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The impact of emerging technologies on education, roles and career progression of radiation therapists: a delphi consensus based on the ESTRO RTT workshop

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Position paper

The impact of emerging technologies on education, roles and career progression of radiation therapists: a delphi consensus based on the ESTRO RTT workshop

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ABSTRACT

Rapid technological advances in radiation oncology, including artificial intelligence (AI), online adaptive radiotherapy, and advanced imaging, are transforming radiotherapy practice and professional roles. Radiation Therapists (RTTs) must adapt their education, scope of practice, and career pathways to safely implement these technologies, yet international consensus on how this should be supported remains limited. A modified Delphi study was conducted following two online international workshops organised by the ESTRO Radiation Therapist (RTT) Committee. Expert RTTs participated in facilitated discussions exploring the impact of emerging technologies on RTT education, role extension, and career progression. Workshop data were thematically analysed to generate consensus statements, which were refined and validated through two survey rounds. Consensus was defined as $\geq$ 80% agreement. High levels of agreement were achieved across all themes. Participants agreed that emerging technologies expand rather than replace RTT roles, shifting responsibilities towards validation, quality

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assurance, and clinical decision-making. Structured education, critical thinking, and clear competency frameworks were identified as essential, alongside defined career pathways and access to continuing professional development. This position paper presents international expert consensus to inform education, workforce planning, and professional development in technologically evolving radiotherapy practice.

Introduction

The field of radiation therapy (RT) is experiencing a rapid technological evolution, such as adaptive radiotherapy, artificial intelligence (AI) supported tools and automated planning, which is reshaping clinical practice and patient pathways. These shifts in technologies increase the need for clear professional responsibilities within the multidisciplinary team [1–3]. In particular, Radiation Therapists (RTTs) are increasingly required to adapt to emerging technologies that demand not only new technical proficiencies, but also enhanced roles in clinical decision making, patient engagement and structured collaboration, with radiation oncologists, medical physicists and other allied health professionals (e.g. nutritionists, social workers, nurses, etc.) [3–6].

Advances in AI, image-guided radiotherapy (IGRT), online adaptive workflows, surface-guided radiation therapy (SGRT), particle therapy and automated treatment planning are increasing the precision, personalisation and efficiency of treatment delivery [3,7,8]. These developments necessitate a parallel transformation in RTT education and training, so the workforce can build the clinical skills needed for modern practice. They also reinforce the need for structured career pathways that support capability growth as these technologies mature, ensuring that the workforce remains competent and adaptable, maintaining safety for patients.

As the scope of practice expands, current and future RTTs face increasing pressure to build new skills, strengthen professional accountability and take on added responsibility in technology enabled workflows. This also puts pressure on workforce sustainability when education, recognition and clear career structures do not keep pace with expectations. These demands may increase the risk of professional fatigue and challenges in workforce retention in settings already affected by rising cancer incidence and workforce shortages [9–13].

Despite existing literature, an international RTT expert consensus on future technologies, roles, and career progression has not yet been presented, thereby leaving a gap that is key to addressing real-world needs in practice. This paper presents the outcomes of a Delphi-based consensus workshop designed with the aim to capture current perspectives from a broad group of international RTT experts on the educational and career-oriented imperatives required for future practice.

The consensus statements resulting from this workshop are considered to serve as recommendations in a strategic vision for academic institutions, professional bodies, government agencies, healthcare providers and policymakers, who aim to advance the RTT profession while ensuring patient safety and treatment accuracy during ongoing innovation in radiation oncology.

Methodology

This study used a mixed-method approach that included qualitative and quantitative components. It applied a descriptive, cross-sectional design using primary data collection and was followed by an inductive and deductive analysis through a Delphi study. The aim was to capture current perspectives of RTT experts on the educational and professional needs linked to future technologies, roles and career-oriented progression. Data was collected between December 2024 and April 2025.

