



Contents lists available at ScienceDirect

# Technical Innovations & Patient Support in Radiation Oncology

journal homepage: [www.elsevier.com/locate/tipsro](http://www.elsevier.com/locate/tipsro)

## Research article

## Intravenous contrast media in radiation therapy planning computed tomography scans – Current practice in Ireland

Shane Minogue<sup>a</sup>, Charles Gillham<sup>b</sup>, Maeve Kearney<sup>a</sup>, Laura Mullaney<sup>a,\*</sup><sup>a</sup> Applied Radiation Therapy Trinity, Discipline of Radiation Therapy, School of Medicine, Trinity College Dublin, Ireland<sup>b</sup> St. Luke's Radiation Oncology Network, Dublin, Ireland

## ARTICLE INFO

## Article history:

Received 23 August 2019

Received in revised form 5 November 2019

Accepted 6 November 2019

## Keywords:

Intravenous contrast

Radiation therapy treatment planning scan

Computerised tomography

Target volume delineation

Radiation therapists' practice

## ABSTRACT

**Introduction:** While Computerised Tomography (CT) remains the gold standard in radiation therapy (RT) planning, inferior soft tissue definition remains a challenge. Intravenous contrast (IVC) use during CT planning can enhance soft tissue contrast optimising Target Volume (TV) and Organ at Risk visualisation and delineation. Despite this known benefit, there are no guidelines for when and how to use IVC in RT planning scans in Ireland.

**Aim:** The study aims to examine the patterns of practice in relation to the use of IVC in RT planning scans in Ireland and to determine the level of compliance with international guidelines. Radiation Therapists (RTT) IVC training will also be investigated.

**Materials and methods:** An anonymised online survey was designed based on previously-reported literature. This was distributed to all RT departments in Ireland. The survey contained open, closed and Likert scale questions that investigated IVC practices in each department.

**Results:** 75% ( $n = 9/12$ ) of Irish departments responded. All responding departments reported using IVC. RTTs cannulated patients in 67% ( $n = 6/9$ ) of the departments and administration contrast in all departments. Variations from recommended guidelines were found in disease sites where IVC was routinely used and in the assessment of renal functioning prior to contrast administration. IVC training varied in duration and number of supervised procedures required to fulfill competencies.

**Conclusion:** IVC is used extensively in Irish RT departments. There are variations in IVC practice between departments and with international recommended guidelines.

© 2019 The Authors. Published by Elsevier B.V. on behalf of European Society for Radiotherapy & Oncology. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## Introduction

Image guided radiation therapy (IGRT) refers to the application of imaging during the entire radiation therapy (RT) process. This includes diagnosis, visualisation and delineation of the target volume (TV) during RT planning and geometric verification prior to, and in some cases, during treatment delivery. The focus of this paper is the application of IGRT in TV localisation and delineation.

The goal of all RT treatment is to deliver a precise radiation dose to a delineated TV while minimising dose to surrounding Organ at Risk (OAR) structures. TV and OAR delineation is completed on CT planning scans. CT imaging remains the gold standard imaging modality for RT treatment planning (RTP) due to its ability to convert Hounsfield units into electron densities that produce dose

calculations in treatment planning systems [1–3]. However one limitation of CT imaging is the soft tissue contrast achieved when compared to other imaging modalities such as Magnetic Resonance Imaging (MRI) [4–6]. Suboptimal images may lead to uncertainties and inconsistencies in TV and OAR delineation.

The administration of Intravenous Contrast (IVC) enhances CT scans by differentiating vascular and non-vascular tissues, facilitating accurate TV and OAR delineation [7–12]. In 2004, the UK Royal College of Radiologists (RCR) published a report 'Imaging for Oncology', recommending IVC for nine specific tumour sites in RT, they also suggested that it may be used for an additional eleven sites [13] (Table 1). Despite these published recommendations, there are variations in the routine application of IVC in clinical practice in RT. Clinical experience and expertise, clinical trial protocols and/or consensus contouring atlases are factors attributed to these variations [11,14,15]. In 2008, Kim *et al.* found that 76% of the responding centres in a UK wide study used IVC for at least

\* Corresponding author.

E-mail address: [laura.mullaney@tcd.ie](mailto:laura.mullaney@tcd.ie) (L. Mullaney).

**Table 1**

The UK Royal College of Radiologists guidelines for intravenous contrast use during the radiation therapy planning scan [13].

