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Identification of research priorities of radiography science: A modified Delphi study in Europe

Sanna Törnroos MHSc, RT[1] | **Miko Pasanen MSc**[2] | **Helena Leino-Kilpi PhD, RN, FAAN, FEANS**[3] | **Eija Metsälä PhD, RT**[1]

[1]Department of Nursing Science, University of Turku and Metropolia University of Applied Sciences, Turku, Finland

[2]Department of Nursing Science, University of Turku, Turku, Finland

[3]Department of Nursing Science, University of Turku and Turku University Hospital, Turku, Finland

Correspondence
Sanna Törnroos, MHSc, RT, Department of Nursing Science, University of Turku and Metropolia University of Applied Sciences. Joukahaisenkatu 3-5, FI-20520 Turku, Finland.
Email: sanna.j.tornroos@utu.fi

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Abstract

Radiography science is a new discipline among health sciences. It is a discipline that investigates phenomena in medical imaging, radiation therapy, and nuclear medicine. It has merged from the need to provide research evidence to support these services. The domain of the discipline needs clarification and more research should be focused on its paradigmatic issues. Radiography research priorities have been previously charted on a national level in different countries but the viewpoint has been that of the needs of the profession, not of the discipline. This study aimed to identify the priorities of the discipline. The method chosen was a modified version of the Delphi technique with two rounds. The expert panel consisted of 24 European radiography researchers with long professional experience. This study shows that the research priorities in radiography science are related to the phenomena of radiographers' profession, clinical practices, and the safe and high-quality use of radiation and technology for medical imaging, radiotherapy, and nuclear medicine. Identifying these priorities can help focus research onto most important topics and clarify disciplinary perspective.

KEYWORDS
Delphi technique, discipline, radiography science, research priorities

Key points

- The research priorities in radiography science are related to the phenomena of radiographers' profession, clinical practices, and the safe and high quality use of radiation and technology for medical imaging, radiotherapy, and nuclear medicine
- Eight research topics were rated high in importance. These were the benefits of using artificial intelligence in radiography, safe integration of artificial intelligence into practice, impact of new technology, evidence-based clinical practices, radiation safety, radiation optimization, patient outcomes in medical imaging, and image interpretation.
- Radiography science differs from other health sciences in its priorities

1 | INTRODUCTION

The European Commission's Horizon Europe (2021), a major funder of health research, includes in its policy aims finding new ways to keep people healthy, and developing better diagnostics and more effective therapies. Almost all patients in health care go through diagnostic examinations at some stage of their care pathway. Medical imaging rates are increasing due to innovations in technology and treatment methods (Smith-Bindman et al., 2019), new applications in screening (Fedewa et al., 2021), the rising number of older people (United Nations, 2019), and increases in multimorbidity (Head et al., 2021) and in cancer cases (Tanskanen et al., 2021). Cancer is a growing health problem, and radiotherapy is used in cancer treatment in about 50 per cent of cases (Baskar et al., 2012). Radiography is an allied health science acting in the field of diagnostic imaging and radiotherapy. The knowledge base in radiography science is a combination of patient care and high technology and consists of medical imaging, radiotherapy, and nuclear medicine (Lundgren et al., 2015). Research in radiography has a long history, but as a discipline of its own it is still evolving. Rapid changes in the field set demands for high-quality research, which is difficult to execute without solid foundations and a clear disciplinary perspective. It would be vital to conduct research from the discipline's own paradigm to develop clinical practices at the grass-roots level where the patients encounter the diagnostic and therapeutic services. Radiography science in Europe is not a unified discipline. There are differences in the education, curricula, and research practices (Couto et al., 2018; McNulty et al., 2016). Advantages of a unified discipline would be closer research collaboration between researchers and academic institutions offering radiography as a discipline, better understanding of what the focus of the discipline is and its philosophical assumptions, not to mention the benefits of sharing limited research funding of small subspecialties. In order to clarify a unified disciplinary perspective, it is important to identify the research priorities of radiography science.

