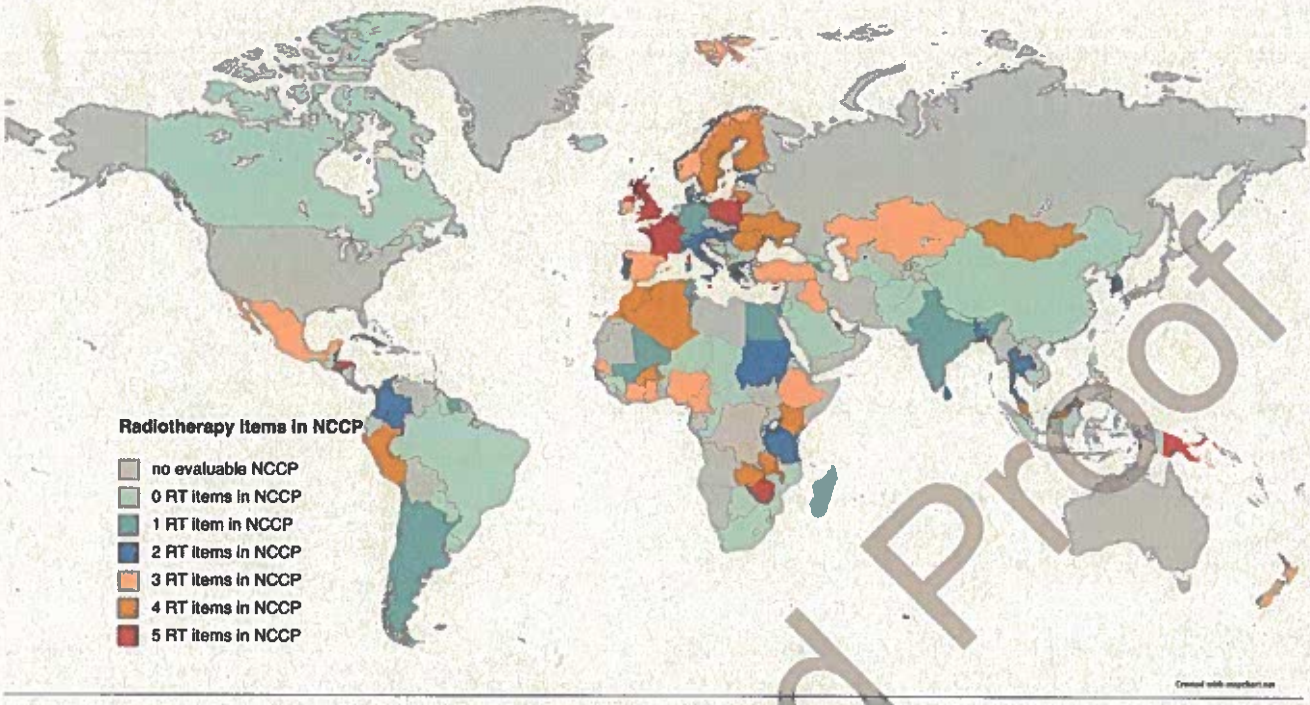

Fig. 1. World map indicating the number of RT related items among countries with evaluable NCCPs.

(46.5%) ($p = 0.008$). Countries in Europe and Latin America were also most likely to mention national guidelines ($p = 0.017$) (Table 2).

Discussion

Radiotherapy is an essential component of any cancer care plan [7], as recognised by the IAEA and the WHO [17]. However, we found that only 55% of all evaluable NCCPs included any provisions for radiotherapy planning, below the target of 80% by 2020 set by the GTFRCC [11]. Moreover, over 2.5 billion people reside in countries with no unified NCCP, or where the existing NCCP does not include radiotherapy.