A modified Delphi method was used (Fig. 1). It included two workshops where qualitative data was collected to develop and refine theories through topic discussions and statement generation, following an inductive approach. These statements were then circulated to participants to confirm their level of agreement and validate the emerging theories, following a deductive approach. This Delphi study included four rounds as shown in Fig. 1. This structure reflects established Delphi methods, where iterative rounds and structured feedback support the development and confirmation of expert consensus.

Two online workshops were facilitated by the faculty members (FS, MB, RS JGC) on behalf of the European Society for Radiotherapy and Oncology (ESTRO) RTT Committee; to explore how technological evolution is shaping education, role extension and career progression of RTT roles in the future. The workshops took place in December 2024 and March 2025 and lasted 2 h each. The data collected during the workshops was analysed, and a series of statements were drafted. After the workshop the level of agreement with the statements was measured using a survey. Details of the method are found below.

Target population, sampling and recruitment

The target population for this study was expert RTTs worldwide. In this study, an expert was defined as an RTT with a minimum of 5 years of experience. This requirement was established to ensure that participants had sufficient experience and knowledge to contribute meaningfully to the research. The primary goal of the study was to explore the impact of technology on role expansion, career progression, and education. Therefore, the sampling aimed to gather a diverse range of perspectives. We employed a purposive sampling approach, specifically maximum variation sampling, to ensure participants were selected based on their extensive knowledge and a wide range of professional experiences. Individuals who had registered for RTT workshops were selected based on their expertise, role, and geographical location, ensuring a rich and varied overview of the topic from multiple perspectives. Roles such as advanced practitioners, managers, and educators were purposefully selected to enrich the discussion.

Delphi round 1 – Workshop December 2024

During the first workshop, faculty members facilitated group discussions in breakout rooms, where participants reflected on how advanced technologies were influencing RTT education, role expansion and career progression. The session was recorded and a transcript was produced. Mindmaps supported the discussions (see Fig. 2). After the workshop, the recordings from the main room and the breakout rooms were transcribed and thematically analysed using a hybrid deductive and indictive Codebook Thematic Analysis by the research team which included the faculty and workshopparticipants. This form of thematic analysis started by using the aims of the research to create a priori codes (deductive phase) followed by open, inductive coding of the sub themes.

Fig. 1. Delphi rounds.

Similar methods were used in previous research which were adapted to address the specific needs of this study [14–16]. Each researcher coded one or two different transcripts and each transcript was coded by seven or eight researchers as shown in Table 1.

The analysis employed a hybrid, deductive, and inductive approach. The analysis began with a deductive strategy, using the predefined workshop topics that constituted the codes in the codebook (advanced technologies, education, role extension, and career progression) as a starting point. However, an inductive approach was used for the sub-themes, which emerged organically from the data through an open coding process. This combined method ensured that the analysis was both guided by key research areas and open to new insights from the participants' experiences.

The workshop participants (PB, MC, TD, DRD, LH, TK, VWS, KO, LR, MS, FS, DS, ET, EVW, AW, SW) coded the transcripts. Following this, the faculty reviewed the coding and drafted the statements per sub-theme (Education, role expansion and career progression). ChatGPT v4.o was used to remove statement duplicates, merge items with similar meaning and compile it into 60 statements, accounting for 20 statements in each theme. Finally, the faculty members reviewed all the statements and corrected where necessary, ensuring that the discussions were accurately represented and summarised. The AI supported rapid processing between Delphi rounds. It did not replace critical judgement. Participants then rated their agreement with these statements in the following Delphi round, which ensured that the content of the discussions was reflect in the final statements.