1.1 | Background

Radiographers consider their own research important but are not actively involved in research (Vikestad et al., 2017). The number of radiographers with a doctorate degree is around 0.1 to 0.3 per cent of the workforce (Andersson et al., 2020; Ekpo et al., 2017). This is significantly lower than the number of nurses with doctorates, around 1 to 1.9 per cent of the workforce (Rosenfeld et al., 2022; Orton et al., 2020). There is an active research community in the discipline but the majority of the published articles are from a small group of researchers (Snaith, 2013). Radiographers are engaged in research activities as assistants or collectors of data but many studies are led by other professionals due to radiographers' limited experience and confidence in conducting research (Saukko et al., 2021; Dennett et al., 2021). However, most radiography professionals tend to think that radiographers should conduct research and lead research projects (Saukko et al., 2021; Ooi et al., 2012). Advancement of research engagement would require knowledge about scientific methods, support from colleagues and other professionals, and a positive research culture in workplaces (Bolejko et al., 2021).In health sciences, research interests and priorities have been studied for reasons such as developing an informed set of research priorities (Shepherd et al., 2017), augmenting previously identified research priorities with a new group (Frankenberger et al., 2019), identifying research topics (Wielenga et al., 2015), developing a research agenda (Brenner et al., 2014), and prioritizing efforts and resources (Garner et al., 2021). In nursing science, research priorities have been set to both broad foci (such as health, practice, education, and leadership) and to various clinical categories (Strobehn et al., 2021). Research regarding dissertation topics in nursing identified quality of life, perception, job satisfaction, sleep, nursing roles, physical activity/exercise, turnover, leadership styles, simulation, and cancer as the most frequent topics (Strobehn et al., 2021). In the Nordic countries, research in nursing focuses mainly on patients' health problems (Lundgren et al., 2009). By contrast, in radiography, dissertations have focused on structural factors, clinical radiography, radiographic technology, and pedagogical approaches (Lundgren et al., 2019), indicating that radiography and nursing have diverging research priorities. The current discourse about radiography science resembles much of the discussion that nursing science faced in the early ages about its disciplinary perspective and focus (Lundgren et al., 2009).Areas of research interests for European radiography researchers have not previously been charted from the perspective of the discipline. Previous studies have explored the needs of the profession. Radiotherapists' research interests have been charted at the national level in Norway and Australia (Egestad & Halkett, 2016; Halkett et al., 2017). Studies in the research interests in radiotherapy indicate that the research interests are connected to patients, technical issues of radiotherapy, radiation safety, and issues of the staff (Egestad & Halkett, 2016). Research areas prioritized as most important were linked to the development of treatment techniques and their benefits and side effects to patients, as well as to concerns of the radiotherapist profession (Cox et al., 2010). Researchers have also stated patient focus and patient outcomes in radiotherapy as areas of research interest (Halkett et al., 2017).The College of Radiographers (2017) studied research priorities for the radiographer profession in the United Kingdom. A Delphi expert panel reached consensus in 133 priority areas. Five key themes for research were identified. These were technical innovations, patient and public experience, service and workforce transformation, accuracy and safety, and education and training. The Society of Radiographers working group for artificial intelligence (AI; Malamateniou et al., 2021) found that radiography research priorities should be set to investigate the impact of AI technologies on patients in medical imaging and radiotherapy, radiographer role development, and the development of practices with emerging AI-based technology. In Finland, the research focus in radiography science is reportedly in clinical radiographers' work, technical radiation usage and radiation protection, patient care and service, and service for a health care context (Sorppanen, 2006). Metsälä and Fridell (2018) found that radiography science primarily has technical and practical knowledge interests, but that critical knowledge interests exist as well.

1.2 | Aim

In this study, our aim is to identify research priorities in radiography science. The objective is to chart the opinions of radiography experts. We ask three questions to guide this study:

1. Which research topics do radiography science experts in Europe consider important for radiography science?
2. Which research topic do they see as most important?
3. Which research topics do experts in the field of radiography agree upon?

Agreement on topics is achieved when there is a consensus. The topics that reach consensus and are rated as being of high importance are considered the priorities of the discipline.

2 | METHODS

The Delphi technique was selected as the method. The Delphi technique is a widely used method in health sciences and it has been used in developing guidelines and establishing research priorities. The Delphi technique is characterized by the use of an expert panel, the members of which are anonymous to each other, and iterative rounds with feedback and the opportunity to alter one's opinion. The classical Delphi technique has at least three successive rounds but modified variations are numerous. The classical Delphi technique starts with an open first round (Varndell et al., 2021). The benefit of using a Delphi technique is the possibility of having an anonymous group opinion from a wide geographical area. It is especially suitable when there is a lack of agreement or incomplete knowledge (Trevelyan & Robinson, 2015). The Delphi technique has been widely used in identifying and building consensus on research interests and priorities in health sciences among health care professionals (e.g., Shepherd et al., 2017; Frankenberger et al., 2019).

2.1 | Design

A modified Delphi method with two rounds was performed. Instead of an open first round, we used a scoping review as the starting point of our study. In an earlier study (Törnroos et al., 2021), we identified 117 research interests for radiography science. They formed the basis of the first-round questionnaire. Some of the similar items were further merged by two authors (S.T. and E.M.) and eventually 84 items were included in the first-round questionnaire. The first-round questionnaire was piloted in Finland in August 2021 by four radiographers with experience and training in research. They commented on the readability and clarity of the questionnaire. The comments concerned the instruction text for the questionnaire, background questions about the discipline, headings, and the size of the open-ended answer box. The questionnaire was modified accordingly. The entire Delphi process is presented in Figure 1.

2.2 | Expert panel sampling

Experts were recruited through the European Federation of Radiographer Societies (EFRS). A recruitment invitation was sent by the EFRS to all member societies (40 national societies and 60 academic institutions of radiography education in Europe). The criteria for a panelist were (i) minimum of a bachelor's degree in any field of radiography (diagnostics, radiation therapy, or nuclear medicine); (ii) at least two published research articles in a scientific journal in the past 5 years; (iii) clinical work experience in the field; (iv) English-language skills (reading and writing); and (v) willingness to participate voluntarily. A total of 29 experts answered the invitation, with all but one expert meeting all the criteria. The first round of the questionnaire was thus sent to 28 experts.

2.3 | Data collection and analysis

Data were collected with the REDCap platform (hosted by the University of Turku). They were analyzed with IBM SPSS Statistics version 27. Categorical variables were summarized with counts and percentages. Variables did not follow normal distribution. High rankings on importance of the topics (6 or 7) were observed with most variables, with a few outliers distorting the mean. Median values and quartiles were thus selected to describe the level of agreement. The level of consensus was set to an interquartile range (IQR) value of ≤1. IQR is a measure of dispersion for the median. IQR of less than one means that more than 50% of all opinions are within one point on the scale. It is often used in Delphi studies as an objective way of determining consensus (von der Gracht, 2012). Stability of the responses between rounds was measured with a bootstrapped paired *t*-test, which is a valid test for two dependent samples with non-normal distribution (Dwivedi et al., 2017). A *p*-value of >0.05 indicates that there is no statistically significant difference between the responses in round two. A smaller *p*-value would indicate that there has been a significant change in the response. To test whether experts' educational background or position at work had a significant effect on their responses, we used the Fisher's extended test. We were unable to use the chi-square test because the expected number of answers per cell was under five.