In this study, we demonstrate a strong correlation between the prioritisation of radiotherapy service planning and machine maintenance in a country's NCCP and the availability of radiotherapy machines to meet demand. While these results do not imply causality, they nonetheless highlight the importance of including radiotherapy planning in NCCPs as a key commitment by governments and stakeholders to develop and expand access to a cost-effective and life-saving treatment [11,18]. Our findings enhance prior efforts to demonstrate the importance of NCCPs in building radiotherapy capacity. Romero et al (2018) demonstrated that the number of radiotherapy units acquired annually by countries increased significantly after implementation of an NCCP [9]. However, this prior analysis also found a similar magnitude of increase in new radiotherapy units acquired in countries where radiotherapy was not mentioned in the NCCP, making it difficult to attribute the increase in units to the inclusion of radiotherapy within the NCCP. Moreover, as radiotherapy demand was not modelled in this prior analysis, it was unclear whether the increase in radiotherapy units related only to population growth, or whether there were real improvements in radiotherapy supply.

This is the first study to examine the inclusion of radiotherapy in NCCPs, stratified by geographic region. We found geographical differences in radiotherapy checklist item inclusion, with Europe having the highest proportion of plans including radiotherapy-specific items and the Asia-Pacific having the lowest, followed by Africa. Prior work has identified Asia-Pacific and Africa as having the greatest challenges with regards to radiotherapy infrastructure and investments [19]. Therefore, these are the regions where radiotherapy should be prioritised during future NCCP development. International and regional organisations such as the IAEA, the International Cancer Control Partnership (ICCP), Federation of Asian Organizations for Radiation Oncology (FARO) and the African Organisation for Research and Training in Cancer (AORTIC) have vital roles to play in ensuring the inclusion of radiotherapy related services and planning in NCCPs. The IAEA's Rays of Hope Initiative is an example of a regional program supporting the establishment and expansion of radiotherapy services to improve access to care for patients globally [20].

Our results also confirm differences in the availability and quality of NCCPs when stratified by country income level. The low proportion of LICs acknowledging radiotherapy in their NCCPs is incongruent with their radiotherapy needs. The gap in radiotherapy supply and demand has widened over a decade in LIC, and 65% of LICs have no radiotherapy available in their country [10]. However, for most individual radiotherapy checklist items, inclusion in NCCPs was poor regardless of income groups. For example, the strategy of reviewing new technology ranged from 4% in LICs to 25% in HICs, while the assessment of radiotherapy safety was included in between 14% to 20% of NCCPs, showing little variability between income groups. While there is an urgent need to expand radiation services globally, it is paramount that radiotherapy is safe and sustainable, and these fundamental elements should be featured within NCCPs.

Countries with existing radiotherapy services may not necessarily be prioritising radiotherapy within their NCCPs, limiting the current analysis. For example, only 64% of HICs included the NCCP checklist item "radiotherapy service planned or in place", a result that is much lower than the 92% of HIC which had radiotherapy services available in 2013 [8]. This suggests that while some

Table 2
Association between Median number of Available Machines per 1000 patients with indication for radiotherapy in 2020 and NCCP questions regarding Radiotherapy (n = 143).

