# A review of the competences of Therapy Radiographers working in the linear accelerator across Europe: Systematic search and thematic analysis

# Introduction

The practice of radiography is over a hundred years old, beginning just after the discovery of x-rays1,2, and from the earliest days there has been much debate about the role of the radiographer in the field of radiotherapy3.

The history of radiotherapy has been one of constant, rapidly changing and ever-expanding technology and radiographers have been at the frontier of the developments that have taken place in health and health care delivery over the years3–6. Financial and societal pressure was made for a specialisation of these professionals7,8 as a result of technological advances, with the profession constantly changing to adapt to these evolutions, affecting the definition of the profession9–11.

The therapy radiographer (TR) can be defined as the health-care professional that uses ionising radiation to treat various pathologies (mainly cancer). However, the role of the TRs also includes the planning of radiotherapy treatments, image acquisition using different techniques and modalities, patient care, among others12. However, the description and roles in Europe can vary from country to country because the profession is not regulated at European level13.

This study focused on the most common role of the TRs which is the administration of radiotherapy to patients using a linear accelerator (linac). This work refers to the linear accelerator therapy radiographers as “linac-TRs” for simplicity, acknowledging this is not a recognised title. Although the role is common, it is very complex as it requires a wide knowledge of anatomy, physics, pathology, radiotherapy techniques, amongst other subjects, as well as a vast number of skills including accurate positioning of the patient or verification of radiologic images, resulting in a panoply of competences.

The European Skills/Competences, qualifications and Occupations (ESCO) recently upgraded the classification of Radiographers from “Technician and associate professions” to “Professionals”14. This supports the notion that the tasks performed by these professionals require a higher level of responsibility and autonomy, reinforcing the need to study the competences of these professionals.

Despite the fact that professionals can move and practice between European countries (especially within the European Economic Area - EEA)13 and several actions have been put in place to achieve homogeneity of education in Europe (such as the Bologna process15,16, the various ERASMUS projects17 and the Tuning project18,19) the discrepancies are still evident in the education of therapy radiographers20,21 and in the regulation of the profession across Europe22.

The competences of these professionals can be found in benchmarking documents from different professional organisations, in national and European regulation and in the literature18,23–27. However, these documents vary in scope: some are specific for TRs, others mention competences for both radiotherapy and medical imaging, while some are specific competences for radiation protection. Therefore, the recommended competences vary across these guidelines and a compilation of data would be of utmost importance. This is particularly useful since the current educational paradigm is to define the learning outcomes in terms of competences28 as it can be seen in the various benchmarking documents regarding TRs’ education18,23–27.

Since this work has a European scope, the definition of “competence” published on the recommendations for the European Qualification Framework (EQF), was used:

“Competence means the proven ability to use knowledge, skills and personal, social and/ or methodological abilities, in work or study situations and in professional and personal development. In the context of the European Qualifications Framework, competence is described in terms of responsibility and autonomy”29(p11).

From the above definition, it can be concluded that the knowledge and skills that underpin the acquisition of these competences is indirectly being studied when studying competences29. In addition, the development of a competence requires two aspects that are especially important for healthcare professionals: responsibility and autonomy29–31.

The identification of competences is a complex process since these can be described at different levels of specificity. Certain general competences can be broken into more specific competences32. An example given by Gillan at al33 is that the competence of “practising based on evidence” would only be achieved by performing a series of other specific competences, namely, “questioning practice, evaluating ideas, critically analysing the evidence, and applying the learning achieved to future practice”33(pp430-431); the former is a general competence and the latter are specific competences.

## Aim

The aim of this study was to identify the competences of the linac-TRs in the European setting, according to published literature. This study entailed the assessment of recent and relevant literature, performed over a period of three months (March-May 2018).

The results are particularly relevant for Universities/Higher Education Institutions, as this work can support educators in the design of academic programmes that cater for a European market. In addition, many other stakeholders can use this newly generated knowledge e.g. (i) employers when employing TRs to practise in the Linac or alternatively it may identify further training that should be offered to the employees; (ii) regulators may define specific competence requirements to practise the profession; (iii) other stakeholders such as patients, students, radiographers

# Methods

A search query was constructed to be used in this systematic search of different databases and journals. This query was based on three main key words: *competences*, *therapy* *radiographer* and *linear accelerator*. A map of the synonym keywords was constructed based on a previous literature review and expertise of the researchers.