2.4 | Round one

The 84 research topics (items) in the questionnaire were structured under six categories identified in the scoping review: (i) radiographer's profession (17 items); (ii) clinical practice in radiography (31 items); (iii) safe and high-quality use of radiation (12 items); (iv) technology in radiography (8 items); (v) discipline of radiography science (5 items); and (vi) management and leadership (11 items). Panelists were asked to rate the importance of the topic to radiography science on a 7-point Likert scale (not at all important, unimportant, low importance, neutral, somewhat important, important, and very important), where 1 represents "not at all important" and 7 is "very important." The questionnaire contained an open-ended question after each category, asking if there ought to be any other topics in that category. The experts were also asked to give a rationale if they considered some

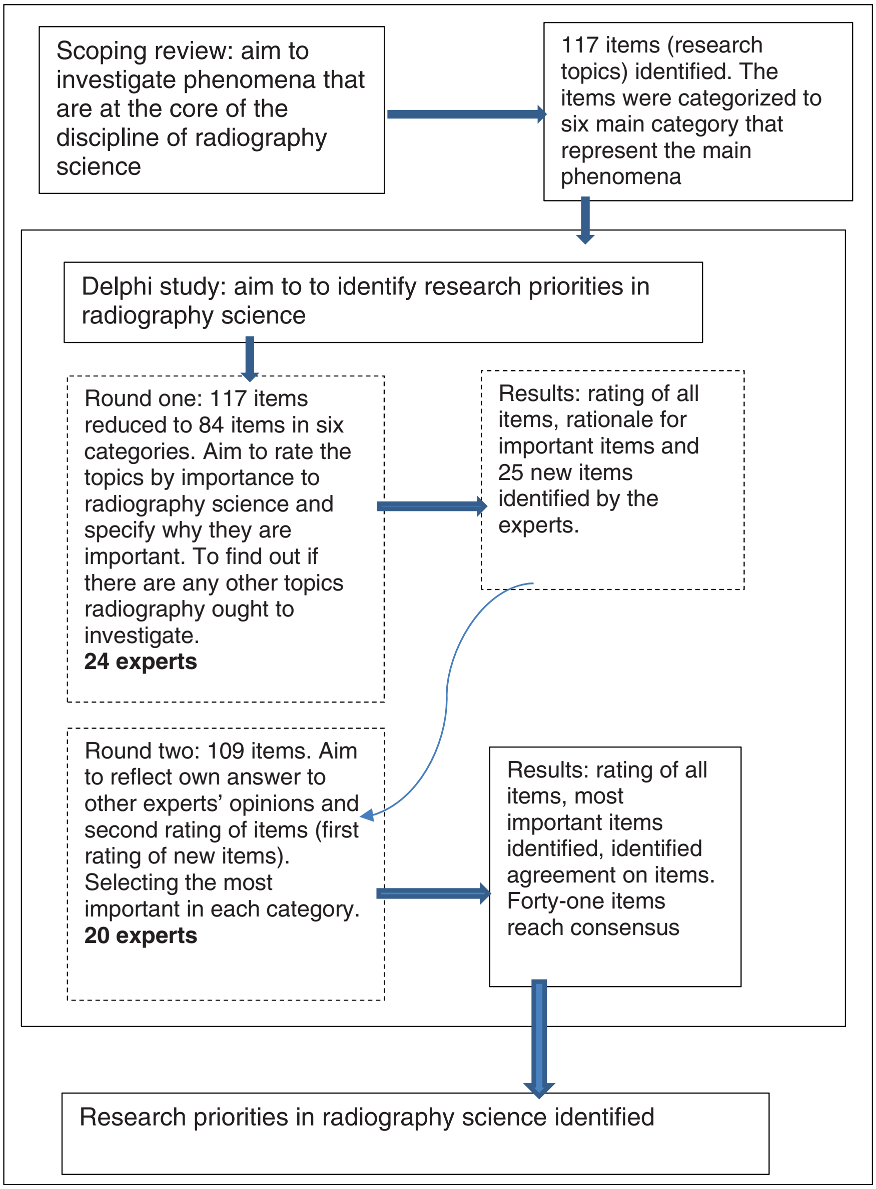

FIGURE 1 Description of the Delphi process. The two steps comprising the top row (scoping review) conducted prior to the current study have been reported in Törnroos et al. (2021)

topic important or very important. At the end of the questionnaire, there was an open-ended question asking if there would be any other topics outside the six categories mentioned in the questionnaire.The experts rated all items and most of the items were rated important or very important (median of 6 or 7). Only 15 items were ranked below a median of 6. The experts presented 25 new research topics for the second round. Twenty-three new topics were placed into existing categories but two of the new topics, veterinary radiography and forensic radiography, did not fit into any pre-existing category and were placed at the end of the second round questionnaire.

2.5 | Round two

In the second round, participants received a reminder of their own answers in round one, and the median answers of the entire expert panel and the range of the answers. Participants were asked to reflect on their own answer and they were given a chance to alter their opinion or remain with the same answer. All research topics (84) and the 25 newly generated topics from the round one answers were included in the second round for a second rating (see Appendix Table A1 for all items). The experts were also asked to choose one most important topic from each of the six categories.