Delphi round 2 – survey February 2025

Statements from the workshop were then circulated to all participants through Google Forms. Participants rated each statement on a 5-point Likert scale (1 totally agree; 2 agree; 3 disagree; 4 totally disagree; 5 no opinion). Consensus was defined as 80% agreement and was calculated as per Equation (1).

$$\text{Agreement} = \frac{\text{Number of participants rating 'totally agree' or 'agree'}}{\text{Number of participants (excluding 'no opinion')}} \quad (1)$$

Participants could also comment, suggest edits or propose new statements. Based on the results of the survey and the written feedback provided by the participants, the faculty added new statements, refined existing ones and identified items to remove.

Delphi round 3 – workshop March 2025

During the second workshop, in which participants were all present, statements that reached 80% agreement were presented. Statements that did not reach this level of consensus, or that had been edited, were discussed in detail. Participants refined the wording and content with the faculty.

Delphi round 4 – survey April 2025

After the workshop, the faculty made final adjustments based on the group discussion. A second survey was then circulated to measure agreement with the refined statements and confirm the degree of consensus.

Table 1
Allocation of transcripts to be coded by each researcher.

TD (T0 + T1)	EVW (T0)	LH (T0 + T1)	DRD (T0 + T1)
ET (T1 + T2)	MS (T1 + T2)	AW (T1 + T2)	PB (T1 + T2)
SW (T2 + T3)	TK (T2 + T3)	DS (T2 + T3)	LR (T2 + T3)
JM (T3 + T4)	VL (T3 + T4)	KO (T3 + T4)	MC (T3 + T4)
FS (T4 + T0)	FS (T4 + T1)	RS (T4 + T0)	GC (T4 + T0)
MB (T0)			

Key: T0 = Transcript of the main room; T1-T4 = Transcript of breakout rooms 1–4.

Ethical considerations

Participants were informed in advance that the workshops would be recorded, and the data would be used for publication. All identities were kept anonymous. Participants were invited to take part in the thematic analysis and manuscript development, and could be named as authors, but individual contributions were not identified and confidentiality was maintained. Participation in the workshops, surveys, data analysis and writing was voluntary. There was no risk of coercion since all participants registered independently. The data, including transcripts, recordings and participant information, were stored in an encrypted password-protected cloud folder hosted by ESTRO.

Results

Participants

Twenty-two RTTs participated in the workshop. Table 2 summarises the participant demographics. Most participants were from Europe (5 from the United Kingdom, 2 from the Netherlands, 2 from Italy, and 1 each from Portugal, Greece, Austria, Denmark, Ireland, and Norway), representing 68% of the group. Participants were mainly between 35 and 45 years of age, accounting for 36%. Nine participants, equal to 41%, identified as advanced practitioners, including not being formally recognised in that capacity. Ten RTTs, equal to 45%, had over 15 years of experience, which ensured experienced input across the discussions. Gender data was not collected.

Round 1 – workshop

Fig. 2 presents an example of a mind map developed during one breakout group discussion. The full set of discussions involved four

Table 2
Workshop participants demographics.

RTTs	N 22 (100%)
Nationality	
European	15 (68%)
Asian	3 (14%)
Australian	3 (14%)
South American	1 (4%)
Age	
<25 years old	0
25–35 years old	5 (23%)
35–45 years old	8 (36%)
45–55 years old	5 (23%)
>55 years old	1 (4%)
Did not reply	3 (14%)
Sub-specialty	
Advanced practitioner (even if not officially accredited)	9 (41%)
Educator	4 (18%)
Treatment floor or pre-treatment RTT	3 (14%)
Manager	2 (9%)
Other	2 (9%)
Did not reply	2 (9%)
Years since qualifying	
<5 years	0
5–10 years	5 (23%)
10–15 years	5 (23%)
>15 years	10 (45%)
Did not reply	2 (9%)

