Radiography 26 (2020) e277–e283

Contents lists available at ScienceDirect

Radiography

journal homepage: www.elsevier.com/locate/radi

Radiographers' assessment of referrals for CT and MR imaging using a web-based data collection tool

C.C. Chilanga [a, *], K.B. Lysdahl [a], H.M. Olerud [a], R.J. Toomey [b], A. Cradock [b], L. Rainford [b]

[a] Department of Radiography, Faculty of Health and Social Sciences, University of South-Eastern Norway, Pb 235, 3603 Kongsberg, Norway
[b] Radiography and Diagnostic Imaging, School of Medicine, University College Dublin, Health Sciences Centre Belfield, Dublin 4, Ireland

ARTICLE INFO

Article history:
Received 28 January 2020
Received in revised form
30 March 2020
Accepted 1 April 2020
Available online 27 April 2020

Keywords:
CT
MRI
Referral appropriateness
Radiographers

ABSTRACT

Introduction: There is limited research related to the radiographers' role in assessing of radiology referrals to justify imaging. This study investigated radiographers' compliance with guidelines in the assessment of CT and MRI referrals and factors that influenced their performance.
Methods: This research was facilitated by the EFRS Research Hub at ECR 2019. Five radiology referral scenarios for CT and/or MRI were distributed to radiographers, as determined by their scope of practice, who volunteered at the Research Hub. A web-based data collection tool was used. The radiographers were required to determine the appropriateness of each referral, highlight any concerns and recommend suitable investigations if applicable. Linear regression analysis was used to determine whether postgraduate qualification, grade/role of the radiographer and use of guidelines influenced the radiographers' performance in assessing the referrals.
Results: Participants originated from 24 countries (n = 51 CT, n = 40 MRI), the majority originating from the UK, Ireland, Italy, Spain, Norway and Austria. Responses consistent with guidelines were 58% and 57% for CT and MRI, respectively. Possession of an MSc qualification in CT was a significant factor of influence for a higher consistency with guidelines ($p = 0.02$) in CT. Employment as a radiographer in a lead professional role and/or educator was a significant factor of influence for a higher consistency with guidelines in MRI ($p = 0.01$).
Conclusion: A total of 58% for CT and 57% for MRI of the radiographers' responses complied with guidelines. Factors such as postgraduate education and leading professional roles are associated with better performance.
Implications for practice: Considering qualifications, experience and managerial role is vital before radiographers are delegated task of justifying CT and MR Imaging.

Introduction

The International Atomic Energy Agency (IAEA)[1] recommends that all radiology examinations conducted, including non-ionising modalities such as ultrasound (US) and magnetic resonance imaging (MRI) should be justified to maximise the benefit-to-risk ratio. The European Council Basic Safety Standards (BSS) Directive[2] advocates for a team approach among clinicians, radiologists and radiographers when it applies to justification of imaging. Justifying of computed tomography (CT) and MRI examinations is legislatively the responsibility of the radiologist in many countries, though in practice radiographers could be delegated the task in consultation with the radiologist.[1] Radiographers are identified as a potential group to act as gatekeepers to ensure appropriate imaging.[3] For radiographers, this entails reviewing a referral to ensure the imaging procedure is appropriately justified, identifying and discussing with the radiologists on doubtful or inappropriate referrals and seeking further information from the referring clinician when needed.[4,5] However, the contribution of the radiographer in the justification process is unclear and under explored.

Abbreviations: IAMs, Internal Auditory Meatus; MGUS, Monoclonal Gammopathy of Undetermined Significance; MRCP, Magnetic Resonance Cholangiopancreatography; MS, Multiple Sclerosis; OPS, Overall Performance Score; TL, Temporal Lobe; WB, Whole Body.

* Corresponding author.
E-mail addresses: catherine.chilanga@usn.no (C.C. Chilanga), Kristin.Bakke.Lysdahl@usn.no (K.B. Lysdahl), Hilde.Olerud@usn.no (H.M. Olerud), rachel.toomey@ucd.ie (R.J. Toomey), andrea.cradock@ucd.ie (A. Cradock), louise.rainford@ucd.ie (L. Rainford).

https://doi.org/10.1016/j.radi.2020.04.001

International radiology referral guidelines to assist selection of appropriate imaging are widely used in most countries[6–9] with national evidenced based variants of the guidelines available in some countries.[10] The positive impact of applying referral guidelines has also proved to be significant.[11]