2.6 | Ethical considerations

The Ethics Committee for Human Sciences at the University of Turku granted ethical review approval (ref 21/2021). Informed consent was received from all participants and they were provided information on how their data was processed. All data were processed according to the European Union's General Data Protection Regulation (GDPR).

3 | RESULTS

3.1 | Demographics of the panelists

Of the 28 experts who indicated willingness to participate, 24 experts eventually (86%) responded to the first round. There was also some attrition between rounds, and only 20 experts answered (71%) for the second round, even though two reminders were sent. The expert panelists participating in the first round were from the United Kingdom ($n = 7$), Norway ($n = 4$), Denmark ($n = 3$), Switzerland ($n = 3$), Sweden ($n = 2$), Hungary ($n = 1$), Italy ($n = 1$), Malta ($n = 1$), Portugal ($n = 1$) and Spain ($n = 1$). The mean age of the panelists was 50 years (range 30–70). On average, they had been working 25 years in the field of radiography (range 2–48). They had each published between 2 to 36 scientific publications in the past 5 years, with the mean being 13 publications. There were 23 degrees higher than Bachelor's. Most of the panelists were academics, with only two working as a clinical radiographer or radiotherapist. Those who described their position at work as "other" were working as clinical consultants, senior advisers, or working in a professional association (Table 1).

3.2 | The importance of the research topics after two rounds

Out of all research topics (109 items) under the six categories identified in the scoping review, there were eight research topics that gained a high median score of 6.5 or 7 after two rounds, and the experts were like-minded in their answers. These eight were as follows: (i) the benefits of using artificial intelligence in radiography; (ii) safe integration of artificial intelligence into practice; (iii) the impact of new technology; (iv) evidence-based clinical practices; (v) radiation safety; (vi) radiation optimization; (vii) patient outcomes in medical imaging; and (viii) image interpretation. Another 27 research topics were rated important, with a median score of 6 and an IQR of 1. Research topics in advanced practice and patient-centered care were also rated high in importance (median 7) but the experts' opinions were divided on these topics and they did not reach consensus (IQR of 2). The lowest rated topics that reached consensus were multidisciplinary education, role and territory of radiography, ergonomics of radiographers, workplace well-being, complementary medicine, and the impact of radiographers' gender on the profession. There were no significant differences in answers with relation to experts' educational background or current position at work. All items included in the second round and statistical analysis are presented in Appendix Table A1.

The expert's rationales for the topics they selected as important or very important are presented next by the six categories identified in the scoping review, under which they were structured in the questionnaire. The topics chosen as most important in each category are also described.

TABLE 1 Demographics of the expert panel in round 1 and round 2

Demographics: n (%)	Round I ($n = 24$)	Round II ($n = 20$)
Gender		
Female	13 (54.2)	12 (60)
Male	11 (45.8)	8 (40)
Academic qualification		
Bachelor	1 (4.2)	1 (5)
Master	9 (37.5)	7 (35)
Doctoral	13 (54.2)	11 (55)
Other	1 (4.2)	1 (5)
Education in bachelor level		
Diagnostic radiography	14 (58.3)	13 (65)
Radiotherapy	3 (12.5)	2 (10)
Combined program	7 (29.2)	5 (25)
Current position at work		
Clinical radiographer/radiotherapist/nuclear medicine technologist	2 (8.3)	1 (5)
Academic	17 (70.8)	15 (75)
Other	5 (20.8)	4 (20)

3.2.1 | Radiographers profession

The importance of these topics was primarily rationalized by the developing needs of the profession. As technology in medical imaging and radiotherapy advances, the demands for the profession rise and more research is required for the competences and education of the professionals. Eventually this will have an impact on patient outcome and experience. The development of the radiographer profession requires research in the area.

> The technical development makes it very important to be ready to acquire new competence and work in changing organizations (multidisciplinary, new technology, new procedures, new demands on the profession, etc.). (Expert 5)

> Development of the profession is important as technology changes. In addition, the quality of the professionals is important for the profession to evolve. (Expert 6)

3.2.2 | Clinical practice in radiography

Evidence-based practice was deemed important for avoiding unnecessary imaging and treatment, and to improve the services and the quality in clinical practice. Patient-centered care should be a priority and it is important to hear patient voices regarding the services they need.

> Good working practices, protocols and procedures are essential in creating time and space to concentrate on the patient and his/her experiences. (Expert 13)

> The radiographers work with technology, so they must know well this aspect but at the same time the radiographers are the bridge between the patient and the machine and if the interaction is not optimized, the examination and/or treatment can be compromised. The interaction with other professionals is also important to be sure that we are providing the best diagnostic/therapeutic to the patients. (Expert 4)

3.2.3 | Safe and high-quality use of radiation

Radiation protection was said to be at the heart of radiography and patient safety and the main expertise area of radiographers.

> Radiographers are the professionals to handle radiation. Therefore, research in radiation is naturally performed by radiographers. (Expert 8)

> Recent advances in radiotherapy dose regimens to include ultra hypofractionated treatments for prostate and breast cancer warrant further investigation of side effects and the radiobiological effect. (Expert 19)

3.2.4 | Technology in radiography

Research into technological development was seen as important, as radiography operates with high technology. There was discussion about radiographers taking an active role in its development.

> AI requires robust, prospective research to assess performance in a clinical setting and how this will be safely integrated into future practice. (Expert 11)

> Radiographers have a lot of room to grow in the field of new technologies. They must be among the actors of these developments and must not be only the users. (Expert 16)

3.2.5 | Discipline of radiography science

Research into the discipline was deemed important for the development of the discipline and research.