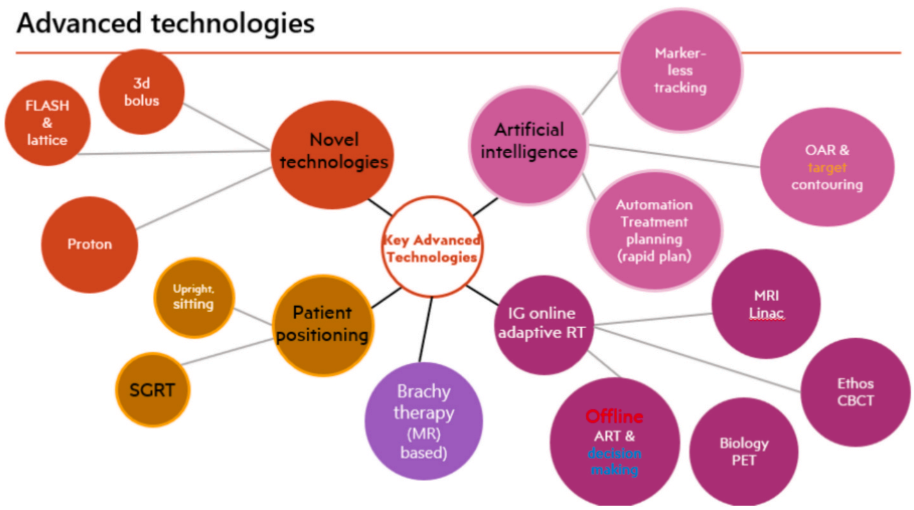

Fig. 2. Example of one of the mindmaps on key advanced technologies, identified in one of the breakout rooms.

groups. Across the groups, emerging and established technologies that have the potential to influence future RT practice and RTT roles were organised into five categories: novel technologies, patient positioning and immobilisation, brachytherapy (BT) innovations such as MR-based BT, image-guided and online adaptive RT, and AI. Fig. 2 reflects one group's output and does not represent the full list generated across all groups. Following the first workshop, sixty statements were developed. Twenty statements were created for each theme: education, role extension and career progression. These statements came directly from the coded outputs of the breakout group discussions and the thematic analysis performed by the faculty and volunteer participants.

Round 2 – survey

Round 2 included ratings from twenty-one participants, representing 95% of the group and the four faculty members. Figs. 3–5 present the statements and the agreement scores for each theme. In total, fifty-three statements reached the 80% consensus threshold. Seven statements fell below this level. The mean agreement across all statements was 92%, ranging from 68 to 100%. Three new statements were proposed by participants during Round 2 to be reviewed in Round 3.

Education statements showed the highest agreement, with a mean score of 96% and only one item not reaching consensus. That statement was "*There is often a disconnect between university education and real-world clinical practice*".

Mean agreement for role extension statements was 90%, with scores ranging from 68 to 100%. Three statements did not reach 80% consensus threshold. An example was "The use of AI for online plan selection, adaptation and dose monitoring upgrades RTT roles". These results are presented in Fig. 4.

The statements drafted for the theme "career progression" are provided in Fig. 5. Three statements in this theme also fell below the consensus threshold. An example of this was "New technologies eliminate certain roles within the RTT profession.".

A high level of agreement was recorded across all themes, however, participants noted that in training and experience in many new

Fig. 3. Statements related to the theme "Education" generated in the thematic analysis and percentage of expert agreement for each statement.