	Median number of Machines per 1000 patients needing radiotherapy in 2020	P value*
Radiotherapy Planning Questions		
1. Does the NCCP acknowledge device/machinery needs and maintenance		**0.02**
Yes (n = 55)	1.48	
No/No consensus (n = 88)	(0–3.35)1.02 (0–4.48)	
2. Is there any strategy/mechanism for review of new technology and mechanisms for purchasing and procurement?		0.27
Yes (n = 21)	1.57 (0–2.85)1.20	
No/No consensus (n = 122)	(0–4.49)	
3. Is there any radiation oncology services planned or in place?	1.68	**<0.001**
Yes (n = 71)	(0–4.48)0.75	
No/No consensus (n = 72)	(0–4.09)	
4. Is there any assessment of radiation oncology machines and safety?		0.21
Yes (n = 23)	1.39	
No/No consensus (n = 120)	(0–2.9)1.22 (0–4.48)	
5. Is there any plan to develop/maintain radiation oncology services?	1.37	0.19
Yes (n = 54)	(0–2.9)1.21	
No/No consensus (n = 89)	(0–4.48)	
6. Any of the above radiotherapy related checklist items included in the NCCP?	1.61	**<0.001**
Yes (n = 79)No (n = 64)	(0–4.48)0.71 (0–4.09)	
Centre Coordination		
6. Is there any coordination between centres or coordination of care for individuals?		**<0.001**
Yes (n = 61)	1.69	
No/No consensus (n = 82)	(0–4.48)0.75 (0–4.09)	
Workforce Planning Questions		
1- Is there any health workforce strategy or plan linked to general workforce?		0.82
Yes (n = 75)	1.24	
No/No consensus (n = 68)	(0–4.48)1.33 (0–3.99)	
Financial Questions		
1. Are financial resources for NCCP activities specified?	1.20	0.49
Yes (n = 74)	(0–4.48)1.40	
No/No consensus (n = 69)	(0–4.09)	
2. Are costs mentioned?	1.18	0.45
Yes (n = 57)	(0–4.48)1.31	
No/No consensus (n = 86)	(0–4.09)	
3. Is there a breakdown of resources or tracking of health accounts versus total cancer expenditure?		0.38
Yes (n = 2)	1.85	
No/No consensus (141)	(1.23–2.45)1.27 (0–4.48)	
Governance and Guideline Questions		
1 – Endorsement of the plan approved by the Ministry of Health and other government		0.87
Yes (n = 137)	1.28	
No/No consensus (n = 6)	(0–4.48)1.23 (0–3.99)	
2 – Is there a reference to cancer treatment guidelines/ protocols?	1.45	**0.007**
Yes (n = 82)	(0–4.48)0.64	
No/No consensus (n = 61)	(0–4.09)	
3 – Are there national guidelines for specified cancers of plans to develop them?		**0.001**
Yes (n = 64)	1.61	
No/No consensus (n = 79)	(0–4.48)0.53 (0–4.09)	
4 – Are there cancer targets and indicators stated	1.27	0.77
Yes (n = 105)	(0–4.09)1.25	
No/No consensus (n = 38)	(0–4.48)	

* Mann-Whitney U for non-parametric data, and Student's t-test use for parametric data.

countries may have radiotherapy services available, the prioritisation of radiotherapy has not necessarily been specified their NCCP. This could limit future maintenance and expansion of radiotherapy service in these countries.

Workforce planning is another essential component for cancer care delivery and is integral to expanding radiotherapy services globally. In this analysis, we did not identify any associations between workforce planning and machine availability. However, HICs and L-MICs were more likely to have a clear health workforce strategy or plan linked to the general workforce within their NCCP. Prior modelling studies have estimated the workforce needed to deliver optimal radiotherapy [11]. The radiation oncology workforce is highly specialised and includes radiation oncologists, medical physicists, radiation therapists, engineers, and information technology specialists. Training the necessary personnel takes many years and requires significant time investment in addition to financial costs. Several international organizations such as the European Society for Radiotherapy and Oncology (ESTRO) have

Table 3
Association between income level and radiotherapy and cancer service planning in NCCPs.