> Research is the only way to develop Radiography as a Science and what is involved in the discipline. (Expert 24)

> Good research is founded on good methods. (Expert 14)

3.2.6 | Management and leadership

These topics were mostly seen as important because of their connection to smooth operation of the clinical practice and well-being.

> Everyone contributes toward smooth workflow for patient care and health and well-being of staff. (Expert 15)

> These topics are important given their link to an advanced level of radiography practice. (Expert 7)

3.2.7 | The most important topic in each category

In addition to rationales, experts were asked to choose the most important topic in each category. The opinions were divided between various topics. Most support was given to "evidence-based clinical practices" backed up by seven experts and "radiation safety" by six experts. The research topics regarded as most important from other categories were "advanced practice," "the benefits of using artificial intelligence in radiography," "the importance of support programs for research activity," and "communication issues."

3.3 | Research topics that reached consensus after two rounds

Forty-one research topics reached consensus (Table 2) and sixty-eight did not. There was very little change in the experts' opinions between rounds; only five items had a statistically significant difference ($p < 0.05$) between the first and second round. There were altogether 22 topics in the category of "radiographer's profession" and 8 of them had medians of 6 or over and an IQR of 1 (36% of items), the "clinical practice in radiography" category had 38 topics of which 15 had medians of 6 or greater (39% of the items), "safe and high-quality use of radiation" had 15 topics and 6 of these had a median of 6 or over (40% of the items), "technology in radiography" had 12 topics with 5 having a median of 6 or greater (42% of the items), "discipline of radiography science" had 8 topics and only 1 received a median of 6 (13%), and in the category of "management and leadership" there were 12 topics but none of them received a median of 6 or over with an IQR of 1. Of these six categories, "radiographer's profession," "clinical practice in radiography," "safe and high-quality use of radiation," and "technology in radiography" had quite equal proportions of high-ranking items, while the remaining two, "discipline of radiography science" and "management and leadership," had but a single research topic between them that was rated important by the experts of this Delphi panel. Therefore, it seems that priority in research should not be given to research topics in these two categories.

TABLE 2 Research topics that received consensus after two rounds in each category

Research topics	Median	IQR	bootstrapped paired *t*-test (p)	Mean difference	Standard error	BCa 95% confidence interval	
						Upper	Lower
Radiographer's profession							
Image interpretation	6.50	1	0.018	−0.500	0.145	−0.750	−0.300
Continuous professional development	6.00	1	0.059	−0.300	0.141	−0.650	0.000
Impact of technological development on professional practice	6.00	1	0.201	0.150	0.106	0.000	0.300
Radiographer role development	6.00	1	0.725	−0.050	0.132	−0.250	0.150
Involvement in research and development activities	6.00	1	0.058	0.300	0.122	0.100	0.550
Collaboration between radiographers	6.00	1	0.223	0.200	0.152	−0.050	0.450
Patients in need of extra support	6.00	1	-	-	-	-	-
Pedagogical aspects in radiography education	6.00	1	0.808	0.050	0.186	−0.300	0.400
Experiences and attitudes of radiography students	6.00	1	0.610	−0.100	0.184	−0.383	0.200
Multidisciplinary education	5.50	1	0.791	0.050	0.185	−0.300	0.350
Impact of radiographers' gender on profession	4.00	1	0.355	−0.150	0.148	−0.450	0.150
Clinical practice in radiography							
Evidence-based clinical practices	7.00	1	0.797	0.050	0.180	−0.250	0.400
Patient outcomes in medical imaging	7.00	1	0.684	0.050	0.110	−0.150	0.250
Development and implementation of protocols	6.00	1	0.816	0.050	0.191	−0.350	0.400
Patient communication	6.00	1	0.442	0.100	0.122	−0.100	0.350
Patient feelings and experiences	6.00	1	0.653	−0.100	0.205	−0.500	0.300
Patient - radiographer interactions	6.00	1	0.243	0.200	0.154	−0.050	0.400
Treatment accuracy	6.00	1	0.309	−0.200	0.184	−0.500	0.050
Evaluating impact of biological modeling tools on patient outcome	6.00	1	0.556	−0.150	0.239	−0.650	0.300
Inter-disciplinary practice	6.00	1	0.034	0.300	0.103	0.150	0.500
Radiography services provided in a health care context	6.00	1	0.835	−0.050	0.221	−0.450	0.300
Care pathways	6.00	1	0.255	0.200	0.168	−0.150	0.550
Treatment planning	6.00	1	0.273	−0.200	0.170	−0.450	0.050
Patient education	6.00	1	0.353	0.150	0.149	−0.100	0.350
Psycho-social support	6.00	1	0.792	−0.050	0.167	−0.300	0.200
Ergonomics of radiographers	5.50	1	0.607	−0.100	0.184	−0.400	0.150
Complementary medicine	5.00	1	0.493	−0.150	0.201	−0.500	0.150
Safe and high-quality use of radiation							
Radiation safety	7.00	1	0.504	−0.100	0.140	−0.350	0.150
Radiation optimization	7.00	1	0.606	0.050	0.088	−0.100	0.200
Image quality	6.00	1	0.289	0.150	0.131	−0.050	0.350
Patient safety	6.00	1	0.787	0.050	0.168	−0.200	0.350
Use of radiation	6.00	1	0.719	−0.050	0.132	−0.250	0.150
Occupational health and safety of radiographers	6.00	1	0.035	0.400	0.167	0.150	0.700

(Continues)

TABLE 2 (Continued)