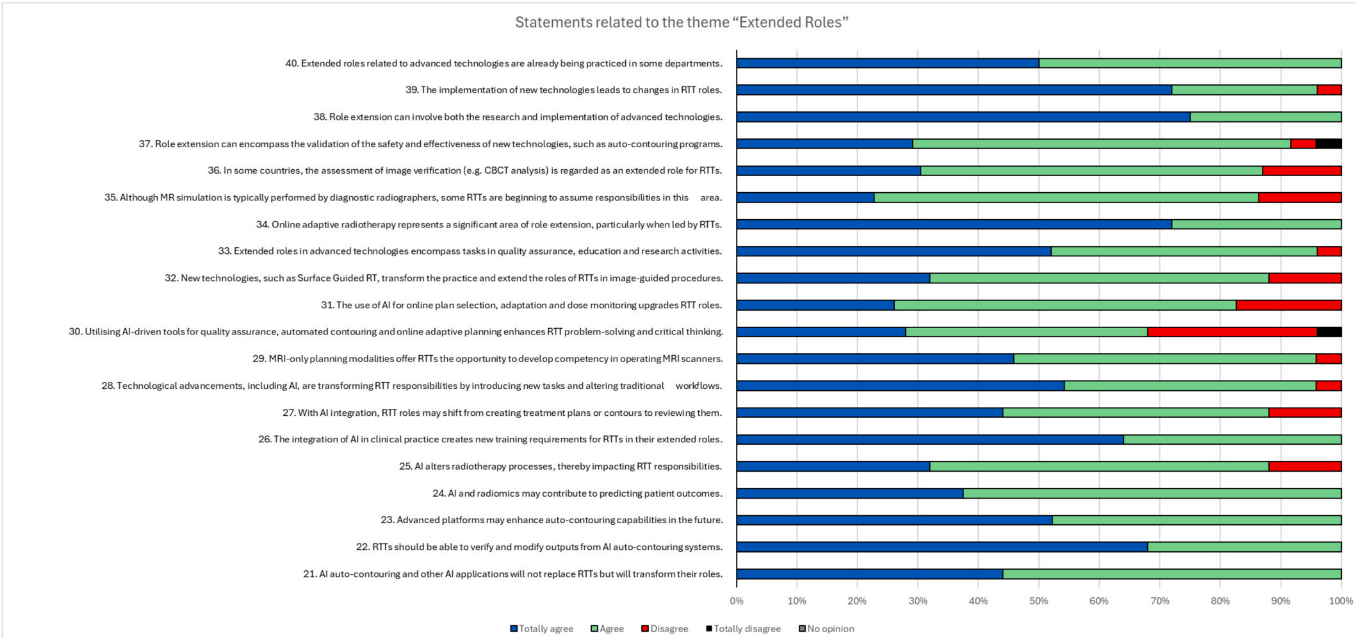

Fig. 4. Statements related to the theme "Role Extension" and percentage of expert agreement for each statement.

