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Research Article

Pan-Canadian assessment of image guided adaptive radiation therapy and the role of the radiation therapist

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ABSTRACT

Purpose: Adaptive radiation therapy (ART) is a close-looped process where anatomic changes observed during treatment are identified, leading to plan modification prior to treatment delivery. The aim of this study was to explore the status of ART across Canada and review the impact of adaptive technologies on the roles and responsibilities of Radiation Therapists (RTTs).

Materials and Methods: Study information and a link to a 30-question survey was sent via email to the RTT manager of all cancer centres across Canada (n = 48). The survey questions included centre demographics, presence of offline and/or online ART activities as standard of care, corresponding roles and responsibilities of the multidisciplinary team, and training activities. The survey was administered electronically and closed after a 3-week accrual period. Responses were analyzed using descriptive statistics.

Results: Thirty-two out of 48 centres responded across all ten provinces (67 % response rate). Twenty-five centres (78 %) currently perform ART, all of which practiced offline ART while 5 practiced online ART. Most common responses for lack of ART were 'technical limitations' and 'lack of resources'. RTTs are responsible for 50 % (offline) versus 58 % (online) ART respectively, with the most notable change being the addition of target delineation to their daily practice.

Conclusions: The status of ART varies across Canada. Offline ART is commonly practiced, but online ART remains an infrequent process due to technical limitations and lack of resources. As centres move towards implementing online ART, the role of the RTT will need to be redefined with corresponding upskilling to support the emergent treatment paradigm.

Introduction

Adaptive radiation therapy (ART) is a close-looped process where anatomic changes observed during treatment are identified, leading to radiation plan modification to improve treatment delivery [1]. ART has become increasingly available in the clinical environment due to technological advances and can be subdivided in two major sections. Offline ART is defined as activities performed between treatment fractions in an attempt to address noted changes, usually of a systemic nature such as weight loss or change in target volume [2–4]. Online ART is defined as real time adaption immediately prior to a treated fraction and can include a range of activities such as 'plan of the day' for cone-beam computed tomography (CBCT) guided radiation therapy or daily contour adaptation and plan generation on both the magnetic resonance linear accelerator (MR-Linac) and CBCT-based linac [2,5,6].

Canadian Radiation Therapists (RTTs) employ a wide scope of practice. Within the traditional treatment paradigm this includes being qualified to work in all areas of radiation treatment preparation and delivery as part of the entry-to-practice competencies [7]. Within the Canadian regulatory bodies there is no division between a treatment therapist and dosimetrist, enabling RTTs to work in planning-CT, treatment planning and treatment delivery. In Canada, the title of Advance Practice Radiation Therapist (APRT) exists, but there are no official delegated responsibilities associated with this designation. Each APRT has the flexibility to develop their own competencies and define their role, including any delegated acts, in collaboration with their

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regulatory body and employer [8].

The role of RTTs, including both standard designations and APRTs, must evolve to incorporate ART as its application becomes more prevalent. In the ART process, all stages of the traditional treatment planning timeline are completed within a condensed timeframe, with a full multidisciplinary team preforming their respective 'traditional' tasks. However, there are instances in the literature where RTTs have expanded their role in other jurisdictions. This can range from a 'traffic light protocol' of clear action thresholds for RTTs to trigger multidisciplinary review and re-planning activities [4,9] to online ART workflows highlights with RTTs modifying contours and plans under varying levels of direct supervision [10–12]. These roles and responsibilities have evolved as ART becomes increasingly mainstream, reducing the human resource burden [13]. In the Canadian context, there is no national legislation specifically addressing RTT tasks in relation to ART. In Ontario, the largest province, legislation exists regarding who can prescribe radiation, including initiating and stopping treatment. However, all other tasks are carried out based on the RTT's knowledge, skills and judgment [14]. To accommodate the change in workflow and delegation of responsibilities, training programs have been designed and utilized to upskill RTTs and could be mirrored in Canada to ensure the knowledge, skills and judgement for RTTs to extend their tasks [15–17].