Research topics	Median	IQR	bootstrapped paired *t*-test (p)	Mean difference	Standard error	BCa 95% confidence interval Upper	Lower
Technology in radiography							
The benefits of using Artificial intelligence in radiography	7.00	1	-	-	-	-	-
Safe integration of artificial intelligence into practice	7.00	1	-	-	-	-	-
Impact of new technology	7.00	1	0.811	0.050	0.195	−0.250	0.400
Innovations in medical imaging technology	6.00	1	1.00	0.000	0.185	−0.300	0.300
Technological development	6.00	1	0.295	0.200	0.183	−0.100	0.500
Discipline of radiography science							
The importance of support programs to research activity	6.00	1	-	-	-	-	-
Role and territory of radiography	5.50	1	0.045	0.350	0.145	0.100	0.600
Leadership and management							
Workplace well-being	5.50	1	0.168	0.400	0.238	0.050	0.800

Abbreviations: BCa, bias-corrected and accelerated; IQR, interquartile range.

4 | DISCUSSION

The eight topics that received a high median of over 6.5 relate to the clinical practices and radiographers' profession, as well as to radiation safety and new technology in radiography. These are rather similar to the findings of the College of Radiographers (2017) for the research priorities of the radiographer profession: technical innovations, patient and public experience (about clinical practices), service and workforce transformation (in relation to advancing roles), accuracy and safety (quality and safe use of radiation), and education and training (of the radiographer profession). Similar priorities on technological development, radiation safety, patient outcomes and matters of the profession have been reported among radiotherapists (Halkett et al., 2017; Egestad & Halkett, 2016).The two topics related to artificial intelligence were rated high in importance. This is where Malamateniou et al. (2021) also recommended that priorities should be set. Artificial Intelligence-based solutions in medical imaging and radiotherapy, and their effect on the entire discipline, including the role of the radiographer profession in the future, have been widely discussed in the radiography community for the past few years (International Society of Radiographers and Radiological Technologists and the European Federation of Radiographer Societies, 2020). This might have influenced expert panelists' opinions. In the rationales given by the experts for the importance of the research areas, technological development—and in particular, the impact that rapidly developing technology has on clinical practices and the radiographer's profession—was often mentioned as the reason for conducting research in the field. When the development in the technology was used as rationale for investigating radiographers' profession, in those cases, the scope was in the competences required, rather than in the actual technology.Evidence-based clinical practices were rated with a high median score of 7. Although discussion of evidence-based practice, which began in the 1990s, soon came to include radiography as well (Hafslund et al., 2008), it still seems to be badly implemented in this field (Munn, 2020; Abrantes et al., 2020). The topic therefore is an ever-relevant area for research. Research alone does not improve the situation; radiographers working in clinical practice would also require skills for implementation. The patient outcomes in medical imaging, another highly rated topic, relate to the same matter: how to secure effective imaging methods to improve diagnostics and eventually the patients' care. In radiation therapy, it is equally important to secure effective therapeutic procedures for the best outcome for patients.According to the expert panelists' reasoning, radiation safety and optimization are at the heart of radiography and radiographers' special expertise area. The topics were also rated high in importance. Radiation safety has improved over the years but there is still room for development and research. Constantly changing technology keeps radiation safety always topical. Even though radiation in health care is highly regulated, at least in the European Union (2013), there is indication that obsolete practices still exist (Maina et al., 2020; Ciraj-Bjelac et al., 2011) and there are gaps in the knowledge of radiation protection measures (Faggioni et al., 2017).The eighth topic rated high, image interpretation, relates to a larger discussion on role extension and transfer of responsibilities from radiologists to radiographers. In the United Kingdom the role extension is well established (Hardy & Snaith, 2009), but there is ongoing debate surrounding the issue internationally due to a shortage of trained radiologists (van de Venter & ten Ham-Baloy, 2019; Ofori-Manteaw & Dzidzornu, 2019). Similar discussions of task-shifting have been topical in other health sciences and we need more research in this area. It will be interesting to see how the rise of AI technology in image interpretation affects this discussion.Studies have shown that radiographers want to conduct research but lack the skills and confidence (Saukko et al., 2021; Dennett et al., 2021). Bolejko et al. (2021) propose a strategy for establishing a research culture that is enhanced by support from colleagues and management. We think that the implantation of research culture requires also a clear perspective of the domain of radiography science. Radiography science differs from nursing science and other health sciences in its priorities. Health and health-related problems that are seen as priorities in nursing research (Strobehn et al., 2021; Lundgren et al., 2009) do not stand out as a priority in this study. Research into clinical practice is a shared research area in health sciences but the locus is in different areas. In the early years of nursing science, a lot of research and theories were focused on nurses and the actions they perform. As the discipline has matured, research has been directed toward the clinical problems of the patients and the essential phenomena of nursing (Tobbell, 2018). Radiography as a scientific discipline is still evolving, and in the future we might see the essential phenomena of radiography science emerging and the professional connection to a radiographer's work fade. In medical imaging and radiotherapy technology, change seems to be continuous. Research topics may vary over time but some phenomena that radiography science investigates are constant. Whatever improvements in technology there might be, it is important to translate the changes into clinical practice and in a manner that is suitable and safe for patients.