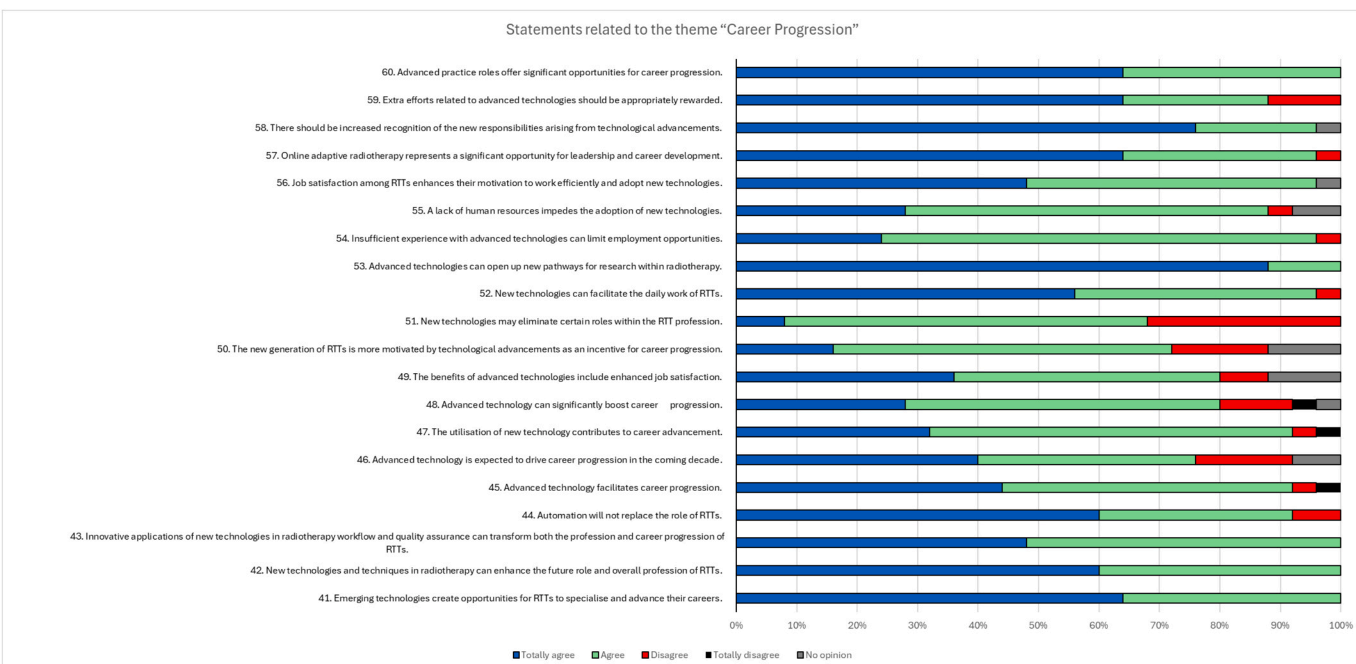

Fig. 5. Statements related to the theme "Career Progression" and percentage of expert agreement for each statement.

technologies remained limited. Interpretation of results are presented in the discussion.

Round 3 – workshop

During the second workshop, the statements that had already met the consensus threshold were presented. The discussion focused on the new statements proposed by participants and on those that did not reach 80% agreement in Round 1 (Fig. 6).

Round 4 – survey

Nineteen participants, equal to 88% of the group, and four faculty members completed the Round 4 scoring of the new statements displayed in figure 6 through the survey circulated after the workshop.

All revised statements achieved agreement above the 80% threshold, with a mean agreement of 98% and a range of 87 to 100%. Workshop 2 discussions emphasised the need for strong foundational knowledge to assess AI generated outputs and highlighted that clear pathways are required for RTTs to transition and progress as technology evolves.

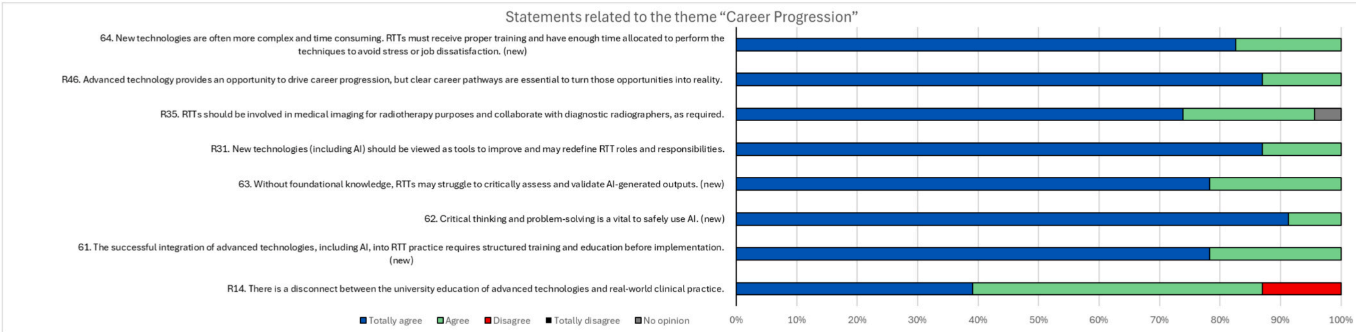

Fig. 6. Round 4 statements and level of agreement.