UK Royal College of Radiologists tumour sites IVC guidelines	
Recommended Tumour Sites	Suggested Tumour Sites
1. Pharynx (including nasopharynx; oropharynx and hypopharynx)	1. Hodgkin's Disease
2. Nodal disease in the neck from head and neck cancer or other sites	2. Non-Hodgkin's Disease
3. Lung	3. Salivary glands
4. Liver	4. Cervix
5. Pancreas	5. Endometrium/ovary
6. Stomach	6. Rectum
7. Cholangiocarcinoma	7. Larynx
8. Oesophagus	8. Colon
9. Kidney	9. Vulva
	10. Bladder
	11. Adrenal glands

one of the nine recommended cancer sites, no department administered IVC for all nine of the recommended sites and 54% wished to administer it to additional tumour sites [15]. In 2016, Williams *et al.* published a follow-up study and found that 98% of these centres deliver IVC to all nine recommended tumour sites [14], but no department administered contrast to all of the RCR suggested sites. Some recommendations from the study stated concerns for patient safety during IVC procedure and the need for definitive regulations and guidelines to ensure patient safety [14].

While IVC agents today are 5–10 times safer than ionic agents used in the past, there are still associated risks with its use [16]. Adverse effects from IV iodine-based contrast media can be categorised into non-renal adverse reactions (e.g. itching, bronchospasm, convulsions) or renal adverse reactions (i.e. Post-Contrast Acute Kidney Injury (PC-AKI)) [17]. Hunt *et al.* investigated the characteristics of adverse effects from a cohort of 450,000 doses and reported hives and nausea as the most common adverse side effects and also, some rare fatalities [18]. Irish Radiation Oncologists are affiliated with the Faculty of Radiologists at the Royal College of Surgeons in Ireland. The Irish Faculty of Radiologists have no policy on IVC use or administration, for this reason international guidelines are consulted. Guidelines on the administration of contrast and the management of adverse reactions are available from the European Society of Urogenital Radiology (RSUR) [17,19,20] and the Royal Australian and New Zealand College of Radiologists (RANZCR) (The RANZCR guidelines are endorsed by the UK RCR) [21]. Despite clear guidance, compliance with these guidelines within radiology departments' is often poor [22].

The primary aim of the study is to examine the patterns of practice in relation to use of IVC in RTP in Ireland and to determine the level of compliance and consistency in use for the disease sites and specific patient safety issues. RTT IVC training will also be investigated.

## Materials and methods

Ethical approval to complete this study was obtained from the School of Medicine Research Ethics Committee in Trinity College Dublin and the St Luke's Radiation Oncology Network Research Management Committee, Dublin and all data collection was in accordance with General Data Protection Regulation.

### IVC guidelines

For the purpose of this study, the UK RCR 'Imaging for Oncology' (2004) guidelines were used as the standard to determine the tumour sites where IVC should and could be used [13] (Table 1). It could be argued that these guidelines are outdated with the

advances in RT imaging and treatment, however there is an absence of alternative comprehensive recommendations and these guidelines were used previously for similar RT studies, making comparisons more meaningful with international practice. The UK RCR also publish guidelines on the administration of IVC, however they have recently endorsed the RANZCR Iodinated Contrast Guidelines (2016). Consequently the RANZCR so these guidelines were used for patient safety comparisons in the survey. National IVC guidelines from the Irish Institute of Radiography and Radiation Therapy (IIRRT - the professional body representing RTTs in Ireland) [23] were also reviewed. These guidelines did not inform the survey development because they did not provide specific recommendations for renal testing but rather referred to the ESUR and the UK RCR (who now endorse the RANZCR) guidelines [20,21]. Hence, the ESUR and RANZCR recommendations were used for practice comparisons in patient safety and PC-AKI assessment (Table 2).

A comprehensive anonymised online survey was designed using SurveyMonkey Inc. to describe current IVC practice in Irish departments (Appendix A). The IVC questions in the survey were

**Table 2**

Recommendations from The Royal Australian and New Zealand College of Radiologists (RANZCR) and The European Society of Urogenital Radiology (ESUR) guidelines on the administration of iodinated contrast.