	Low Income	Low-middle Income	Upper Middle Income	High Income	P value
NCCP Data (n = 185)	**N = 35**	**N = 44**	**N = 48**	**N = 58**	
NCCP Plan	26	21	24	24	**0.02**
No	(74.3%)9	(47.7%)23	(50%)24	(41.4%)34	
Yes	(25.7%)	(52.3%)	(50%)	(58.6%)	
NCD/Other Plan	16	16	14	31	0.06
No	(45.7%)19	(36.4%)28	(29.2%)34	(53.4%)27	
Yes	(54.3%)	(63.6%)	(70.8%)	(46.5%)	
NCCP Related Questions (n = 143)	**N = 25**	**N = 35**	**N = 39**	**N = 44**	
Radiotherapy Planning Questions					
1 – Does the NCCP acknowledge device/machinery needs and maintenance					
No/No consensus	19 (76.0%)6	22 (62.9%)13	24 (61.5%)15	23 (52.3%)21	0.28
Yes	(24.0%)	(37.1%)	(38.5%)	(47.7%)	
2– Is there any strategy/mechanism for review of new technology and mechanisms for purchasing and procurement?					
No/ No consensus	24 (96%)1	29 (82.6%)6	36 (92.3%)3	33 (75%)11	**0.05**
Yes	(4%)	(17.1%)	(7.7%)	(25%)	
3 – Is there any radiation oncology services planned or in place?					
No/ No consensus	16 (64.0%)9	17 (48.6%)18	23 (59.0%)16	16 (36.4%)28	0.09
Yes	(36.0%)	(51.4%)	(41.0%)	(63.6%)	
4 – Is there any assessment of radiation oncology machines and safety?					
No/No consensus	20 (80%)5	30 (85.7%)5	33 (84.6%)6	37 (84.1%)7	0.94
Yes	(20%)	(14.3%)	(15.4%)	(15.9%)	
5 – Is there any plan to develop/maintain radiation oncology services?					
No/No consensus	17 (68.0%)8	21 (60.0%)14	25 (64.1%)14	26 (59.1%)18	0.88
Yes	(32.0%)	(40%)	(35.9%)	(40.9%)	
6. Are any of the above radiotherapy related checklist items (Questions 1–5) included in the NCCP?					
No/ No consensus	15 (60.0%)10	16 (45.7%)19	20 (51.3%)19	13 (29.6%)31	0.067
Yes	(40%)	(54.3%)	(48.7%)	(70.4%)	
Mean number of radiotherapy related checklist items in the NCCP					
	1.16	1.6	1.38	1.9	0.30
Centre Coordination					
1- Is there any coordination between centres or coordination of care for individuals?					
No/ No consensus	20 (80%)5	21 (60%)14	23 (59%)16	18 (40.9%)26	**0.017**
Yes	(20%)	(40%)	(41%)	(59.1%)	
Workforce Planning Questions					
1- Is there any health workforce strategy or plan linked to general workforce?					
No/ No consensus	14 (56%)11	9 (25.7%)26	26 (66.7%)13	19 (43.2%)25	**0.004**
Yes	(44%)	(74.3%)	(33.3%)	(56.8%)	
Financial Planning Questions					
1 – Are financial resources for NCCP activities specified					
No/No consensus	13 (52%)12	15 (42.9%)20	17 (43.6%)22	24 (54.6%)20	0.66
Yes	(48%)	(57.1%)	(56.4%)	(45.4%)	
2- Are costs mentioned					
No/ No consensus	16 (64.0%)9	17 (48.6%)18	24 (61.5%)15	29 (65.9%)15	0.43
Yes	(36.0%)	(51.4%)	(38.5%)	(34.1%)	
3 – Is there a breakdown of resources or tracking of health accounts versus total cancer expenditure?					
No/ No consensus	25 (100%)	34 (97.1%)1	39 (100%)	43 (97.7%)1	0.64
Yes	0	(2.9%)	0	(2.3%)	
Governance and Guideline Questions					
1 – Endorsement of the plan approved by the Ministry of Health and other government					
No/ No consensus	1 (4%)24	1 (2.9%)34	2 (5.1%)37	2 (4.6%)42	0.97
Yes	(96%)	(97.1%)	(94.9%)	(95.4%)	
2 – Is there a reference to cancer treatment guidelines/ protocols?					
No/ No consensus	18 (72%)7	15 (42.9%)20	15 (38.5%)24	13 (29.6%)31	**0.007**
Yes	(28%)	(57.1%)	(61.5%)	(70.4%)	
3 – Are there national guidelines for specified cancers of plans to develop them?					
No/ No consensus	17 (68%)8	16 (45.7%)19	15 (38.5%)24	16 (36.4%)28	0.061
Yes	(32%)	(54.3%)	(61.5%)	(63.6%)	
4 – Are there cancer targets and indicators stated					
No/ No consensus	9 (36%)16	9 (25.7%)26	8 (20.5%)31	12 (27.3%)32	0.59
Yes	(64%)	(74.3%)	(79.5%)	(72.7%)	