Where confronted with inadequately filled referrals Matthews and Brennan[5] report of radiographers seeking further information from the patient or referring physician before conducting the examination. Triantopoulou et al.[12] reports of the usefulness of detailed clinical information to enable adequate justification of CT imaging. Koutalonis and Horrocks[13] have studied how both radiologists and radiographers assessed risks and benefits when justifying imaging and reported the most important criteria being the patient's medical condition, age, sex, and alternative techniques using less or non-ionising radiation. Others have reported on radiographers' knowledge of radiation protection and doses for various modalities.[14,15] This study aimed to examine the radiographers' compliance with radiology referral guidelines in assessing of designed referrals for CT and MRI examinations and to identify factors that potentially enhanced their performance. A web based data collection tool was used because it allows for real time and high quality data collection and analyses.[16]

Methods

Ethical approvals were obtained from University College Dublin (UCD) Institutional HREC in Ireland and from the Norwegian Centre for research data (NSD) reference number 776616 in Norway.

Development of the web-based data collection tool

Five referral clinical cases for both CT and MRI indicating only the diagnostic condition were prepared for participants to review in a short period of approximately 20 min within a "pop-up research hub" scenario.[17] Each case was determined as realistic by an expert MRI radiographer employed as an academic lecturer, with extensive experience and knowledge in medical imaging. The case content was supported by recognised international guidelines and literature (Table 1).

The designed clinical cases are commonly seen referrals for CT and MRI and were chosen to assess the radiographers' knowledge of benefits of an imaging modality for a given case, taking into account factors such as, clinical appropriateness to provide accurate diagnosis, urgency of the referral and radiation exposure. Participants were asked to assess and determine if the referral was *appropriate*, or *not appropriate*, or *possibly appropriate*, and whether further discussion with the referring clinician or with the radiologist was required. Space for free text was provided to enable the participants to explain any concerns they had about the referral or whether they would recommend an alternative examination, and if so to specify the recommended examination.

The participants were also asked to indicate which, if any, referral guidelines they used routinely; options included the American College of Radiology (ACR) Appropriateness Criteria, Royal College of Radiologists (RCR) iRefer, European Society of Radiology (ESR) iGuide and Western Australia Diagnostic Imaging Pathways, or participants could specify any others. Participants for either the CT and/or MRI referral cases had to state whether they assessed these imaging speciality referrals as part of their clinical work and how often they undertook this role. Finally, they were asked if they were permitted to modify referrals as part of clinical practice. In designing the cases and questions, written text was kept to a minimum, and clinical abbreviations limited with typed explanation of a limited number of medical words was provided to assist non-native English participants.

Demographic data was collected pertaining to the participants: country of training and practice; years of practice in radiography; radiography grade/role (clinical/academic); postgraduate education or training within a specific imaging modality; experience (years) working in CT and/or MRI.

Recruitment of participants

The sample population were radiographers who attended the European Congress of Radiology (ECR) 2019 in Vienna, Austria. A "pop-up research hub" was organised by the European Federation of Radiographer Societies (EFRS) in collaboration with the European Society of Radiology (ESR). The Research Hub initiative was based in a meeting room located adjacent to the Radiographers' Lounge area at ECR, and conference attendees could volunteer to take part in this and several other research activities. Advertisement of the research hub was approved by the EFRS and ESR, a flyer was sent through mailshots by the EFRS prior to ECR 2019, and the research activity was promoted at the conference venue. A total of 1767 fully qualified radiographers attended the congress originating from 84 countries.[30] Volunteers were allowed to select which study(ies) they wished to participate in provided they met the study inclusion criteria, with those reporting that they worked in CT and/or MRI invited to take part in the current study.

Data collection

The data for obtaining the demographics and for the designed cases was inserted into a password-protected, web-based user interface (Ziltron Ltd., Dublin, Ireland). The data collection tool was accessed via ten 4th generation (Apple) iPad tablet computers running IOS10.3.3 (Cupertino, CA, USA). Multiple tablets enabled several volunteers to take part simultaneously, although they were instructed to complete the task without conferring. The resultant data were saved in real time in secure cloud-based storage.

Participants were not provided with access to any referral guidelines or other aids while completing the task; however, to accommodate the wide array of nationalities and backgrounds of participants, the researchers provided clarification on terminology where necessary. A summary of the background to the study was also provided to explain the study aim and origin. Participants could also opt to provide email contact for a certificate of participation upon completion of the research activity; this was recorded at the Research Hub reception desk and was not associated with the study data, which was collected with no identifying details and identified participants only by code (e.g. "CT1" was the first participant in the CT study).