All titles for the profession as found on the Regulated Profession Database and published by the European Federation of Radiography Societies (EFRS) were included in the query.

The inclusion of keywords related to “Linear accelerator” may not focus on this role, since these terms are also mentioned in other roles of the TR, however, it filtered to roles in radiotherapy. The selection of publications related to the actual practice of the profession in the linac was performed through the appraisal of the publications.

The search query was as follows:

(Competenc\* OR task\* OR role\* OR skill\*) AND (radiographer\* OR ((radiolog\* OR radiograph\* OR roentgen OR diagnostic OR electroradiology OR radiation) AND (technologist\* OR technician\* OR therapist\* OR engineer)) OR Radiotherapist\* OR RTT\*) AND (“linear accelerator” OR “linear accelerators” OR linac\*)

This query was run on the following databases and journals: Academic search complete, CINAHL Plus with Full Text, MEDLINE and PubMed, ScienceDirect, ProQuest Education Journals, ERIC (ProQuest), Radiography journal, tipsRO journal.

Since the role of the TR is constantly changing due to the evolution of medicine and technology, the studies included were limited to those published in the 10 years prior to the literature review. In all databases, an alarm was setup to inform the researcher about new publications matching the query. The impact factors of the journals or citations of the paper indicate the prestigious nature of the publication but were not considered as inclusion or exclusion criteria.

The compilation of the list of competences was done through the identification of all competences that might be performed by the linac-TR and the relevant publications were selected based on the following inclusion/exclusion criteria:

|  |  |
| --- | --- |
| **Inclusion criteria:** | * Competences of TRs practising on the linear accelerator.
* IMRT/VMAT techniques are included due to extended use of this modality in current practice.

The statements in the literature were considered to be a “competence” when:* The literature considered them as such or
* The literature identified that a certain task is performed under radiographers’ autonomy and responsibility (as per EFQ definition29).
 |
| **Exclusion criteria:**  | * Competences specific to other roles of the TR (planning, CT, mould room, manual calculations).
* Competences related to advanced techniques (SRT, SRS, adaptive RT, MRI-linac)
* Competences in veterinary radiotherapy
* Competences developed in further education (above the required to practise)
* Non-English publications
* Publications discussing competences from countries outside Europe
 |

To increase the breadth of the search, relevant grey literature was also analysed. Recommendations from European and worldwide organisations, regarding the competences or curriculum of the radiography courses were also used to identify competences18,23–27. In addition, snowballing34 was also performed (Figure 1).

These competences were assessed and an inductive open thematic analysis35 was performed using NVivo software (v. 11.0) for coding and analysis. The thematic analysis allowed organisation of the competences identified across different documents, under the corresponding themes. It also allowed the compilation of a comprehensive list of the dimensions of these professionals’ competences. The coding was performed by a single researcher with expertise in the education of radiographers. The resulting competences and themes were assessed by all researchers and five external experts resulting in further amendments to the list and themes.

# Results

## Results of the literature search

The query was run on the databases and journals described above, a total of 114 sources were identified. After removal of duplicates, a total of 110 sources were left. Following assessment of these papers, a total of 22 sources were considered relevant to answer the research question. Snowballing was performed which added other scientific publications, benchmarking documents, guidelines and recommendations, reaching a total of 28 sources (Figure 1).

Figure 1 – Literature selection process

## Thematic analysis

From these sources, a total of 363 competences were identified in the literature. These were analysed by the researchers and coded using NVivo (v 11.0). A total of 72 sub-themes were identified and then in order to easily understand them, these were grouped under 16 themes. Using the mentioned themes as a guideline, the competences were listed and the repeats were removed resulting in a total of 170 competences (Table 1). The competences for each theme are discussed in more detail below.