Discussion

The ESTRO RTT Committee workshop explored how technological innovation is reshaping RTT education, role extension and career progression. The Delphi process produced sixty-one consensus statements (with agreement > 80%) (figures 3–6), outlining clear recommendations for universities, employers, professional bodies and policymakers, indicating how the RTT workforce must evolve in response to rapid developments in radiation oncology. This Delphi methodology allowed us to follow a robust process, representing participants' perspective from diverse regions and roles.The range of technologies considered in this work covered established clinical tools to near-future innovations and merging therapeutic techniques, all influencing how RTTs are educated, trained and deployed. These included IGRT, online ART and MRI-only based planning and emerging forms of automation and AI, among others. The 2022 ESTRO RTT workshop described how these tools are transforming imaging, planning, QA and decision-making [3]. This current Delphi consensus extends this work and shows that AI is now central to how RTT practice is developing (Fig. 2), a trend mirrored in other research [7,8,17,18].

The participants strongly agreed that advanced technologies expand RTT roles rather than replace them. RTTs must be able to check, verify, modify and validate AI-generated outputs, such as auto-contours and adaptive plans, increasingly shifting their responsibilities from task execution to task oversight and clinical decision support. Reflective practice, problem solving and critical thinking were consistently identified as essential skills, particularly for AI- and ART-based workflows. Although some authors warn that technology may reduce RTTs to "button pushers," extensive literature supports our finding that RTT roles will increasingly focus on validation and QA, with time saved redirected toward patient care [17,18].

This study highlights that the profession is advancing alongside technology and requires enhanced skills across all levels of practice. Participants supported expanded RTT involvement in medical imaging, including collaboration with diagnostic radiographers, provided that governance prevents role creep. Shared MRI-based workflows were seen as particularly beneficial. They emphasised that not all changes in scope require advanced practice roles and that workplace culture should support broad skills development. Ryan et al. (2021) similarly noted that new technologies, such as AI, can redefine the profession. However, the authors also emphasise that skills are key to ensuring the successful implementation of these technologies [18]. Therefore, to ensure that RTTs' professional role evolves and is redefined in a favourable way for this profession, it is key to invest in their upskilling. Our results demonstrate that technology can support career progression when clear pathways exist, though current training opportunities remain limited. According to group consensus, AI should be viewed as an opportunity to improve accuracy, manage workload and foster leadership, provided sufficient education and protected learning time are available.

We also found that new technologies can enhance job satisfaction and professional motivation, but these benefits depend on adequate training, supervision and resources. However, persistent gaps in training and recognition undermine engagement and limit progression [9,13]. Workforce planning, education systems and professional recognition must align with technological change to support retention and sustainability. This may also explain why statement 50 ('The next generation of RTTs is more motivated by technological advancements as an incentive for career progression') did not reach consensus after Round 1. Motivation for career progression is likely influenced by multiple factors beyond technology alone, including recognition, structured career pathways, organisational culture, and access to training opportunities [11,19,20]. Similar observations have been reported in comparable workforce and professional development studies, where technological innovation was not consistently identified as the primary driver of career motivation reinforcing the view that career progression in RTTs is multifactorial and context dependent [3,19,20].

It also became clear that exposure to and understanding of new technologies must be built into formal education in both pre- and post-graduation. Structured continuing professional development (CPD), simulation-based learning and cross-centre collaboration were identified as key to equitable access and alignment with current clinical needs to support effective patient care [21,22]. Although ESTRO provides frameworks for RTTs for both bachelor's and post-graduate (master's level) education, significant international variation persists in RTT pre- and post-graduate educational programmes worldwide [23–26]. Differences in regulations, professional structures and culture continue to challenge standardisation [19,22,27,28]. In several countries, RTT education is not at the bachelor's level, and combined imaging-RT programs reduce RT-specific training and competencies [22,28].

The workshop participants supported standardised educational frameworks and stronger university–clinical partnerships to bridge theoretical learning and clinical expectations, aligned with ESTRO European Qualifications Framework levels 6–8 standards, which defines knowledge, skills and competency expectations for Radiation Therapists from graduate to expert level and are used to harmonise education, support advanced practice development, and promote quality and safety in radiotherapy practice internationally [23–26]. However, the perceptions of the gap between academic training and real-world practice varied considerably among participants, as demonstrated by the wide variation in agreement with this statement (see Fig. 3), reflecting the international differences in clinical exposure, resources and access to technology in RTT programmes [22]. Participants identified these differences based on their own geographical and institutional backgrounds.