RANZCR Guidelines	ESUR Guidelines
1. Renal function testing: who and how? Renal function testing should be assessed if the patient (a) has known kidney disease or (b) presence of diabetes or (c) taking a drug containing metformin	Renal function testing should be assessed if the patient a. has a known eGFR less than 60 ml/min/1.73 m <sup>2</sup> or b. will receive intra-arterial contrast medium or c. aged over 70 or d. at risk of reaction
Estimated Glomerular Filtration Rate (eGFR) using the Chronic Kidney Disease Epidemiology Collaboration proposed equation (CKD-EPI) should be used to assess renal function	
2. Risk groups intravenous contrast media related post-contrast acute kidney injury (PC-AKI) eGFR of less than 45 ml/min/1.73 m <sup>2</sup> is a risk factor for PC-AKI The risk of PC-AKI is likely to be non-existent for patients with eGFR greater than 45 ml/min/1.73 m <sup>2</sup> Low or non-existent risk for patients with eGFR 30–45 ml/min/1.73 m <sup>2</sup>	a risk factor for PC-AKI The risk of PC-AKI with eGFR ≥ 30 ml/min/1.73 m <sup>2</sup> is very low Preventive measures are recommended for patients with eGFR < 45 ml/min/1.73 m <sup>2</sup> if they are in ICU
eGFR less than 30 ml/min/1.73 m <sup>2</sup> or actively deteriorating renal function the risk versus the benefit should be carefully considered	Preventive measures are recommended for patients with eGFR < 30 ml/min/1.73 m <sup>2</sup> before intravenous

taken or adapted from similar research published in this area [14,15,24] and based on the UK RCR 'Imaging for Oncology' publication [13]. The questions relating to patient safety and PC-AKI were informed by the ESUR and RANZCR guidelines [20,21]. Additional questions were added to investigate the participants' perception of guidelines.

To promote objectivity and minimise researcher bias, the survey included both qualitative and quantitative questions [25] with open and closed and Likert Scale questions. The survey was piloted on a small number of radiation therapists (RTTs) to ensure the questions, participant information leaflets and consent forms were comprehensible and appropriately addressed the research question. All data collected was anonymous and non-identifiable.

An Executive Officer unrelated to the research team acted as the gatekeeper. Each of the twelve RT departments in the Republic of Ireland were invited to participate in the survey by the gatekeeper via email containing a link to the online survey. Radiation Therapy Service Managers were asked to designate a suitably qualified RTT in their respective departments to complete the survey. The survey was open for a four-week period in September- October 2018, with a reminder email sent by the gatekeeper one week before the closing date.

Completed surveys were exported to Microsoft Office 365 Excel for analysis using descriptive statistics (percentages, mode and mean). Departments were labelled from 'A' to 'I' to illustrate results.

## Results

75% of RT departments responded to the survey ( $n = 9/12$ ) and all nine departments fully completed the survey.

RTTs cannulated patients in 67% ( $n = 6$ ) of departments that responded. Nurses and junior doctors were responsible for cannulation in the remaining 33.3% ( $n = 3$ ) departments. IVC administration was completed by RTTs in all departments. IVC protocols were based on diagnostic imaging protocols in eight out of nine responding departments, with the final department adapting diagnostic imaging protocols to achieve 'improved results' When asked if their department's current protocol was adequate, all respondents 'agreed' ( $n = 7$ ) or 'strongly agreed' ( $n = 2$ ). When asked if enhance-

ment achieved from current IVC protocols was sufficient, 22% responded it was 'always' sufficient, while the remainder stated that it was in 'most cases'. The consistent scan enhancement reported was by the two departments where additional administrative techniques were used (saline chaser ( $n = 2$ ) and bolus tracking ( $n = 1$ )). No other departments used additional enhancement techniques. Where IVC use was contraindicated 33% of departments fused the planning scan with a diagnostic scan for delineation purposes while the remainder took no further action.

### IVC use

All responding departments used IVC in clinical practice to varying degrees. IVC enhanced CT scans made up 10%–60% (Mean 35%, Median 30%) of the total monthly CT output in responding departments (Fig. 1). Three departments stated that  $\geq 50\%$  of patients per month required contrast, while six departments used contrast for  $< 50\%$  of patients scanned. One department stated that IVC was administered for approximately 10% of their patients.

Four departments used IVC for  $\geq 16$  sites, eight departments used IVC for  $\geq 10$  different tumour sites, while one department used IVC for four tumour sites. Figs. 2 and 3 illustrate the range of sites where IVC is administered. 33% ( $n = 3$ ) departments stated that they had plans for improving/extending their use of IVC while 66% ( $n = 6$ ) of respondents had no future plans to do so. Two departments responded when asked the reason why IVC was not routinely used in their departments, they identified staff training ( $n = 1$ ) and the lack of hospital policy surrounding IVC use ( $n = 1$ ) as reasons.