Data analysis

A score of consistency with recommended practice and participants' responses on each of the CT and MRI cases was recorded, from *cannot answer* (0) to *fully consistent response* (3), as outlined in Table 2 for each individual case for each participant response. Further to expert statistical advice the scores were then grouped as a inconsistent (score 0 and 1) or consistent score (2 and 3). This consistency score was based on responses for questions (q) for the decision of appropriateness (q1) followed by any concerned stated (q2) and a review of participants' responses to alternative appropriate examination(s) (q3) in line with referral guidelines and recommendations as stated in Table 1.

To enable accurate analysis for linear regression an overall performance score (OPS) was then determined for the participant across all five cases in the CT or MRI data set reviewed. The OPS was a summation of an individual participant's scores (1 = consistent, 0 = inconsistent, as indicated in Table 2) with a maximum score of 5

Table 1
Case description and preferred examination according to guidelines and other references.

Modality: CT		Preferred Examination	Appropriate guidelines/references
Case 1	CT Brain: Patient presents to emergency department with seizures. Query temporal lobe (TL) epilepsy	MRI	ACR Appropriateness Criteria,[18] Western Australia Diagnostic Imaging Pathways[19]
Case 2	CT abdomen: Pregnant patient. Severe abdominal pain. Query appendicitis	US	ACR Appropriateness Criteria[20]
Case 3	CT Brain: Patient has tingling and numbness in face. Query multiple sclerosis (MS)	MRI	RCR iRefer[21]
Case 4	CT Abdomen: Acute low abdominal pain. Query stone in urinary tract	CT low dose	ACR Appropriateness Criteria[22]
Case 5	CT Whole Body (WB): Patient with a history of monoclonal gammopathy of undetermined significance (MGUS) now has bone pain and loss of appetite. Query multiple myeloma	MRI WB	Chantry et al.[23] on behalf of the British Society for Haematology Guidelines
Modality: MRI		**Preferred Examination**	**Appropriate guidelines/references**
Case 1	MR cholangiopancreatography (MRCP) Patient presents with severe abdominal pain and jaundice. Query gallstones	US	ACR Appropriateness Criteria[24]
Case 2	MRI Knee: Chronic knee pain. Query Osteoarthritis (OA)	X-Rays	ACR Appropriateness Criteria,[25] RCR iRefer,[21] Australia diagnostic imaging pathway[26]
Case 3	MRI Lumbar Spine: Patient involved in heavy lifting as part of work. Low back pain with saddle paraesthesia	MRI, Urgent within 6 h	ACR Appropriateness Criteria[27]
Case 4	MRI Internal Auditory Meatus (IAMs): Severe facial pain. Family history of cancer. Query tumour	MRI whole Brain	ACR Appropriateness Criteria: Expert Panel on Neurologic Imaging[28]
Case 5	MRI Brain: History of lung cancer. Query brain metastases.	MRI	ACR Appropriateness Criteria: Expert Panel on Radiation Oncology–Brain Metastases[29]

if a participant was consistent across all five cases and a score of 0 if a participant was inconsistent across all five cases for CT or MRI.

Linear regression analysis was performed to identify whether the factors: possession of postgraduate qualification in that modality, grade/role of the radiographer and use of referral guidelines correlated with the OPS. A two tailed p value < 0.05 was considered significant. A preliminary analysis was performed to ensure no violation of assumptions of normality, linearity and multicollinearity and to analyse the relationship between the variables of interest. Furthermore, variables namely in categories of postgraduate education (i.e. graduate diploma and certificate) and radiographer position (i.e. radiographer chief/leads, teachers, radiographer managers, other) were grouped within each category as one variable. This was conducted to reduce the independent variables for analysis of the sample size $N = 91$ using the formula $N \geq 50 + 8\ (k)$ where k is the required number of independent variables in linear regression analysis as outlined by Green.[31] The results are presented as beta coefficients with accompanying 95%

Table 2
Grading and scores of assessed referral cases, based on the combination of participants' responses to referral appropriateness decision (q1), concern stated (q2) and alterative examination suggested (q3).