4.1 | Limitations

The panelists of this Delphi study had a long professional history in the field of radiography and expertise in research. They represented different countries in Europe and different educational backgrounds. From some European countries there was only one expert in the panel and therefore we cannot make any generalizations that the results of this study would represent the opinion of the whole of Europe. Experts with diagnostic radiography education were over-represented, constituting over half of the experts. Generally, of the European radiographers, about 63% have a combined qualification (diagnostic imaging, radiotherapy, and nuclear medicine), 34% diagnostic imaging only, and a small percentage are specifically qualified in radiotherapy and nuclear medicine only (McNulty et al., 2016). The research topics were previously identified through the literature, and the experts were asked to judge the topics in relation to their importance to radiography science (not to their own research field), so the over-representation of diagnostic radiography researchers did not significantly bias the results. Of course, this might have had an effect on the prioritizing of research topics. It is possible that with a larger group of experts and wider geographical representation, the results of the study might be somewhat different. We received a confirmation from the EFRS that the invitation to participate in the study had been sent to all member organizations, but we could have enhanced the participation rates by advertising further.It is important to understand that achieving consensus does not mean that the correct answer has been definitively found (Keeney et al., 2006). For example, patient-centered care, which has been recognized as an important research area in radiography (Halkett et al., 2012), was rated high in importance in this study, yet the topic did not achieve consensus. Some of the research topics might be more important to radiotherapists than to diagnostic radiographers and vice versa, but it was not the scope of this study to compare differences but rather to find commonalities that could be studied inside the discipline of radiography science. A further stated limitation of the Delphi method is a poor response rate in the sequential rounds (Keeney et al., 2006), and we also had a decline of participants in the second round. However, the response rate of 71% in the second round can be still considered sufficient.

5 | CONCLUSIONS

This study has provided knowledge on research priorities of radiography science that are shared by experts of the Delphi panel, who were from different fields of radiography and different areas of Europe. Radiography science in this study is understood as a common field of inquiry that researchers in diagnostic imaging, radiotherapy, and nuclear medicine share. The priorities therefore are the research areas where a common ground, a consensus, can be found. We had previously discovered six main phenomena from the literature which radiography science investigates; however, the results of this study indicate that only four of them are priority areas for the discipline. The research priorities in radiography science are related to the phenomena of radiographers' profession, clinical practices, safe and high-quality use of radiation and technology used in medical imaging, radiotherapy, and nuclear medicine. This finding is also supported by previous studies of priorities of the profession. There are several research topics inside these categories and the topics that received the most support from the experts were identified.

5.1 | Relevance for clinical practice

The application of evidence-based practices, and the development of diagnostic and therapeutic services provided in health care, require strong research evidence. This evidence can be produced with research done in radiography science. As we have now identified the priorities of radiography science, researchers in the discipline could focus their studies on these topics.

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AUTHOR CONTRIBUTIONS

Study design: Sanna Törnroos, Miko Pasanen, Helena Leino-Kilpi, Eija Metsälä. Data collection: Sanna Törnroos. Data analysis: Sanna Törnroos, Miko Pasanen. Manuscript writing: Sanna Törnroos, Helena Leino-Kilpi, Eija Metsälä.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in Zenodo at http://doi.org/10.5281/zenodo.6322928

ORCID

Sanna Törnroos https://orcid.org/0000-0003-2965-9207

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APPENDIX A

TABLE A1 All items included for round two, in same order as they appear in the questionnaire and statistical significance (Fisher's extended test) of experts' answers by the level of education, background education, and position at work, with items that were only rated in round two are marked as new

	N		A) Educational level	B) Background education	C) Position at work
	Valid	Missing	*p*-value	*p*-value	*p*-value
Radiographers profession					
Radiographer role development	20	0	0.496	1.00	1
Advanced practice	20	0	0.708	0.908	0.527
Image interpretation	20	0	0.9	0.878	1
Continuous professional development	20	0	0.053	0.647	1
Professional identity	20	0	0.844	0.19	0.274
Professional competence	20	0	0.363	0.062	0.142
Impact of technological development on professional practice	20	0	0.93	1	0.053
History of the profession	20	0	0.68	0.854	0.331
Organization of radiography education	20	0	0.867	0.38	0.331
Pedagogical aspects in radiography education	20	0	0.875	0.92	0.628
Experiences and attitudes of radiography students	20	0	0.7	0.486	0.122
Multidisciplinary education	20	0	1.00	0.939	0.679
Social phenomena that influence the radiography profession	20	0	0.708	0.598	0.086
Development and changes affecting radiography profession	20	0	0.201	0.53	0.698
Involvement in research and development activities	20	0	0.685	0.168	0.484
Collaboration between radiographers	20	0	1.00	1	0.626
Impact of radiographers' gender on profession	20	0	0.837	0.587	0.698
New! Uniformization of radiographer profession in Europe	20	0	1.00	1	0.139
New! Articulation between education, practice and research	20	0	0.52	0.927	0.044
New! Use of simulation in education	20	0	1.00	0.898	0.213
New! Impact of Covid-19 to current radiography students	20	0	0.157	0.334	0.755
New! Patient perception of radiographers working in 'non-traditional' roles	20	0	0.564	0.111	0.617
Clinical practice in radiography					
Working practices in clinical radiography	20	0	0.778	0.447	0.269
Evidence-based clinical practices	20	0	1.00	1	0.205
Inter-disciplinary practice	20	0	0.664	0.497	0.372
Cultural beliefs in clinical practice	20	0	0.928	0.37	0.483
Effectiveness of imaging procedures	20	0	0.903	0.731	0.51
Development and implementation of protocols	20	0	0.581	0.291	0.083
Development and implementation of guidelines	20	0	0.207	0.739	0.091
Development and implementation of processes	20	0	0.529	0.595	0.097
Patient outcomes in medical imaging	20	0	0.001	0.002	0.51
Patient outcomes in radiation therapy	20	0	0.084	0.482	0.175
Evaluating impact of biological modeling tools on patient outcome	20	0	0.694	0.941	0.082