### RCR tumour sites

The RCR recommends [13] using IVC routinely for 9 sites (Table 1). No department administered IVC to all nine recommended sites (Fig. 2). Three departments administered contrast to six of the nine recommended sites. The nine responding departments reported routine use of IVC for head and neck patients ( $n = 9$ ), followed by lung ( $n = 8$ ), pancreas ( $n = 7$ ) and pharynx/oesophagus patients (both  $n = 5$ ). IVC use was less common in the other RCR recommended tumours; with one department rou-

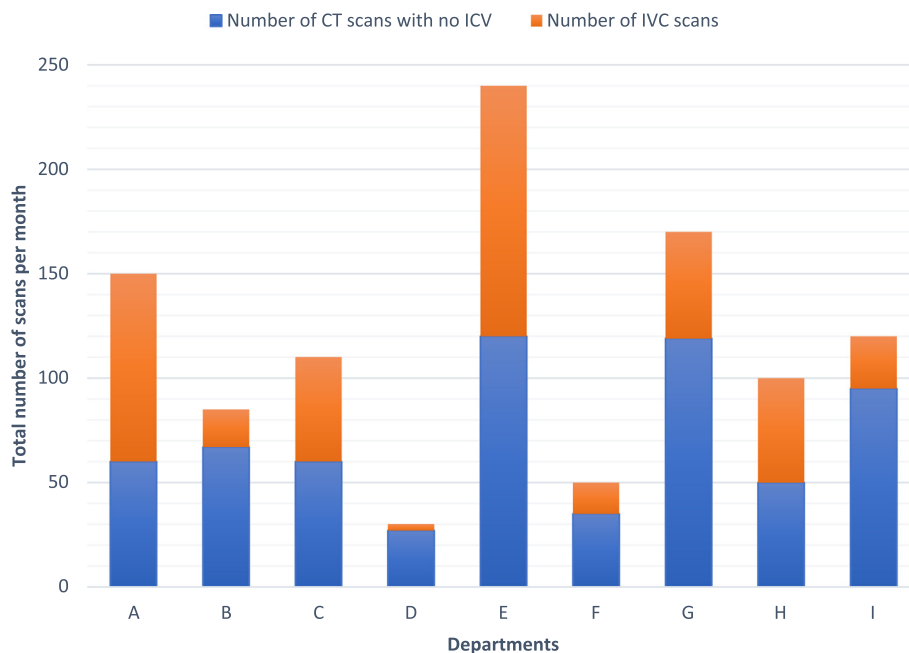


Fig. 1. The frequency of intravenous contrast (IVC) usage per department per month.

tinely administered IVC for cholangiocarcinoma ( $n = 1$ ) while two departments routinely administered IVC for liver patients ( $n = 2$ ).

The RCR guidelines suggest the IVC can be used in an additional 11 sites (Fig. 3). No department administered IVC to all these suggested sites. Hodgkin's Lymphoma was the most common site where contrast was given (87%,  $n = 8$ ); followed by endometrium; cervix; parotid and Non Hodgkin's Lymphoma, with 7 departments (78%) administer IVC to these sites. Several sites were identified to which centres gave IVC which are not supported by the RCR (Fig. 3) including: prostate ( $n = 6$ ); brain and paranasal sinus ( $n = 5$ ) and thyroid ( $n = 4$ ).

*Patient safety*

Prior to IVC administration, the vast majority of departments ( $n = 8/9$ ) routinely checked the kidney function for every patient. One department routinely checking kidney function for high-risk patients only. RTTs were responsible for checking kidney function in 78% of departments ( $n = 7$ ), while a diagnostic radiographer ( $n = 1$ ) and nursing staff ( $n = 1$ ) were responsible in the other departments.