OPS	Score	Grading		Referral Appropriateness (q1)	Concern (q2)	Alternative examination (q3)
Inconsistent = 0	0	Cannot answer		Answered as "not sure"	None given	None given
	1	Not consistent	a)	Answered incorrectly as justified or not justified	None given or not reasonable	None given or inappropriate alternative examination(s) given
			b)	Answered possibly "appropriate (discuss with radiologist or clinician)" where correct answer in not appropriate	Unreasonable answers given	Inappropriate alternative examination(s) given or none given
			c)	Answered as "not sure"	Unreasonable answers given	Inappropriate alternative examination(s) given or none given
Consistent = 1	2	Acceptable	a)	Answered incorrectly as justified or not justified	Reasonable answers are given	Appropriate alternative examination(s) given
			b)	Answered "possibly appropriate (to discuss with radiologist or clinician)" where correct answer is not appropriate	Reasonable answers are given	Appropriate alternative examination(s) given
			c)	Answered "not sure"	Reasonable answers are given	Appropriate alternative examination(s) given
	3	Fully consistent	a)	Correctly answered that justified or not justified	Reasonable answers are given or none given	Appropriate alternative examination(s) given/not contradict the correct answer or none given
			b)	Answered "possibly appropriate (want to discuss with radiologist or clinician)" where correct answer is appropriate	Reasonable concerns are given or none given	Appropriate alternative examination(s) or none given

Table 3
Demographics for the participants' responses for CT and MRI cases.

Characteristics	CT responses	MRI responses	Total Responses
	n (%)	*n* (%)	*n* (%)
	51 (100.0)	40 (100.0)	91 (100.0)
Radiography position			
Radiography lead professional role/educator	14 (27.5)	22 (55)	36 (39.6)
Senior radiographer	16 (31.4)	4 (10.0)	20 (21.9)
Radiographer	21 (41.2)	14 (35.0)	35 (38.5)
Post-graduate training level studied			
MSc 120ECTs	9 (17.6)	12 (30.0)	21 (23.1)
Diploma/Certificate 60 to 30 ECTs	19 (37.2)	14 (35)	33 (36.3)
Hospital (in house) Training	23 (45.1)	14 (35.0)	37 (40.6)
Work full time in CT/MRI			
Yes	19 (37.3)	19 (47.5)	38 (41.8)
No	32 (62.7)	21 (52.5)	53 (58.2)
Years working in CT/MRI			
<5	18 (36.0)	12 (30.0)	30 (33.3)
5–9	11 (22.0)	9 (22.5)	20 (22.2)
10–14	14 (28.0)	8 (20.0)	22 (24.4)
15+	7 (14.0)	11 (27.5)	18 (20.0)
Missing	1	1	1

confidence intervals (CI) and p values. The data was analysed using SPSS Version 25 (IBM, Armonk, NY, USA).

Results

Demographics

A total 91 responses of radiographers from 24 countries were obtained in the study. The majority of the responses ($n = 81$) were from radiographers working in Europe; mainly in the United Kingdom (UK), Ireland, Italy, Spain, Norway and Austria. Within each imaging modality cohort, 55% and 65% of participants had attained CT and MRI postgraduate education, respectively ranging from certificate (30 ECTs) to Master's Degree (MSc 120 ECT) level. The remaining participants reported receiving in-house training in the indicated modality (Table 3).

Participants' responses

The overall findings for participant responses to the cases within the CT and MRI data sets regarding appropriateness with recommended practice, referral concerns and suggested examination, when analysed against referral guidelines are shown in Fig. 1 (for CT) and 2 (for MRI).