It has been previously reported that new technology is unevenly applied not only across countries but also across Canadian provinces [18,19]. As the newest technological approach, ART has slowly become increasingly prevalent in the Canadian landscape. To use this technology, the roles and responsibilities of RTTs will need to evolve. National best practice guidelines for this emerging technology are lacking, and it is unclear how many centres are currently performing ART and to what extent Canadian RTTs participate in those workflows. Only once we understand the current landscape can we work to standardize both ART practices as well as the role of the RTT across the country.

This study aimed to report the patterns of practice of adaptive radiation therapy across Canada and review the impact these technologies have on the roles and responsibilities of Canadian Radiation Therapists.

Materials and methods

To establish patterns of practice for ART in Canada, a survey was developed and distributed to the managers of all radiation therapy centres across the country. This study was approved by the institutional Research Ethic Board (ID: 23-5899) and included an informed consent form prior to participation. ART can be applied at different timescales; 'offline' was defined as adaptation that occurring between fractions (e.g. a re-plan). For the purposes of this survey, offline ART does not include multiphase planning. 'Online' was defined as adaptation performed immediately prior to each fraction (e.g. plan of the day, online re-contouring and re-planning).

Study population

Due to the Pan-Canadian goal of this study, the identified target population included all radiation therapy clinics across Canada. A complete list of institutions was compiled by the national Radiation Therapist professional association (Canadian Association of Medical Radiation Technologists (CAMRT). A total of 48 centres were identified. No sampling procedures were performed, and the entire population was included in this research.

Survey Development

A 30-item questionnaire was developed from published outlines of the adaptive radiotherapy process [1,20]. In addition to cancer centre characteristics questions (n = 10), the survey asked for descriptors of current practices within each department. Questions were related to the presence of offline and/or online ART activities as standard of care, corresponding roles and responsibilities of the HCP team, and training activities for Radiation Therapists. Additional questions were included if centres were not performing ART, which asked about the most significant barrier(s) to ART implementation. The survey questions were designed to be clear and unambiguous. They were piloted prior to distribution to ensure clarity and content validity, with input from four RTTs holding various roles within the department but possessing expert knowledge of the ART process. No additional items or points in need of clarification were identified by the pilot participants. The questionnaire was then translated into French by the study team and validated by an additional French first language RTT. The final version of the questionnaire can be found in Appenix A.

Distribution

In May 2024, 48 Radiation Therapy managers from across Canada were contacted via email by the CAMRT and asked to complete the questionnaire as the representative of their department. This email contained an informed consent form and an outline of the study. A link to the study questionnaire in both French and English was provided via REDCap (version 14.0.39). All responses were anonymous and housed in a secure research server, accessible only to the study team.

Data Analysis

After the 3-week accrual period, during which a reminder email was sent, the questionnaire was closed, and responses from the electronic survey were analyzed. Completed survey responses were summarized using descriptive statistics including the roles and responsibilities of the RTT for both offline and online ART to compare the impact of these new technologies. Statistical evaluation was conducted via Chi-square test using demographic questions to identify differences in naturally occurring cohorts (e.g. language, centre sizes etc.). Responses from the RTT training section will be reported separately.

Results

Of the 48 centres contacted, 32 centres responded, representing a 67 % response rate with all 10 provinces containing radiation therapy centres represented by at least 1 response (Fig. 1). Most survey responses were completed in English, but responses were evenly split across centres with and without an academic affiliation with a local university (Table 1). There were no statistically significant differences between the characteristics of centres using any form of ART versus those who were not (p values in Table 1). Although all those who practiced online ART had access to an MRI for treatment planning, worked in English and had more than 50 RTTs on staff.

Offline adaptation (Replan between fractions)

Among the 25 centres utilizing offline ART, the majority practiced across a variety of treatment sites (Fig. 2). The least adapted treatment site was brain with only 56 % of offline ART capable centres doing so. Conversely, all but 1 centre chose to employ offline ART for head and neck treatments. Of the centres who answered 'other', responses included oligometastases (n = 1), bladder (n = 1), any site that requires it (n = 1).

Only two centres pre-scheduled their offline ART activities, and each did so once per treatment course for brain and head & neck treatments. All other respondents practiced offline ART in a manner that was 'triggered based on imaging' (61 %) and/or on an 'ad-hoc' basis (37 %) across all pooled treatment sites.