Table 1 – List of competences of the therapy radiographer practising in the linear accelerator in the European setting, according to published literature.

|  |  |
| --- | --- |
| **THEME/Sub-theme** | **Competence** |
| **QUALITY AND RISK MANAGEMENT** |
| **Risk Management** | * Perform risk and hazard analysis in the workplace
* Reduce risks and hazards for patients and staff
* Ensure appropriate workload for safe practice
* Report incidents and near-misses
 |
| **Quality Improvement** | * Contribute to the a continuous improvement of practice
* Analyse errors and near-misses and ensure prevention of future events
* Develop technology and its application into practice
 |
| **Radiation Protection** | * Recognise the radiation hazards in the workplace
* Ensure protection of staff and public against radiation
* Ensure protection of patients against radiation
* Use personal dosimeters
* Know and adhere to legislation regarding radiation protection
 |
| **Justification** | * Be able to select a suitable treatment, based on own analysis
* Critically question radiological referrals
* Refuse to carry out an exposure which, in one’s professional opinion, is inadvisable
 |
| **Optimisation** | * Maintain ALARA principle
* Minimise dose to normal tissues
 |
| **Carry out audits** | * Develop and implement audit programmes
 |
| **Evidence-Based Practice** | * Apply relevant scientific evidence into practice
* Take decisions based on scientific evidence
* Apply results of research into practice
 |
| **Individual Professional Development** | * Continuously assess their own competences, knowledge and skills
* Ensure their own professional development
 |
| **Development of the profession** | * Contribute to the profiling of the profession
* Contribute to the content-related development of the profession
 |
| **Protocols, Standards, Guidelines and Regulations** | * Implement professional standards into professional practice
* Adhere to legal regulations
* Follow national and international guidelines
* Implement institutional protocols into practice
 |
| **Application of Knowledge** | * Be able to apply necessary knowledge into critical analysis and decision making
 |
| **DECISION MAKING AND CRITICAL ANALYSIS** |
| **Critical Analysis** | * Critically analyse results from any procedure
* Critically analyse results from research and literature
* Continuously question practice
 |
| **Decision Making** | * Make decisions within the remits of own competences
* Be aware of the process of decision making
* Take decisions to improve patient outcome
* Be able to apply corrective actions
 |
| **MANAGEMENT AND LEADERSHIP** |
| **Management** | * Plan the workload of the treatment unit for safe practice
* Set priorities
* Manage the use of resources
* Assess educational needs
* Identify factors of burnout
* Promote transparency
* Participate in project management
 |
| **Leadership** | * Contribute to team development
* Contribute to conflict resolution
* Promote expertise of colleagues
* Promote openness to discussion
* Give feedback to colleagues
* Lead new initiatives and projects
 |
| **Efficiency** | * Practise efficiently
* Ensure organisation of the treatment unit is optimum
* Ensure an interruption-free environment
 |
| **PATIENT CARE** |
| **Patient Dignity** | * Adopt a holistic approach to the patient
* Maintain a respectful approach
* Take patient’s perspective into account during practice and decision making
* Show intercultural awareness
* Respect patient’s privacy
* Demonstrate care towards the patient
* Act as an advocate for the patient
* Empower the patient to be involved in their treatment
 |
| **Patient Identification** | * Perform appropriate patient identification
 |
| **Patient assessment** | * Identify patient requirements and concerns
* Assess patient physically
* Assess patient psychologically
* Assess treatment side effects
* Assess social aspects of patient interaction
* Develop patient assessment protocols
 |
| **Management of Side-Effects** | * Give advice with regards to management of side effects
* Refer to other professionals when advisable
 |
| **Patient Information** | * Give information prior to treatment
* Give information during treatment
* Adapt the information for individual patient needs
* Explain the radiotherapy process to the patient
* Develop patient information material
 |
| **Consent** | * Seek consent prior to any procedure
 |
| **Follow up** | * Give information after the last treatment
* Perform patient review after the last treatment
 |
| **First Aid** | * Provide first aid to patients, if necessary
 |
| **Infection Control** | * Perform appropriate infection control prior, during and after each procedure
 |
| **TEAM WORK AND MULTIDISCIPLINARITY** |
| **Team Work** | * Promote collaboration
* Promote expertise of other colleagues
 |
| **Multidisciplinary** | * Be involved in a multidisciplinary approach to the patient
* Work with other professionals to improve practice
* Recognise limits of the radiographers roles
* Seek other professionals expertise when required
 |
| **Peer review** | * Implement and participate in the peer-review processes
* Analyse the results of peer-reviewing
 |
| **COMMUNICATION** |
| **Communication with other TRs** | * Provide the necessary information to colleagues
* Establish appropriate verbal and non-verbal communication with other TRs