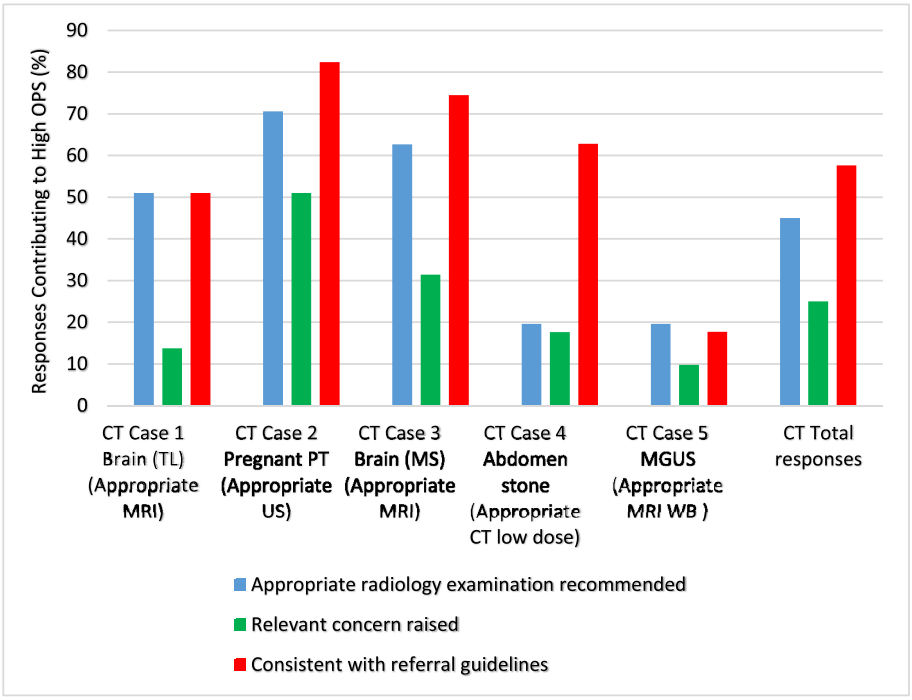

Figure 1. The proportion of participants' CT cases responses that were consistent with referral guidelines (red bars), that raised relevant concerns (green bars), and that recommended an appropriate radiology examinations (blue bars). The recommended appropriate modality for each case is indicated in parentheses. Note that for case 4 the CT referral was appropriate and appropriate recommendation responses here is therefore equal to a further specification of the examination.

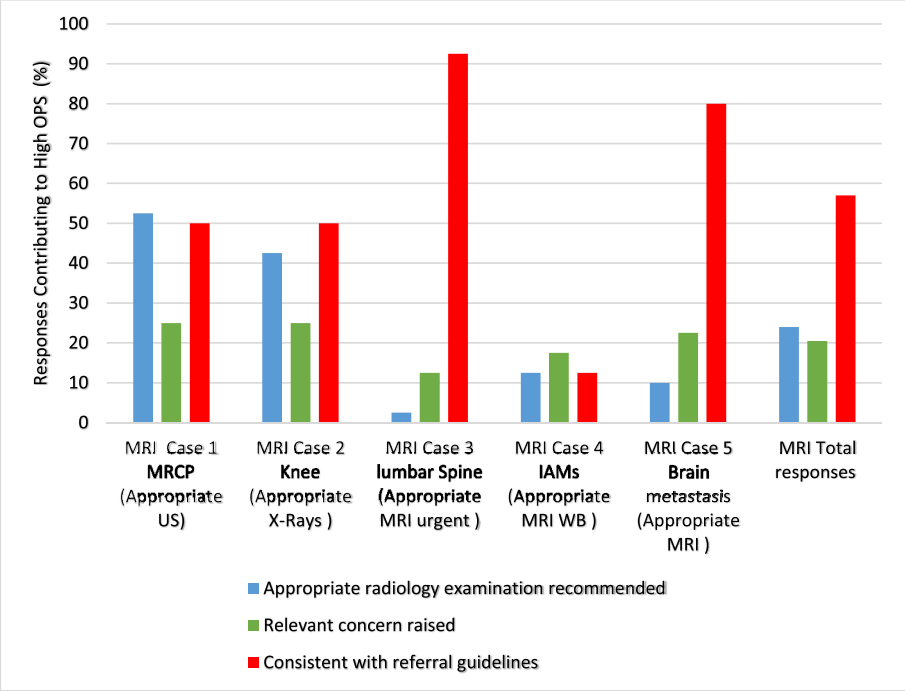

Figure 2. The proportion of participants' MRI cases responses that were consistent with referral guidelines (red bars), that raised relevant concerns (green bars), and that recommended an appropriate radiology examinations (blue bars). The recommended appropriate modality for each case is indicated in parentheses. Note that for case 3 and 5 the MRI referral was appropriate, and appropriate recommendation responses here is therefore equal to a further specification of the examination.

CT case findings

The overall performance score for the CT cases showed that a total of 58% of the participants accurately identified the appropriateness of the referrals (Fig. 1). High scores were obtained in Case 2 CT abdomen, pregnant patient (82%), Case 3 CT brain, MS patient (75%) and Case 4 CT abdomen urinary tract stone (63%). Case 5, CT WB, patient with MGUS, received the lowest score (18%).

Across the five CT cases, 25% of the responses raised concerns such as high radiation doses and sensitivity of the modality for accurate diagnosis for the referral. A common concern recorded was the need for more information within the referral, which was sought in 13% of the responses. Examples of further information requested included; age, status of the patient and gestation stage of pregnancy (Case 2). Most concerns for radiation dose were raised in CT Case 2, the pregnant patient. In Case 4 - CT abdomen urinary tract stone scenario, 20% of the radiographers further suggested the use of low dose CT imaging.