Centres across Canada used a variety of imaging methods for offline ART (Fig. 3). The most common was CBCT, which was cited for 73 % of responses across all pooled treatment sites. The next most common imaging method for offline ART was kilovoltage (KV) planar imaging (19 % across all sites), which was used most often for breast offline ART. Breast was also the only treatment site listed as using megavoltage (MV) planar images to trigger offline ART. All responses of MVCT for offline ART guidance came from a single centre which reported treating brain,

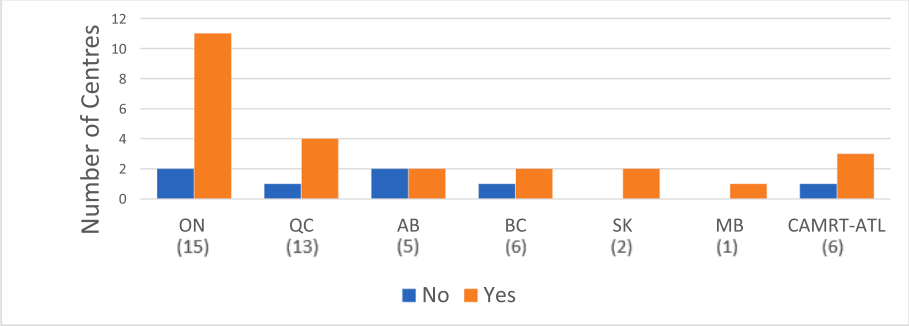

Fig. 1. Number of Centres currently practicing offline ART by province, with total number of centres per province in parentheses. AB = Alberta, BC = British Columbia, MB = Manitoba, ON = Ontario, QC = Quebec and SK = Saskatchewan. Results from provinces with a single centre have been grouped, CAMRT-ATL = New Brunswick, Newfoundland, Nova Scotia and Prince Edward County.

Table 1
Summary of Survey Responses, n = 32 with results of chi-square test between each characteristic.

Demographics (n = 32)		All responses		Offline ART (n = 25)		Online ART (n = 5)		No ART vs ART
		N	(%)	N	(%)	N	(%)	P-value
Language	English	27	(84)	21	(84)	5	(100)	0.91
	French	5	(16)	4	(16)	0	(0)	
Academic affiliation with university	Yes	15	(47)	14	(56)	3	(60)	0.05
	No	17	(53)	11	(44)	2	(40)	
Access to MRI for planning	Yes	26	(81)	22	(88)	5	(100)	0.06
	No	6	(19)	3	(12)	0	(0)	
Number of Linear Accelerators	<5	10	(31)	6	(24)	0	(0)	0.09
	≥5	22	(69)	19	(76)	5	(100)	
Number of Radiation Therapists	<50	15	(47)	10	(40)	0	(0)	0.14
	≥50	17	(53)	15	(60)	5	(100)	

head and neck, lung, breast, upper GI, lower GI, prostate, cervix and sarcoma. Surface Guided Radiation Therapy (SGRT) was reported by two centres to facilitate offline ART.

Online adaptation (adjusting the plan immediately before each fraction)

Five centres (16 %) responded that they were currently employing online ART. Of these centres, 3 were using a CBCT linear accelerator (linac) (ETHOS, Varian Medical Systems, United States) and 2 used a 1.5 T MR-linac (Unity, Elekta AB Stockholm, Sweden). Additionally, one of the centres with an MR-linac also reported performing online ART with a Gamma Knife. Interestingly, these centres were spread across 3 provinces and are not limited to large urban centres. Furthermore, there is a range of centre size in those preforming online ART with the smallest having below the average number of linear accelerators of our respondents, 5, and the largest having 16.

All centres who reported using online ART, adapted all treatment plans for ART sites at each fraction. All 5 centres were daily adapting for prostate patients. Other sites treated with online ART were more diverse across centres with the next most common site being brain, upper GI, and lower GI, which were treated by 40 % of online ART capable centres. None of the 5 centres performing online ART reported doing so for head and neck, breast or sarcoma.