TABLE A1 (Continued)

	N		A) Educational level	B) Background education	C) Position at work
	Valid	Missing	*p*-value	*p*-value	*p*-value
Patient-centered care	20	0	0.462	0.311	0.872
Palliative care	20	0	0.067	0.027	0.114
Care pathways	20	0	0.102	0.041	0.541
Radiography services provided in a health care context	20	0	0.174	0.224	0.728
Treatment compliance	20	0	0.461	0.123	0.528
Patient nutrition	20	0	0.318	0.572	0.731
Symptom management	20	0	0.356	0.469	0.708
Identifying which patients would benefit from imaging in radiation therapy	20	0	0.684	1	0.42
Treatment planning	20	0	0.277	0.923	0.447
Treatment accuracy	20	0	0.363	0.678	0.527
Treatment procedures	20	0	0.53	0.209	0.381
Complementary medicine	20	0	0.303	0.811	0.098
Ergonomics of radiographers	20	0	1	0.748	0.486
Patient - radiographer interactions	20	0	0.213	0.062	0.318
Patient support and counseling	20	0	0.722	0.121	0.398
Patient feelings and experiences	20	0	0.217	0.323	0.383
Family members feelings and experiences	20	0	0.629	0.559	0.563
Patient communication	20	0	0.232	0.363	0.471
Patient education	20	0	0.638	0.119	0.582
Psycho-social support	20	0	0.515	0.165	0.764
New! Justification of medical imaging	20	0	0.64	0.716	0.044
New! Pediatric procedures	20	0	0.187	0.722	0.558
New! Health promotion among clinical radiographers	20	0	0.058	0.51	0.615
New! Impact of covid-19 to cancer outcomes	20	0	0.491	0.866	0.311
New! Patients in need of extra support	20	0	0.342	0.756	0.121
New! Antenatal screening with ultrasound	20	0	0.455	0.171	0.77
New! Alternative imaging approaches linked to patient pathway	20	0	0.305	0.452	0.147
Safe and high-quality use of radiation					
Radiation safety	20	0	0.785	0.156	0.301
Use of radiation	20	0	0.795	0.697	0.307
Radiation optimization	20	0	0.764	0.847	0.098
Radiation risk	20	0	0.159	0.653	0.284
Dose measurement	20	0	0.177	1	0.465
Treatment side effects	20	0	0.43	0.252	0.481
Total body irradiation	20	0	0.44	0.856	0.138
Biological effects of radiation	20	0	0.942	1	0.491
Patient safety	20	0	0.907	0.51	0.123
Occupational health and safety of radiographers	20	0	0.445	0.564	0.776
Image quality	20	0	1.00	1	1
Quality assessment	20	0	0.578	1	1
New! Diagnostic reference levels in diagnostic radiography	20	0	0.94	0.559	0.779

(Continues)

TABLE A1 (Continued)

	N		A) Educational level	B) Background education	C) Position at work
	Valid	Missing	*p*-value	*p*-value	*p*-value
New! The use of PA vs AP	20	0	0.682	0.61	1
New! Radiographers' role and responsibility regarding radiation protection	20	0	0.74	0.919	0.652
Technology in radiography					
Image-guided radiotherapy	20	0	0.722	0.773	0.107
Radiotherapy techniques	20	0	0.464	0.725	0.123
Imaging techniques	20	0	0.396	0.587	0.183
Post-processing	20	0	0.19	0.778	0.689
Technology development	20	0	0.148	0.165	0.442
Impact of new technology	20	0	0.086	0.37	1
Innovations in medical imaging technology	20	0	0.226	0.584	1
Technological performance	20	0	0.151	0.837	1
New! Safe integration of artificial intelligence into practice	20	0	0.222	1	0.777
New! The benefits of using Artificial intelligence in radiography	20	0	0.611	1	0.333
New! Optimization of imaging methods	20	0	0.187	0.144	0.558
New! Innovations in medical imaging, radiation therapy and nuclear medicine	20	0	0.9	0.245	0.466
Discipline of radiography science					
Radiography research priorities	20	0	0.107	0.833	0.06
Instrument development and testing	20	0	0.493	0.464	0.162
Interdisciplinary nature of radiography research	20	0	0.844	0.19	0.22
Research methods	20	0	0.694	0.747	0.161
Role and territory of radiography	20	0	0.95	0.629	0.866
New! Ontology and epistemology of radiography science	20	0	0.21	0.004	0.885
New! Radiography as a science	20	0	0.71	0.89	0.886
New! The importance of support programs to research activity	20	0	0.14	0.377	0.598
Management and leadership					
Information infrastructure of medical images and data	20	0	0.971	0.228	0.032
Workflow	20	0	0.829	0.403	0.884
Workplace well-being	20	0	0.64	0.967	0.824
Management	20	0	0.500	0.415	0.964
Organizational issues	20	0	0.651	0.924	0.81
Workforce issues	20	0	0.37	0.066	0.897
Organization of work	20	0	0.593	0.193	0.68
Staff issues	20	0	0.253	0.124	1
Workload	20	0	0.504	0.206	0.81
Department efficiency	20	0	0.671	0.115	0.896
Communication issues	20	0	0.419	0.946	0.605
New! Cost effectiveness	20	0	0.393	0.645	0.549
New! veterinary radiography	20	0	0.863	0.883	0.632
New! forensic radiography	20	0	0.537	0.763	0.494