well established training opportunities for member states which can form the basis of a core curricula in radiation oncology [21]. We encourage countries to build radiotherapy workforce planning into future iterations of their NCCP in order to help meet growing treatment demands [22].

Radiotherapy is an evidence-based treatment, indicated in approximately half of cancer patients based on clinical practice guidelines [23]. We found that countries whose NCCP referenced cancer treatment guidelines and/or protocols had higher machine availability to meet demand. While such an association does not prove causation, it does highlight the potential importance of clear guidelines in optimizing the delivery of evidence-based care, including radiotherapy. HICs and European countries, were most likely to reference clinical guidelines in their NCCPs. However, guidelines are dynamic, and change based on new evidence. The recent introduction of hypofractionation for breast and prostate cancer, driven in part by the need to reduce patient contact times during the COVID-19 pandemic, is an example of rapid adaptation of clinical practice guidelines [24]. These recent guideline changes are not all reflected in the current estimates of radiotherapy demand, and this could affect estimates of machine need. Developing country-specific guidelines or referencing resource-stratified

Table 4
Association between geographic region and radiotherapy and cancer service planning in NCCPs.

	Africa	Asia-Pacific	Europe	Latin America	North America	P-value*
NCCP (n = 185)	N = 54	N = 57	N = 40	N = 32	N = 2	
NCCP Plan	32	35	8	19	1	**<0.001**
No	(59.2%)22	(61.5%)22	(20.0%)32	(59.4%)13	(50%)1	
Yes	(40.7%)	(38.6%)	(80.0%)	(40.6%)	(50%)	
NCD/Other Plan	26	19	18	13	1	0.59
No	(48.1%)28	(33.3%)38	(45%)22	(40.6%)19	(50%)1	
Yes	(51.9%)	(66.7%)	(55%)	(59.4%)	(50%)	
NCCP Related Questions (n = 143)	N = 40	N = 43	N = 37	N = 22	N = 1	
Radiotherapy Planning Questions						
1 – Does the NCCP acknowledge device/machinery needs and maintenance						
No/No consensus	26 (65%)14	31 (72.1%)12	15 (40.5%)22	15 (68.2%)7	1(100%)	**0.023**
Yes	(35%)	(27.9%)	(59.5%)	(31.8%)	0	
2– Is there any strategy/mechanism for review of new technology and mechanisms for purchasing and procurement?						
No/No consensus	36 (90%)4	41 (95.3%)2	25 (67.6%)12	19 (86.4%)3	1 (100%)	**0.004**
Yes	(10%)	(4.65%)	(32.4%)	(13.6%)	0	
3 – Is there any radiation oncology services planned or in place?						
No/No consensus	19 (47.5%)21	31 (72.1%)12	11 (29.7%)26	10 (45.4%)12	1 (100%)	**0.002**
Yes	(52.5%)	(27.9%)	(70.3%)	(54.6%)	0	
4 – Is there any assessment of radiation oncology machines and safety?						
No/No consensus	32 (80%)8	39 (90.7%)4	28 (75.7%)9	20 (90.9%)2	1 (100%)	0.21