Barriers

The majority of responding centres (85 %) were not currently performing any online ART activities, although 4 intended to start within the next 12 months. Of those centres who did not intend to start an online ART program, the most commonly identified barrier was 'technical limitations (e.g. treatment, imaging, and planning systems not capable of online ART)' and 'inadequate clinical resources to accommodate procedure'. These two responses were both reported substantially more often (n = 18) than the next most common item of 'lack of Radiation Therapist knowledge and skills' (n = 7) (Fig. 4). "Other" free text responses included 'online ART was not a priority' for one centre and 'general upskilling of all professions' as barriers.

Radiation Therapist roles and responsibilities

Overall RTTs were responsible for a similar percentage of tasks in both ART workflows. RTTs were responsible for 50 % of offline ART tasks vs 58 % of online ART tasks with the most notable difference being the addition of target delineation to their activities (Fig. 5a.Fig. 5b.).

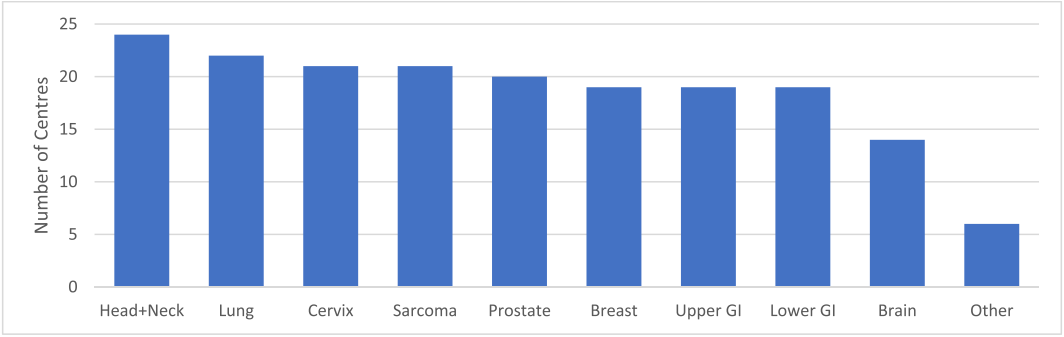

Fig. 2. Treatment sites utilizing offline ART (n = 25 centres). GI = Gastrointestinal.

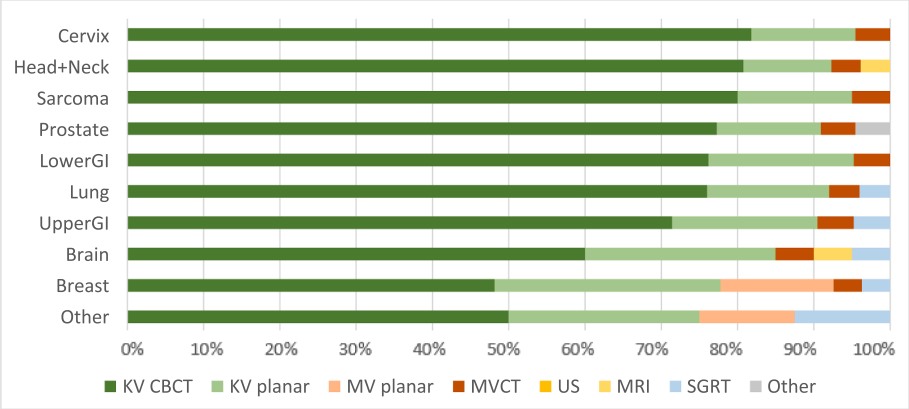

Fig. 3. The type of image guidance most frequently used for offline ART sites. KV = kilo Voltage, CBCT = Cone-beam CT, MV = Mega Voltage, US = Ultrasound, MRI = Magnetic Resonance Imaging, SGRT = Surface Guided Radiation Therapy.