* Advise other members of the team
 |
| **Communication with multidisciplinary team** | * Provide other professionals with necessary information
* Establish appropriate verbal and non-verbal communication with other professionals
* Advise other professionals
 |
| **EDUCATION** |
| **Education of other members of staff** | * Teach and supervise staff to develop their expertise
* Transmit new knowledge to other staff members
* Participate in the education of other professionals
 |
| **Education of students** | * Teach and supervise students
* Transmit knowledge to students
* Be responsible for the student’s acquisition of clinical skills
 |
| **PHARMACOLOGY** |
| **Administration of pharmaceuticals** | * Administer pharmaceuticals to patient
* Critically assess the pharmaceuticals prescribed
* Take responsibility for pharmaceuticals-related tasks
 |
| **Response to complications** | * Respond to complications of the administration of pharmaceuticals
* Seek advice from other professionals when necessary
 |
| **PROFESSIONAL AND ETHICAL PRACTICE** |
| **Autonomy** | * Practise autonomously
* Perform decision making autonomously
 |
| **Responsibility** | * Take responsibility for the tasks performed
 |
| **Limitations** | * Develop self-awareness
* Recognise limitations of their scope of practice
* Seek advice when necessary
 |
| **Accuracy** | * Practise with high levels of accuracy
* Accurately prepare and administer radiotherapy treatments
* Accurately complete documentation and reports
 |
| **Best Practice** | * Practise following the highest scientific, ethical and moral standards
* Ensure all aspects of their practice are optimum
 |
| **Confidentiality** | * Maintain confidentiality at all times
 |
| **Ethics** | * Demonstrate ethical approach to the patient
* Take decisions ethically
* Deal with ethical issues in the workplace
 |
| **Good Character** | * Exemplify good character within a professional context
* Internalise professional standards in private life
 |
| **Professional appearance and manner** | * Project a professional image at all times
* Ensure a professional manner and appearance
 |
| **Self-reflection** | * Practise self-reflection on a regular basis
 |
| **RESEARCH** |
| **Carry out research** | * Initiate and develop research ideas
* Carry out research independently and as part of a multidisciplinary team
 |
| **Clinical Trials** | * Participate in national and international clinical trials
 |
| **Dissemination of research results** | * Present and publish results of research
 |
| **Implement results of research** | * Implement the results of research into practice
 |
| **RECORDING AND HANDLING OF DATA** |
| **Record data** | * Maintain and update records of any relevant information
* Record patient’s side effects
* Document any information in a coherent way
 |
| **Handle and archive data** | * Administer and archive data
 |
| **FILE VERIFICATION** |
| **Assess patient’s file** | * Revise the file prior to irradiation
* Report errors
 |
| **Plan analysis** | * Assess dose distribution in the radiotherapy plan
* Evaluate the dose volume histogram
* Evaluate other plan options
* Assess plans for clinical acceptability
 |
| **Verify prescription** | * Interpret treatment prescriptions
* Verify treatment prescription and report discrepancies
* Compare the plan with the prescription
 |
| **Data transfer** | * Carry out necessary data transfer checks
 |
| **POSITIONNING AND IMMOBILISATION**  |
| **Critically assess immobilisation**  | * Confirm appropriate immobilisation considering aim of treatment and patient condition
 |
| **Reproduce immobilisation** | * Position the patient according to planning and simulation
 |
| **Accuracy**  | * Ensure accuracy in positioning
 |
| **Patient comfort** | * Promote patient comfort, as much as possible
 |
| **DELIVERY OF TREATMENT** |
| **Choice of devices** | * Choose the appropriate therapeutic, imaging and ancillary devices
 |
| **Parameters check** | * Check if appropriate treatment parameters were selected
 |
| **Treatment administration** | * Administer treatment accurately and safely
* Apply best practice at all times
* Interrupt treatment, if required, in an emergency
 |
| **Patient observation** | * Constantly observe the patient during treatment
 |
| **Avoid treatment gaps** | * Avoid radiotherapy treatment gaps
 |
| **VERIFICATION OF PATIENT SETUP** |
| **Image acquisition** | * Select the appropriate image modality
* Acquire planar (2D) images
* Acquire volumetric (3D) images
 |
| **Image interpretation** | * Analyse verification images:
	+ Analyse planar (2D) verification images\*
	+ Analyse volumetric (3D) verification images\*
* Take decisions regarding the action to take following image analysis, within the protocols
* Follow patient setup verification protocols
* Develop patient setup verification protocols
* Analyse images to evaluate the result of radiotherapy treatments
 |
| \* The sub-theme “Image interpretation” was further divided to include two sub-themes: Analysis of 2D and 3D images. |
| **EQUIPMENT QUALITY ASSURANCE** |
| **Perform QA** | * Perform daily QA of the linear accelerator
* Perform QA of imaging systems
* Carry out *in vivo* dosimetry
 |
| **Evaluate and report results of QA** | * Evaluate results of QA procedures
* Take corrective actions in view of QA results
* Report inconsistencies in QA procedures
 |