Yes	(20%)	(9.3%)	(24.3%)	(9.1%)	0	
5 – Is there any plan to develop/maintain radiation oncology services?						
No/No consensus	22 (55.0%)18	35 (81.4%)8	16 (43.2%)21	15 (68.2%)7	1 (100%)	**0.004**
Yes	(45.0%)	(18.6%)	(56.8%)	(31.8%)	0	
6. Any of the above radiotherapy related checklist items included in the NCCP?						
No	18 (45%)22	28 (65.1%)15	9 (24.3%)29	8 (36.4%)14	1 (100%)	**0.003**
Yes	(55%)	(34.9%)	(75.7%)	(63.4%)	0	
Mean number of radiotherapy related checklist items in the NCCP						
	1.6	0.88	2.4	1.4	-	**<0.001**
Centre Coordination						
1 – Is there any coordination between centres or coordination of care for individuals?						
No/No consensus	24 (60.0%)16	31 (72.1%)12	9 (24.3%)28	17 (77.3%)5	1 (100%)	**<0.001**
Yes	(40.0%)	(27.9%)	(75.7%)	(22.7%)	0	
Workforce Planning Questions						
1-Is there any health workforce strategy or plan linked to general workforce?						
No/No consensus	19 (47.5)21	20 (46.5%)23	18 (48.6%)19	11 (50%)11	1 (100%)	0.99
Yes	(52.5%)	(53.5%)	(51.4%)	(50%)	0	
Financial Planning Questions						
1 – Are financial resources for NCCP activities specified						
No/No consensus	17 (42.5%)23	24 (55.8%)19	13 (35.1%)24	14 (63.6%)8	1 (100%)	0.11
Yes	(57.5%)	(44.2%)	(64.9%)	(36.4%)	0	
2- Are costs mentioned						
No/No consensus	18 (45%)22	30 (69.8%)13	21 (56.8%)16	16 (72.7%)6	01	0.07
Yes	(55%)	(30.2%)	(43.2%)	(27.3%)	(100%)	
3 – Is there a breakdown of resources or tracking of health accounts versus total cancer expenditure?						
No/No consensus	40 (100%)	43 (100%)	35 (94.6%)2	22 (100%)	1 (100%)	0.12
Yes	0	0	(5.4%)	0	0	
Governance and Guideline Questions						
1 – Endorsement of the plan approved by the Ministry of Health and other government						
No	1 (2.5%)39	3 (7.0%)40	2 (5.4%)35	022	01	0.53
Yes	(97.5%)	(93.0%)	(94.6%)	(100%)	(100%)	
2 – Is there a reference to cancer treatment guidelines/ protocols?						
No/No consensus	22 (55.0%)18	23 (53.5%)20	10 (27.0%)27	5 (22.7%)17	1 (100%)	**0.008**
Yes	(45.0%)	(46.5%)	(73.0%)	(77.3%)	0	
3 – Are there national guidelines for specified cancers of plans to develop them?						
No/No consensus	21 (52.5%)19	25 (58.1%)18	11 (29.7%)26	6 (27.3%)16	1 (100%)	**0.017**
Yes	(47.5%)	(41.9%)	(70.3%)	(72.7%)	0	
4 – Are there cancer targets and indicators stated						
No	9 (22.5%)31	16 (37.2%)27	10 (27.0%)27	2 (13.6%)19	01	0.19
Yes	(77.5%)	(62.8%)	(73.0%)	(86.4%)	(100%)	

* Chi-squared p-values exclude North America from the comparison as N = 1, except for the questions regarding the presence/absence of NCCP or NCD/Other.

guidelines for radiotherapy services within the NCCP could encourage the prioritisation of high-value interventions and improve service planning despite resource constraints [25].