Beyond technical operation of advanced systems, our findings also suggest a growing need to integrate AI literacy, data ethics, and informatics into both pre- and post-graduate RTT education. This aligns with consensus statements highlighting that safe AI implementation requires structured training, as well as strong critical thinking skills to evaluate AI-generated outputs. Literature shows that technological innovation is expanding RTT decision-making responsibilities and requires understanding of automation limitations and data interpretation [3,7,8,17,18].

Inequitable access to advanced technologies also contributes to practice variation. Disparities between high-, middle- and low-income countries limit opportunities for developing practical competencies [27,29]. This affects the opportunities students have to develop practical skills during their training and early career stages. Virtual and blended learning can mitigate this by enabling international expert input providing the opportunity to strengthen RTT preparation, specifically in middle- and low-income countries [30].

As mentioned before, CPD is considered essential for maintaining a skilled and adaptable workforce, but is constrained by barriers such as lack of funding, protected time and formal recognition [19]. Participants encouraged integrating learning into the clinical day to improve access and impact. Support for CPD varied widely. Some RTTs received departmental or government-funded development. Others relied on self-funding. This highlights the need for more equitable CPD structures across Europe and beyond. Stronger collaboration between hospitals, academia and industry partners can help address these gaps and support high-quality oncology care [31–34]. These partnerships can provide real-world training opportunities, support the integration of innovative technologies, strengthen clinical skills and improve patient outcomes.

A new role pushing technological innovation forward is that of Advanced Practice Radiation Therapists (APRTs), who strengthen patient care, clinical implementation, services and modern RT practice. Beyond delegated tasks, APRTs apply specialist knowledge, leadership and autonomous decision-making to optimise pathways. Evidence shows they improve access, satisfaction, capacity, and cost-effectiveness, while enhancing professional motivation and creating opportunities for career progression [6,20,35,36], advanced practice varies widely across Europe and beyond in terms of titles, scope, and education [37,38]. Participants supported standardised frameworks, including a tiered competency model defining entry-level, advanced and expert roles aligned with national contexts. Clear structures support safe practice and career development (Fig. 3).

Although technological advancement was viewed as a driver for specialisation and leadership roles. Many extended tasks, such as image verification and MR simulation, are already routine but recognised inconsistently worldwide. Role expansion requires access to training, clear competencies and institutional support. According to the participants, career progression further depends on pathways that recognise increasing autonomy and responsibility. While an expanded scope of practice does not always lead to a formal advanced practice designation, professional development should be supported and recognized across all levels of the workforce.

Conclusion

Technological innovations are fundamentally transforming the RTT practice, creating both opportunities and alongside notable challenges. To ensure the resilience and continued relevance of the RTT profession, it is imperative to establish standardised and adaptable educational frameworks across all levels of training. Fostering an environment that supports lifelong learning and CPD is essential. This requires active collaboration between hospital, academia, industry and dedicated investment from both institutional and governmental sources.

As the discipline evolves, roles of RTTs are expanding and gaining clearer recognition, particularly in emerging areas such as AI, particle therapy, image-guided RT, ART and advanced imaging techniques. Structured career pathways in these domains can strengthen retention, motivating practitioners, and promoting professional satisfaction.

T his paper synthesises recommendations that reflect consensus for management, policy, education, training, careers and professional roles of RTTs in the context of advanced and innovative technologies. The consensus reflects the collective views of a diverse group of experts and provides an important practical direction for the accelerated and effective use of these technologies. Strengthening the RTT workforce through education, role clarity and professional recognition will support high quality are across global RT services.

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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