# Discussion

The themes described above vary with regards to how technical and how specific to the linac-TR the competences are (Table 2). Technical competences are those required to perform a specific job (or group of jobs) and are in alignment with the autonomous and responsible application of knowledge and skills in specialised fields such as radiography36. These are complemented by non-technical competences (”soft skills”) which can be applied to several professions36.

Table 2 – Classification of the competences with regards to technicality and specificity

|  |  |  |
| --- | --- | --- |
| **Non-technical competences** | **Technical competences (not specific of the linac-TR)** | **Technical competences (specific of the linac-TR)** |
| * Quality and risk management
* Decision making and critical analysis
* Management and leadership
* Team work and multidisciplinary
* Communication
 | * Professionalism
* Patient Care
* Pharmacology
* Research
* Education
* Equipment quality assurance
 | * File verification
* Positioning and immobilisation
* Delivery of treatment
* Verification of patient setup
 |

This demonstrates the complexity of the tasks performed by the linac-TR which include technical competences that are specific for the profession but also non-radiography specific competences such as research or team-work.

With regards to the literature sources, we can clearly distinguish between three types of literature: the grey literature with recommendations regarding the competences that should be developed by radiographers, white literature that aim to study competences and white literature that aims to study other matters but part of their discussion or conclusions includes the identification of competences. All were relevant for this study. The well-established competences were mostly found in the benchmarking documents18,23–27. Newly established competences of the linac-TR32,37–43 and very specific competences33,37,44–52 were more commonly discussed in the white literature.

The different dimensions of the competences developed by the linac-TRs are discussed in more detail below:

## Quality and Risk assessment

Quality and risk assessment processes was the most coded theme. The frequency of this theme may be correlated to the importance of these competences for these professionals in view of the risks of using ionising radiation. As part of this theme, there was also emphasis on continuous improvement in quality as a result of personal development and the application of research, guidelines and protocols into practice to protect all groups of people. This can be observed in literature, for example:

“Develop individual responsibility for the use of appropriate methods to reduce all risks and hazards which may affect self, patients, staff and the general public.”27(p7)

Ensuring that particular aspects of the TR practice, such as optimisation and justifications, are covered such as to “avoid unnecessary exposure and minimise necessary exposure as part of optimisation”23(p66)

## Decision making and critical analysis

The competences that fall under this theme ensure that the linac-TR must be autonomous and responsible for assessing each situation, using critical analysis and as a result apply decisions that allow improvement in the patient’s outcome and overall safety:

Radiographers should perform their roles “questioning practice, evaluating ideas [and] critically analysing the evidence”33(pp430-431)

 “Use professional decision making, independently or as a team member when carrying out radiation therapy”19(p9)

## Management and leadership

Linac-TRs must “Take on administration and leadership roles through supervisory responsibilities, process development, leading new initiatives, driving improvement [and] project management (...)”50(p390) as well as proper use of resources in an efficient matter47. This includes the management of the workload to ensure safe practice48.

## Patient Care

The competences around patient care were found to have multiple dimensions. Starting by ensuring adequate patient identification and finishing with following-up after the completion of the RT treatment. The patient care has a holistic scope and should include the patient’s family. The linac-TR must “facilitate the smooth entry into treatment for patients and family members experiencing radiotherapy for the first time”49(p21), “taking the patient’s physical and psychological aspects into consideration”24(p35).