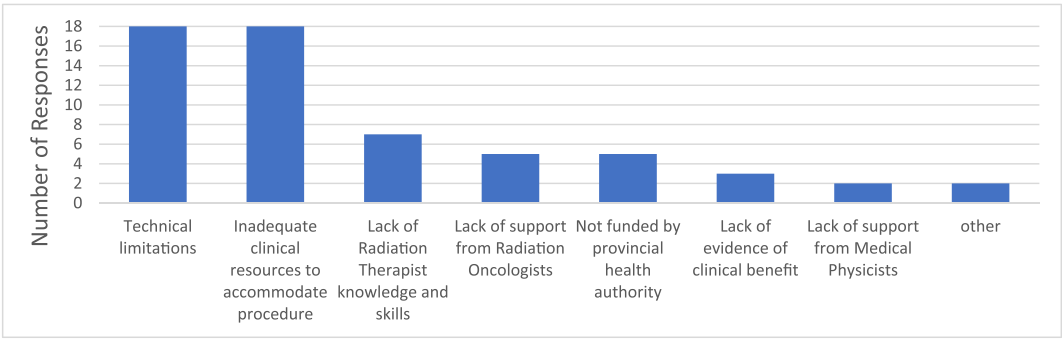

Fig. 4. Responses to barriers to the implementation of online ART.

RTT roles could be further sub-categorized into dosimetry, treatment delivery and Advanced Practice Radiation Therapists (APRTs).

In the offline ART setting, centres reported that 100 % of target delineation was completed by the Radiation Oncologist (RO) but for online ART that figure dropped to 71 %, with RTTs taking over this task. Interestingly the contouring of organs at risk (OARs) by the RO was similar in the offline vs online setting (28 % vs 22 %), but which profession completed the task in the other ~75 % of the time varied. In the offline setting this was completed entirely by RTTs of various designations, e.g. Therapists in planning CT, Therapists in dosimetry and a small number of APRTs, while in the online setting this task included participation by a Medical Physicist.

There were two free text questions about the role of RTTs in online ART. When asked 'how their department was organized to perform online ART', 4/5 responses stated there was a specific dedicated team of specially trained RTTs. The remaining department chose to integrate online ART into the RTT work rotations with 30 % of their RTTs trained to work on their Ethos machine. All 5 centres used a multidisciplinary team approach to develop new ART initiatives. When asked about the specific role of the RTT, responses most commented on workflow/couch-side processes (n = 4) and one centre elaborated that their RTTs play a significant role in 'meeting training needs, workflow considerations, patient advocacy, unit scheduling and imaging considerations'.

Discussion

In radiation therapy centres across Canada who responded to the

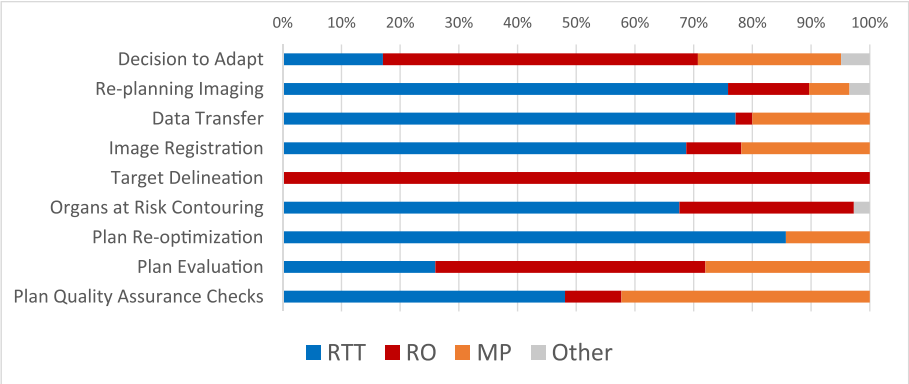

Fig. 5a. Role distribution across the multidisciplinary team in offline ART. RTT = Radiation Therapist, RO = Radiation oncologist, MP = Medical physicist.