Limitations and future directions

The validity of our results is dependent on the quality of the checklist used to evaluate the core elements of NCCPs and the review process adopted to evaluate each NCCP, as previously described [7,9], as well as the accuracy DIRAC and GLOBOCAN data. Despite the robust methods which led to the development of a 111-item quality check list, only 5 pertain directly to radiotherapy, which cannot capture all the aspects needed for a functional radiotherapy service. The questions pertaining to workforce, finances, governance, and guidelines are related questions but are not specific to radiotherapy. Ongoing research examining the extent of radiotherapy prioritisation in NCCPs, and including additional important aspects such as demand modelling, financial needs,

radiotherapy workforce and brachytherapy are needed. Furthermore, while this current project correlates the presence of NCCPs with machine availability, evaluating for correlations with cancer outcomes is beyond the scope of this work. Complete GLOBOCAN, DIRAC and NCCP data was only available for 143 countries worldwide. The exclusion of countries with incomplete data may generate a selection bias, and ongoing research to collect and analyses data for missing countries is warranted. At present DIRAC data does not include specific information on brachytherapy, and ongoing work is underway to increase the level of detail which could inform future analyses.

The current study demonstrates a correlation between NCCPs and machine availability but does not demonstrate causation, or directionality. Countries with a high supply of radiotherapy machines may be more likely to include radiotherapy within their NCCPs, due to the need for clear strategies for maintenance, equipment procurement and training. On the other hand, countries that include radiotherapy within their NCCP may be more likely to invest in radiotherapy due to an increased awareness of its importance, and therefore may have higher machine availability. Therefore, while our results support the inclusion of radiotherapy in NCCPs to provide clear cancer planning and support machine availability, there is no implied causality between NCCPs and machine availability. Acknowledging radiotherapy within an NCCP is an important first step towards recognizing radiotherapy as a key component of cancer care and developing effective strategies to acquire machines and develop radiotherapy programs within a country.

While NCCPs are important documents for cancer control and require clear targets and actions, successful implementation of the plans is not guaranteed. This important task requires input from multiple stakeholders across all levels of health and government, as well the support of international organisations. Even the most comprehensive NCCP will not lead to meaningful changes in the availability of cancer services without significant investment and support from all relevant in-country institutions. A recent study in cervical cancer demonstrated that countries with mature HPV vaccination programs were more likely to have implementation strategies detailed within their NCCPs [25], illustrating the importance of including clear targets, actions, and implementation details for radiotherapy within NCCPs.

Over time, updating metrics for treatment demand to reflect the most recent clinical practice guidelines will be important. Repeating this analysis in the future to determine if countries with NCCPs that include radiotherapy planning were better able to increase radiotherapy services and machine availability to match growing demand would objectively confirm the value of NCCPs in improving access to radiotherapy services.

Conclusion

NCCPs form a vital part of global efforts to improve access to cancer care services, including access to radiotherapy. Current inclusion rates of radiotherapy within NCCPs fall short of the 80% target set by the GTFRCC and vary according to country income group and geographic region. This GIRO project highlights that the inclusion of radiotherapy in a country's NCCP is correlated with increased machine availability, with variability by country income level and geographic location. Radiotherapy service provision must be safe and sustainable, and these elements should be prioritised within an NCCP. A future study is planned examining time trends in NCCP quality and radiotherapy availability and could support the importance of NCCPs in expanding services over time. The leadership and advocacy of local stakeholders, regional organisations and international groups is important to promote the inclusion of radiotherapy specific services in future iterations of NCCPs.

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Disclaimer

Where authors are identified as personnel of the International Agency for Research on Cancer / World Health Organization, the authors alone are responsible for the views expressed in this article and they do not necessarily represent the decisions, policy or views of the International Agency for Research on Cancer / World Health Organization.