Competences related to communication with patient were extensively discussed in the literature. These are sub-divided into several dimensions: patient information, empowerment, identification, assessment, consent and follow-up. Therefore the linac-TR must “inform, encourage, advise and support each patient before, during and post examination/treatment”27(p8)

## Team work and multidisciplinarity

This theme cropped up as a result of the multiple literature sources identifying the responsibility of “cooperation among team members”48(p575). This includes promoting each professional group and individual’s area of expertise47, “recognise the limitations to one’s own scope of competence and seek advice and guidance accordingly”23(p66) in order to offer the patient the best possible care. But also the assessment of each other’s practice for the sake of a better service to the patient:

“The specific inclusion of peer review as a component of the scope of practice for radiation therapists (...) is an emerging trend in radiation therapy clinical practice”32(pp321-322)

## Communication

Communication with patient was coded under “Patient Care”, therefore, this theme focused on communication with colleagues (radiographers and other professions):

The TR must “interpret, apply and disseminate the appropriate information for each stage of the process to the relevant personnel”53(p15) to “ensure an appropriate chain of care”27(p9)

## Education

Despite being a competence identified in most guidelines/benchmarking documents19,23,24,27,53, Smoke et al (2015) argue that it is an, “often overlooked, [TR] role. This includes undergraduate, graduate, and postgraduate students within the radiation oncology program. Education and orientation of other staff within the hospital may also be done by [TR]s”50(p390)

## Pharmacology

The TR should be competent to “assess and administer essential medication used in the professional context”19(p9) and “respond appropriately to contra-indications, complications and emergencies”27(p9) in both cases as part of the competences of both diagnostic and therapy radiographers.

## Professionalism

This theme was related to competences that can be considered generic to all professions and therefore was divided into multiple sub-themes such as ethical practice, autonomy, responsibility, accuracy, confidentiality, limitations and best practice (please see Table 1 for the complete list of sub-themes). Some example competences cited in the literature can be found below:

“Take individual responsibility for carrying out work in a safe manner”27(p6)

“Accept responsibility for one’s own actions within the scope of professional practice”19(p30)

“Accurately prepare and deliver a course of treatment”53(p7)

“Carry out treatment preparation and delivery based on best practice at all times”24(p19)

“Address identified gaps in the knowledge, skills, and judgment within [TRs] scope of practice”33(p104)

## Research

According to the literature found, “research and development [is] an essential component for a new staffing model [for TRs]”50(p390) and the TRs should be autonomous and undertake responsibility for audits and research (including trials)19,24,27,43,50. In addition, it is part of their competences to “disseminate results of clinical audit and research”27(p12) and “participate in the implementation of the research findings”24(p43)

## Recording and handling data

The linac-TR must be autonomous and responsible for “accurately and comprehensively complete all documentation”24(p38) and for the appropriate “archiving of [...] treatment data”27(p7) and “of data related to the patient”27(p8)

## File Verification

The linac-TR must be competent to “interpret the radiation prescription and treatment plan”27(p16). Some literature discusses this competence in detail and identifies which aspects must be checked by the TR, such as Dose-Volume Histograms (DVH) or Monitor Units (MU)19. The TR must perform critical analysis, with the aim of carrying out “plan evaluation for clinically acceptability”39(p677) and identifying and reporting errors23.

## Positioning and immobilisation

This theme encompasses very specific competences of the TRs practising on the linac. These professionals are responsible for “correctly positioning the patient consistent with implementation of the treatment prescription, (...) consistent with optimum treatment delivery”24(pp23-24). This demonstrates the responsibility for reproducing the patient setup that was defined during planning but also the critical assessment that this setup is optimum for patient. The linac-TR must also be responsible for “taking the patient’s physical and psychological aspects into consideration”24(p35) and “ensuring comfort as far as possible”24(p32)

## Delivery of treatment

Another of the specific technical competences of the linac-TR is to “accurately (...) deliver a course of treatment to an individual patient”53(p7) using critical analysis to ensure the “use appropriate diagnostic, therapeutic and ancillary devices (...)”19(p30) and that “treatment delivery [occurs] in an accurate and safe environment”24(p35).