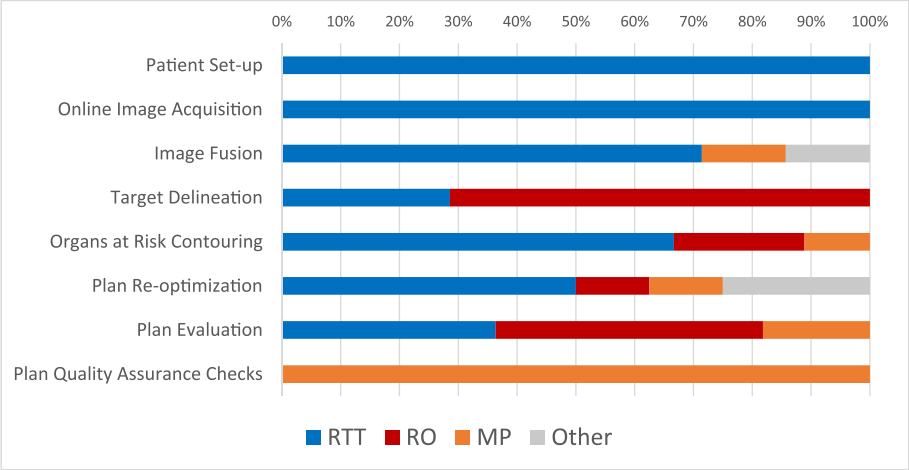

Fig. 5b. Role distribution across the multidisciplinary team in online ART. RTT = Radiation Therapist, RO = Radiation oncologist, MP = Medical physicist.

survey, 78 % currently perform offline ART and 16 % utilize online ART. While the prevalence of offline ART is similar to that found in Europe (61 %), only 6 % of European centres who took part in the POP-ART RT survey were applying online ART [20]. Although it is likely that the fast-paced adoption of ART in Europe may have increased that number in the 4 years since publication. Despite this, the low rate of online ART adoption in Canadian centres (particularly in small and/or French-speaking centres) suggests a disparity in the availability of state-of-the-art personalized radiation medicine across the country. Having ART at a minimum in every province would improve health equity and decrease out-of-province travel for patients. Unfortunately, the desire to increase the use of ART (particularly resource-intensive online ART), is coming at a time when Canadian radiation therapy departments are under resource constraints [21,22].

The main barriers to implementing an ART program in Canada were reported as 'technical limitations' and 'inadequate clinical resources to accommodate procedure'. This aligns with similar studies conducted in European institutions, although there may be an additional factor, as not all centres in Canada utilize CBCT. In centers without 3D imaging, there are technical limitations, as they do not observe anatomical changes during treatment, and as a result, would not make adaptations [19]. Bertholet et al. found that both 'technical limitations' and 'equipment/financial resources' were substantial barriers, although the most significant barrier was identified as 'human resources' [20]. Similarly, a multi-country survey of MR guided ART ranked the most important barrier as 'lack of medical doctors/ lack of medical doctors time' [13]. This barrier is not just significant in the ART environment, but its influence can be extrapolated to most novel healthcare procedures [18]. As 'plug-and-play' CBCT-guided online ART becomes commercially available, it is anticipated that the capital and operational budget required to purchase an online ART system will be reduced. Additionally, as software technologies improve, auto-contouring, machine learning plan generation and automated plan QA will alleviate the human resource burden. In combination, these may mitigate the major barrier to online ART adoption in Canada, and allow wider access to online ART.

Head and neck was the site most widely adapted in an offline setting with all but one offline ART centre doing so. Conversely, none of the 5 centres performed online ART for head and neck. This could be due to concerns regarding the time needed to daily contour the large number of head and neck structures, increasing daily treatment time beyond patient tolerance [23]. Deep learning segmentation may minimize this barrier in the future [24]. Conversely, the lack of online ART for Head and Neck could be due to the systematic and predictable nature of changes within this population such as weight loss or shrinkage of the target volumes or parotid glands [4,25]. This may allow such patients to be managed adequately through ad-hoc or scheduled offline ART.

The most frequently online adapted site was prostate (all 5 centres). Interestingly, centres indicated that they started their online ART program with the prostate site due to perceived ease and well-documented daily anatomical variation. This is consistent with the approach to implementation of intensity modulation (IMRT) and image guidance techniques, however several recent publications indicated that online adaptive may only be minimally better than online image guidance for prostate [26,27]. In the absence of evidence demonstrating the impact of adaptive treatment on meaningful endpoints, such as acute and late toxicity, patient quality of life, local control, and overall survival, across all treated sites, it remains uncertain whether this labour and resource intensive yields significant benefits. We postulate that similar to the introduction of IMRT, the established dosimetric advantages of ART will ultimately lead to positive clinical outcomes and supporting evidence.