MRI cases findings

The overall performance score for the MRI cases showed that a total of 57% of the participants identified the appropriateness of the referral accurately (Fig. 2). High scores were obtained in MRI Case 3 lumbar spine urgent, saddle paraesthesia (93%) and MRI Case 5 brain metastases (80%). Case 4 MRI - IAMs, proved most challenging with a score of 13%.

Across the five MRI cases, concerns were stated with 21% of the responses to include; urgency of the referral, sensitive of the modality to provide accurate diagnosis, the need of wider exploratory scan and use of contrast media for better anatomy and pathology visualisation. Although MRI Case 3 lumbar spine saddle paraesthesia, was identified as an appropriate referral by a high number of the radiographers, only 13% of the respondents stated urgency, whilst 3 participants inappropriately recommended observational physiotherapy as other suggested investigation.

Table 4
Variables associated with overall performance score of the radiographers ($n = 91$).

Variables	CT			MRI		
	Beta	95% CI	p-value	Beta	95% CI	p-value
Radiography position						
Radiographer	Ref.			Ref.		
Radiography lead professional role/educator	0.28	−0.03 to 1.43	0.06	0.45	0.25 to 1.42	**0.01**
Senior radiographer	0.24	−0.15 to 1.28	0.12	−0.10	−1.27 to 0.66	0.53
Post-graduate training level studied						
Hospital (in house) Training	Ref.			Ref.		
MSc	0.35	0.19 to 1.88	**0.02**	0.07	−0.55 to 0.84	0.67
Diploma/Certificate	−0.03	−0.72 to 0.60	0.86	−0.27	−1.17 to 0.10	0.10
Use of referral guidelines						
No	Ref.			Ref.		
Yes	0.04	−0.66 to 0.89	0.77	−0.10	−0.90 to 0.43	0.48

CI: Confidence interval.
Statistically significant p-values in bold.

Linear regression analysis: factors influencing performance

Multivariable linear regression analysis was used to assess whether postgraduate education, the radiographers' position and usage of guidelines was associated to the overall performance score (OPS) of $n = 91$ radiographers' responses (CT $n = 51$, MRI $n = 40$) as indicated in Table 4. Possession of an MSc degree was a statistically significant influencing factor for a higher OPS in the CT participants at $p = 0.02$, but was not significant for those in MRI. Radiography lead professional role and/or educator in the MRI participants was also a statistically significant influencing factor for a higher OPS at $p = 0.01$, but failed to reach significant for CT imaging ($p = 0.06$). The use of referral guidelines were not a statistically significant influencing factor on OPS in neither CT nor MRI participants.

Discussion

In clinical practice, radiographers are required to review referrals to ensure imaging is justified for each examination.[3] Therefore radiographers should be able to identify anomalies of a referral and contribute to decision making together with radiologists and referring physicians accordingly. This study showed that 58% of participants for CT and 57% for MRI were able to identify anomalies and assess the designed referrals in compliance with recommended practice. It is important to note that availability of alternative imaging modalities plays a significant role in justification of imaging therefore the recommended practices outlined in this study may not be the routine pathways in every radiology department. The radiographers, however, were able to identify referral appropriateness for 4 out of 5 cases in each modality taking into account that no referral guidelines or other supporting tools were available when they assessed the referrals.

Imaging modality selection and knowledge of radiation doses

The IAEA[1] stipulates that the benefits and risks of an exposure including alternative investigations should be considered to ensure that the diagnostic benefits outweigh the harm. The selection of appropriate imaging should adhere to this regulation. In 80% (4/5) of the designed cases for both CT and MRI, the radiographers identified the appropriate imaging modality. The radiographers further demonstrated knowledge of the benefits of each modality through highlighting the sensitivity of a modality for specific pathologies. Furthermore the radiographers were able to apply radiation protection showing knowledge of radiation doses through suggesting non ionising modality or techniques that would ensure use of low doses in specific cases appropriately.

Information seeking

Obtaining optimal clinical information aides decisions that lead to appropriate imaging.[4,5,12] Our study showed a tendency of the radiographers to seek further or clearer information on a referral when required. The evaluation of a referral is based on clinical notes and patient information.[3] A similar trend as reported by Koutalonis and Horrocks[13] of the main information sought and criteria used when assessing referrals was also shown.