In particular, the literature states that the linac-TR has the responsibility to be vigilant during the exposure, in virtue of the multiple parameters to be selected during a RT treatment51 and their responsibility in “avoiding gaps in radiotherapy”39(p678)

## Verification of patient setup

The most relevant competence of the linac-TR in this theme is the acquisition of the verification images following the justification of the appropriate image modality19.

The verification image interpretation was the only sub-theme that was further divided as a result of one article where it described the competence to “interpret and critically evaluate the verification images”24(p32) for volumetric images (CBCTs) in addition to planar images45 and “make adjustments as necessary and in accordance with protocol”24(p32).

Despite the fact that development of protocols in radiotherapy was discussed before (under the theme “Quality and Risk Management”), the specific competence of “develop [the] position verification process”45(pp127-128) was mentioned in the literature.

## Equipment quality assurance

With regards to equipment QA competences, the TR must “apply quality assurance techniques”19(p30) but also “analyse and record the results and report any deviations”23(p72). Not only with regards to treatment machine but also the accessory equipment24 and “carry out in-vivo dosimetry”23(p72).

## Limitations of the study

Competences in languages other than English were not assessed, therefore, there is the potential for having excluded competences practised in non-English speaking countries. Despite the large range of documents found by the search query, there is the small chance of relevant literature to have been missed during the systematic search.

With regards to the coding process, this was performed by a single researcher. To reduce researcher bias the thematic analysis was followed by the verification of the competences list by three other researcher and five external experts.

Another limitation of this methodology was that the competences identified may not be practised by TRs across Europe: they may not be developed in all countries. In addition, some of the competences are part of recommendations, and may not be in practice yet. These competences may, in some countries/institutions, be practised by other professions, however, these results show that in some cases they can also be performed by TRs. Regardless of the profession practising the task, patient safety can only be ensured if the individual is competent to do so. In view of this, the list should be used as a recommendation for the design of educational programmes or for further development for professionals already in practice and not as a list of practised competences across Europe.

# Conclusion

This is the first study to comprehensively collate all of the competences recommended to be developed by TRs practising in the linear accelerator across Europe from all the available literature.

The most evident conclusion of this study is that there is a great number of competences that are identified in the literature as being the responsibility of linac-TRs. This is the result of very intricate tasks that require the TR to apply their knowledge and skills in order to autonomously take responsibility for those tasks.

Differences in regulation of the profession led to differences in the competences developed and practised by TRs in a specific country, therefore, the competences identified in this literature review are not country-specific but aim to develop education in the pan-European setting.

The lack of a single guideline for the practice of the linac-TRs has both positive and negative aspects. On the negative side it is not possible to define from a single source the competences of these professionals, while, on the positive side, different researchers and entities published recommendations for these professionals from different perspectives leading to a richer availability of information. This work aimed to eliminate the negative aspect by gathering all the different points of view into a single document.

A recommendation is that the competences identified in this study (Table 1) should be endorsed by education institutions across Europe. This would promote the free movement of professionals between countries since one of the requisites to achieve recognition of qualifications in the EEA is to have similar curriculum13,54. However, all the other criteria must also be achieved such as a similar academic level and course duration.

Different levels of competence can be achieved as a result of education at different academic levels21,22. When academic level was discussed in the analysed literature, the recommended level is the university first cycle (EQF level 6)19,23,24,27,53 which corresponds to the following competence descriptor, according to EQF:

“Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts (and) take responsibility for managing professional development of individuals and groups”29(p13)

In addition, and perhaps more importantly, patients undergoing radiotherapy can only be offered the best treatment and consequently the best chances of a cure independent of their country, if professionals undertake roles for which they are competent. Therefore, ensuring that appropriate competences are developed by TRs before entering the job market is of utmost importance for the success of the RT treatment.

These competences can also be used to identify the gaps in training of linac-TRs and act as a support to evidence-based decision-making by all stakeholders (such as universities, employers, radiographers, patients, regulation agencies and students).

Further research is required to determine which of these competences are developed in educational institutions across Europe and which are practised by TRs in the clinical setting. It is also recommended that the same procedure is applied to other roles of the radiographers in both diagnostic and therapy.

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