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Appendix A. Supplementary material

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References

[1] Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA: A Cancer J Clinicians 2021;71:209–49.
[2] Wild C, Weiderpass E, Stewart B. World cancer report: cancer research for cancer prevention. Lyon: International Agency for Research on Cancer; 2020.
[3] WHO. National Cancer Control Programmes 2016 [February 25, 2019]. Available from: http://www.who.int/cancer/nccp/en/.
[4] Cancer Care: Assuring Quality to Improve Survival 2013 [February 18, 2020]. Available from: https://www.oecd-ilibrary.org/content/publication/9789264181052-en.
[5] Cancer prevention and control in the context of an integrated approach WHA 70.12. 70th World Health Assembly; 2017.
[6] Gorgojo L, Harris M, Garcia-Lopez E. National Cancer Control programmes: analysis of primary data from questionnaires. Report from European Partnership for Action Against. Cancer 2012.
[7] Oar A, Moraes FY, Romero Y, Ilbawi A, Yap ML. Core elements of national cancer control plans: a tool to support plan development and review. Lancet 2019;20:e645–52.
[8] WHO. WHO report on cancer: setting priorities, investing wisely and providing care for all. 2020.
[9] Romero Y, Trapani D, Johnson S, Tittenbrun Z, Given L, Hohman K, et al. National cancer control plans: a global analysis. Lancet Oncol 2018;19:e546–55.

[10] Yap ML, Zubizarreta E, Bray F, Ferlay J, Barton M. Global access to radiotherapy services: have we made progress during the past decade? J Glob Oncol 2016;2:207–15.
[11] Atun R, Jaffray DA, Barton MB, Bray F, Baumann M, Vikram B, et al. Expanding global access to radiotherapy. Lancet 2015;16:1153–86.
[12] Aiello Bowles EJ, Tuzzio L, Wiese CJ, Kirlin B, Greene SM, Clauser SB, et al. Understanding high-quality cancer care: a summary of expert perspectives. Cancer 2008;112:934–42.
[13] Delaney GP, Barton MB. Evidence-based estimates of the demand for radiotherapy. Clin Oncol 2015;27:70–6.
[14] Directory of Radiotherapy Centers 2020 [February 18, 2020]. Available from: https://dirac.iaea.org.
[15] World Bank Country and Lending Groups 2020 [February 18, 2020]. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519.
[16] IAEA. Roadmap towards a National Cancer Control Programme: Milestones for establishing nuclear medicine, diagnostic imaging and radiotherapy services. 2019.
[17] Lievens Y, Gospodarowicz M, Grover S, Jaffray D, Rodin D, Torode J, et al. Global impact of radiotherapy in oncology: Saving one million lives by 2035. Radiother Oncol 2017;125:175–7.
[18] Zubizarreta E, Van Dyk J, Lievens Y. Analysis of global radiotherapy needs and costs by geographic region and income level. Clin Oncol 2017;29:84–92.
[19] IAEA. Rays of Hope: Cancer care for all 2020.
[20] Benstead K, Lara PC, Eller Y, Engell-Noerregaard L, Eriksen JG, Gaye PM, et al. Clinical oncology module for the ESTRO core curriculum. Radiother Oncol 2021;156:19–22.
[21] Srivastava A, Jalink M, de Moraes FY, Booth CM, Berry SR, Rubagumya F, et al. Tracking the Workforce 2020–2030: Making the Case for a Cancer Workforce Registry. J Glob Oncol 2021;7:925–33.
[22] Hanna T, Shafiq J, Delaney G, Vinod S, Thompson S, Barton M. The population benefit of evidence-based radiotherapy: 5-year local control and overall survival benefits. Radiother Oncol 2018;126:191–7.
[23] Rodin D, Tawk B, Mohamad O, Grover S, Moraes FY, Yap ML, et al. Hypofractionated radiotherapy in the real-world setting: an international ESTRO-GIRO survey. Radiother Oncol 2021;157:32–9.
[24] Wilson BE, Elliott MJ, Pearson SA, Amir E, Barton MB. Resource stratified guidelines for cancer: Are they all the same? Interguideline concordance for systemic treatment recommendations. Int J Cancer 2022;150:91–9.
[25] Haruyama R, Okawa S, Akaba H, Obara H, Fujita N. A Review of the Implementation Status of and National Plans on HPV Vaccination in 17 Middle-Income Countries of the WHO Western Pacific Region. Vaccines 2021;9:1355.