Factors influencing performance

The factors that influenced the radiographers' OPS was attributed to occupying a radiography lead professional role and/or educator for MRI and possession of an MSc degree for CT imaging as shown in Table 4, indicating the positive impact of postgraduate education and clinical experience on the radiographers' ability to identify appropriate referrals.[13,32] McNulty et al.[32] however reports insufficient postgraduate programs in Europe for radiographers. If we aim to effectively involve radiographers to ensure appropriate imaging, adhere to international guidelines in justification of imaging as stated by the IAEA,[1] and enhance radiography practice, the availability of higher education courses for radiographers in imaging specialities and justification of imaging is evidenced by this study's finding as a priority.

Limitations and strengths of study

The participants were radiographers, professionally active through their ECR 2019 attendance and predominantly working in Europe therefore caution to translate the outcomes outside this cohort is warranted. It should be noted that participants volunteered between conference activities, which may have caused participants to spend reduced time on questions. This may account for the limited responses in open-ended comment boxes. Additionally, the referral cases were designed with minimal text to enable easy comprehension for non-native English participants however greater referral text content was requested by some participants. The cases were limited to only five cases in each modality to allow sufficient time for the participants to adequately assess the cases as recommended of pop up research hubs. However, this represents a small sample of clinical conditions routinely seen in practice and could have an impact on study findings. A strength of the study was access to radiographers from a wide variety of clinical practices in different countries internationally.

Conclusion

Understanding the contribution of radiographers in assessing referrals is vital to ensure appropriate imaging is conducted in radiology departments. Furthermore, identifying the factors supporting radiographers that act as gatekeepers is vital. Our study identifies postgraduate education as particularly important and that those occupying lead radiography positions in both clinical and academic settings performed most optimally. Further research is warranted to investigate this subject across larger cohorts of radiographers and across the spectrum of medical imaging subspecialities.

Conflict of interest statement

None.

Acknowledgements

This research was conducted, and supported, as part of the European Federation of Radiographer Societies (EFRS) Research Hub during the European Congress of Radiology (ECR) 2019. We wish to thank Dr John Ryan from Ziltron Ltd Dublin, Ireland for assistance with the software and upload of the web based data collection tool, all the researchers and administrative staff from UCD and USN for assistance during collection of data. We also wish to thank Ragnhild Sørum Falk from the Oslo Centre for Biostatistics and Epidemiology for the assistance with data statistics analysis. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.radi.2020.04.001.