Two of five Canadian centres used online ART for abdominal cancers. The literature reports that abdominal cases (pancreas in particular) may see the largest dosimetric benefit from daily online ART [28–30]. This suggests that as more centres join the Canadian online ART practice environment or increase their eligible cadre of online ART disease sites, we should strive to implement protocols for abdominal target volumes. Although the complexity of abdominal treatments is generally considered greater due to increased respiratory motion and the need to contour additional OARs compared to pelvic treatments, advancements in breath-hold MR imaging, the rapid nature of CBCT acquisition and enhanced staff training make these challenges manageable. As with any new technology, once the initial resource-intensive implementation is complete, time and resources can be shifted back to standard-of-care levels through task reallocation.

The time constraints associated with delivery of online ART have required some task shifting within the multidisciplinary team. Participants reported a target delineation task shift from ROs to RTTs. This shift has been thoroughly evaluated for prostate ART in the literature [12,16,17] and has begun to expand to other pelvic sites [11]. There is also variation in the level of supervision following comprehensive training for this task shift. In some cases, the ART process, including target delineation, are completed by RTTs under no direct supervision [11,12] or without direct supervision after the first fraction [16,17]. Conversely, a task shift for plan QA from RTTs and ROs to MPs was reported. Notably, this task is performed by RTTs in other countries, such as the Netherlands, where a 'traffic light' system indicates if physics review is needed [31]. If this system was adopted in Canada, the online ART process could be further streamlined, and the impact of online ART on medical physicist resources could be reduced. This becomes vitally important when framed within the global Medical Physics human resource shortage, a challenge from which Canada is not exempt [32].

It is interesting to note that Canadian RTTs were more involved in plan re-optimization compared to previously published European data, possibly due to Canadian training programs which result in the inclusion of dosimetry in the scope of practice of all RTTs, as opposed to the separate dosimetry designation commonly seen in Europe [13].

Due to the absence of national legislation on ART from regulatory bodies in Canada, each centre has been left to interpret provincial legislation that were established before the introduction of ART. Centres that have adopted task-shifting for target delineation or plan evaluation have done so under the interpretation that they are fulling the original treatment intent, which is still prescribed by the RO. As long as RTTs are equipped with the necessary knowledge, skills and judgement for these tasks, this would be in compliance with current legislation [7]. The breadth and depth of RTT roles in offline and online ART highlights the need for a formal competency framework to define the necessary knowledge, skills and judgement for RTTs that encompasses increased activity in target contouring and plan evaluation. The data gathered during this project regarding the training currently provided to RTTs in the ART environment, as well as a standardized adaptive competency framework for this new environment, will be the subject of subsequent publications.

This study is the first to evaluate the prevalence, utilization, barriers and task shifting associated with ART in Canadian radiation therapy centres. Despite the distinctiveness of the data and insights presented in this study, there is a moderate likelihood of survey response bias. Although multiple attempts were made to reach all centres, not all responded. It is possible that those centres who did not utilize ART were more likely to not respond to the survey [33], thus the proportion of Canadian centres currently practicing ART may be overestimated. However, given the diversity of practice settings and the collection of data from each province it is reasonable to generalize the descriptions of current practice and task shifting to the country.

Conclusions

The application of ART across Canada is varied with most centres performing some form of ART. Offline ART is commonly practiced for a variety of sites but online ART remains infrequently applied due to technical limitations and lack of resources. This represents a major barrier in access to not only the newest technology but personalized medicine for radiation therapy patients in Canada.

Additionally, the role and responsibilities of the RTT varies by centre with no formalized training or competency framework in place to follow. Task shifting to RTTs during the online ART process should be underpinned with corresponding upskilling to support the emergent treatment paradigm. Leveraging the knowledge, skills and judgment of RTTs decrease the overall resource burden of this technology and would allow ART to become more prevalent across Canadian centres.

Declaration of competing interest

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.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tipsro.2025.100303.

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