References

1. International Atomic Energy Agency IAEA. *Safety standards for protecting people and the environment: radiation protection and safety in medical uses of ionizing radiation*. Vienna: IAEA Safety Standards Series No. SSG-46 IAEA; 2018.
2. European Commission Basic Safety Standards (BSS) Directive. Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. Official Journal of the European Union L-13 of 17 January. 2014.
3. Vom J, Williams I. Justification of radiographic examinations: what are the key issues? *J Med Radiat Sci* 2017;**64**(3):212–9.
4. Australian Society of Medical Imaging and Radiation ASMIRT. *Professional practice standards. Melborne, Australia*. 2018. Avaliable at: https://www.asmirt.org/media/371/371.pdf. [Accessed 15 November 2019].
5. Matthews K, Brennan PC. Justification of x-ray examinations: general principles and an Irish perspective. *Radiography* 2008;**14**(4):349–55.
6. *American College of radiology ACR appropriateness criteria*. 2019. Available at: https://www.acr.org/Clinical-Resources/ACR-Appropriateness-Criteria/About-the-ACR-AC. [Accessed 6 June 2019].
7. The Royal College of Radiologists RCR irefer. *Making the best use of clinical radiology eighth edition of the guidelines, Version 8.0.1. 2017*. Available at: https://www.irefer.org.uk/about. [Accessed 6 June 2019].
8. Western Australia Diagnostic Imaging Pathways Australia. *About imaging: about guidance*. 2018. Available at: http://www.imagingpathways.health.wa.gov.au/index.php/about-imaging/about-guidance. [Accessed 6 June 2019].
9. European Societ of Radiology ESR iGuide. *Clinical decision support using European imaging referral guidelines*. 2019. Available at: https://www.myesr.org/esriguide. [Accessed 6 June 2019].
10. Remedios D, Hierath M, Ashford N, Cavanagh P, Grenier PA, Lloyd CM, et al. European survey on imaging referral guidelines. *Insights Imag* 2014;**5**(1):15–23.
11. Tahvonen P, Oikarinen H, Paakko E, Karttunen A, Blanco Sequeiros R, Tervonen O. Justification of CT examinations in young adults and children can be improved by education, guideline implementation and increased MRI capacity. *Br J Radiol* 2013;**86**(1029):20130337.
12. Triantopoulou C, Tsalafoutas I, Maniatis P, Papavdis D, Raios G, Siafas I, et al. Analysis of radiological examination request forms in conjunction with justification of X-ray exposures. *Eur J Radiol* 2005;**53**(2):306–11.
13. Koutalonis M, Horrocks J. Justification in clinical radiological practice: a survey among staff of five London hospitals. *Radiat Protect Dosim* 2012;**149**(2):124–37.
14. Paolicchi F, Creonti I, Miniati F, Bastiani L, Sottocornola C, Faggioni L, et al. Assessment of radiation protection awareness and knowledge about radiological examination doses among Italian radiographers. *Insights Imag* 2016;**7**:233–42.
15. Foley SJ, Evanoff MG, Rainford LA. A questionnaire survey reviewing radiologists' and clinical specialist radiographers' knowledge of CT exposure parameters. *Insights Imag* 2013;**4**(5):637–46.
16. Gill FJ, Leslie GD, Grech C, Latour JM. Using a web-based survey tool to undertake a Delphi study: application for nurse education research. *Nurse Educ Today* 2013;**33**(11):1322–8.
17. Toomey RJ, McEntee MF, Rainford LA. The pop-up research centre - challenges and opportunities. *Radiography (Lond)* 2019;**25**(1):S19–24.
18. American College of Radiology ACR Appropriateness Criteria. *Seizures and epilepsy ACR guidelines*. 2014. Available at: https://acsearch.acr.org/docs/69479/Narrative/. [Accessed 30 May 2019].
19. Western Australia Diagnostic Imaging Pathways. *Diagnostic imaging pathways - seizure (investigation), governmnent of western Australia*. 2014. Available at: http://www.imagingpathways.health.wa.gov.au/index.php/about-imaging/ionising-radiation. [Accessed 30 May 2019].
20. American College of Radiology ACR Appropriateness Criteria. *Right lower quadrant pain-suspected appendicitis*. 2018. Available at: https://acsearch.acr.org/docs/69357/Narrative/. [Accessed 25 August 2019].
21. European commission EC Radiation Protection. *2000 Guidelines for imaging*. European Commission Directorate-General for the Environment; 2000.
22. American College of Radiology ACR Appropriateness Criteria. *Acute onset flank pain-suspicion of stone disease (urolithiasis)*. 2015. Available at: https://acsearch.acr.org/docs/69362/Narrative/. [Accessed 24 August 2019].
23. Chantry A, Kazmi M, Barrington S, Goh V, Mulholland N, Streetly M, et al. Guidelines for the use of imaging in the management of patients with myeloma. *Br J Haematol* 2017;**178**(3):380–93.
24. American College of Radiology ACR Appropriateness Criteria. *Right upper quadrant pain*. 2018. Available at: https://acsearch.acr.org/docs/69474/Narrative/. [Accessed 30 May 2019].
25. American College of Radiology ACR Appropriateness Criteria. *Chronic knee pain*. 2018. Available at: https://acsearch.acr.org/docs/69432/Narrative/. [Accessed 30 May 2019].
26. *Australia diagnostic imaging pathway. Knee Pain (Non-Traumatic)*. Government of Western Australia; 2013. Available at: http://www.imagingpathways.health.wa.gov.au/index.php/image-galleries/medical-images/musculoskeletal-trauma?id=314#pathway-home. [Accessed 30 May 2019].
27. American College of Radiology ACR Appropriateness Criteria. *Low back pain*. 2015. Available at: https://acsearch.acr.org/docs/69483/Narrative/. [Accessed 30 May 2019].
28. Expert Panel on Neurologic Imaging, Policeni B, Corey AS, Burns J, Conley DB, Crowley RW, et al. ACR appropriateness criteria cranial neuropathy. *J Am Coll Radiol* 2017;**14**(11S):S406–20.
29. Expert Panel on Radiation Oncology–Brain Metastases, Lo SS, Gore EM, Bradley JD, Buatti JM, Germano I, et al. ACR Appropriateness Criteria pre-irradiation evaluation and management of brain metastases. *J Palliat Med* 2014;**17**(8):880–6.
30. European Society of Radiology ESR. *Radiographer attendence ECR2019 official statistics*. 2019. Available at: https://www.myesr.org/media/4718. [Accessed 14 April 2019].
31. Green SB. How many subjects does it take to do A regression analysis. *Multivariate Behav Res* 1991;**26**(3):499–510.
32. McNulty JP, Rainford L, Bezzina P, Henner A, KukkesT, Pronk-Larive D, et al. A picture of radiography education across Europe. *Radiography* 2016;**22**(1):5–11.