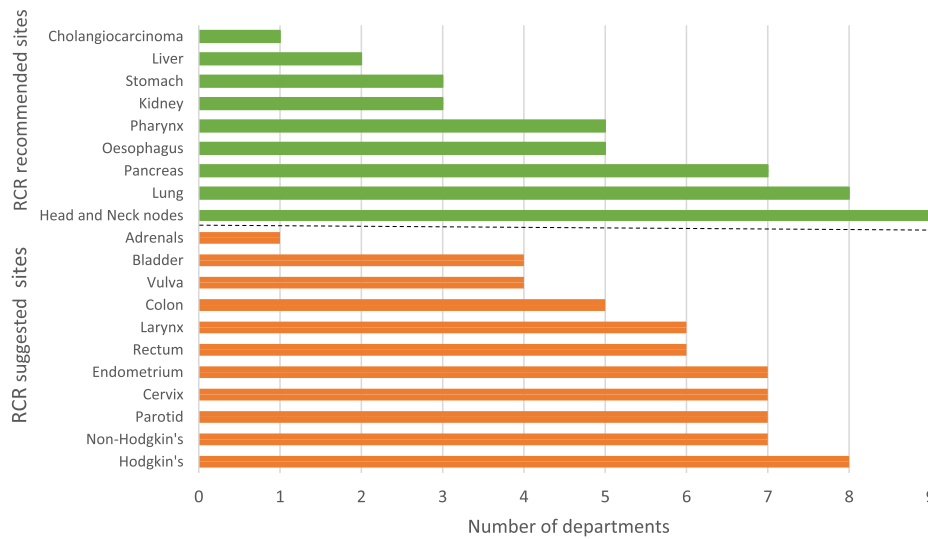
Five departments used estimated Glomerular Filtration Rate (eGFR) to assess kidney function, using a variety of different calculations to assess this: the Cockcroft Gault formula ( $n = 2$ ); the Modification of Diet in Renal Disease (MDRD) formula ( $n = 2$ ) and one

department did not know the formula used to calculate eGFR. Four other departments assessed kidney function by measuring creatinine levels. Where departments used eGFR to assess kidney function, the most common eGFR threshold where IVC can be administered without intervention was  $>60 \text{ mL/min/1.73 m}^2$  (75%  $n = 3$ ) and a lower limit of  $<30 \text{ mL/min/1.73 m}^2$  (50%  $n = 2$ ), where no contrast is administered. The intervention ranges were as follows: eGFR 45–59  $\text{mL/min/1.73 m}^2$  1 l oral hydration over 2 h ( $n = 2$ ) and eGFR30–44  $\text{mL/min/1.73 m}^2$ , 1 l IV hydration over 2 h ( $n = 2$ ) or  $>45 \text{ mL/min/1.73 m}^2$  a doctor was required to make the decision ( $n = 1$ ) One department did not provide the eGFR bands.

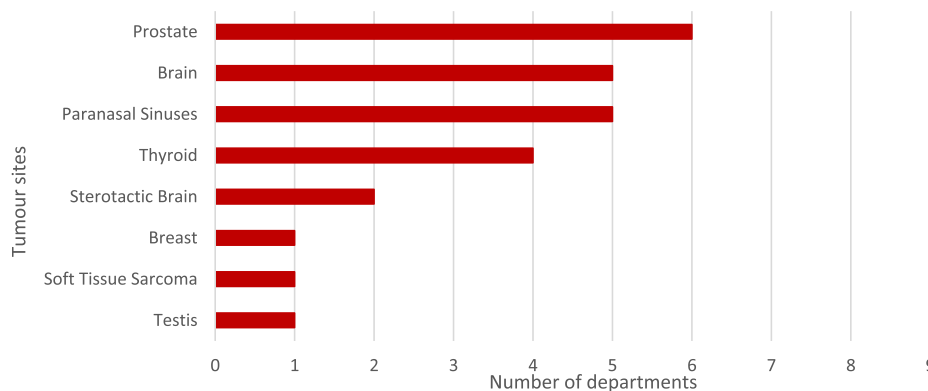
Eight departments (89%) offered post contrast advice to patients, the advice focusing on remaining vigilant for signs and symptoms of a delayed reaction and the importance of increasing oral hydration to aid IVC excretion. One department reported that no advice was given post procedure. Information regarding extravasation was provided to patients in most of the departments (89%,  $n = 8$ ), in one department the advice given was unknown.

*Training*

All training received covered cannulation and IVC administration procedures. The training was largely university based in 78% ( $n = 7$ ) of the responding departments, with the remaining two departments using an IIRRT accredited hospital based training



**Fig. 2.** Usage of intravenous contrast (IVC) for radiation therapy planning scans based on the Royal College Radiologists (RCR) guidelines.



**Fig. 3.** The range of tumour sites (excluding the RCR sites) where intravenous contrast (IVC) is administered during radiation therapy planning scans.

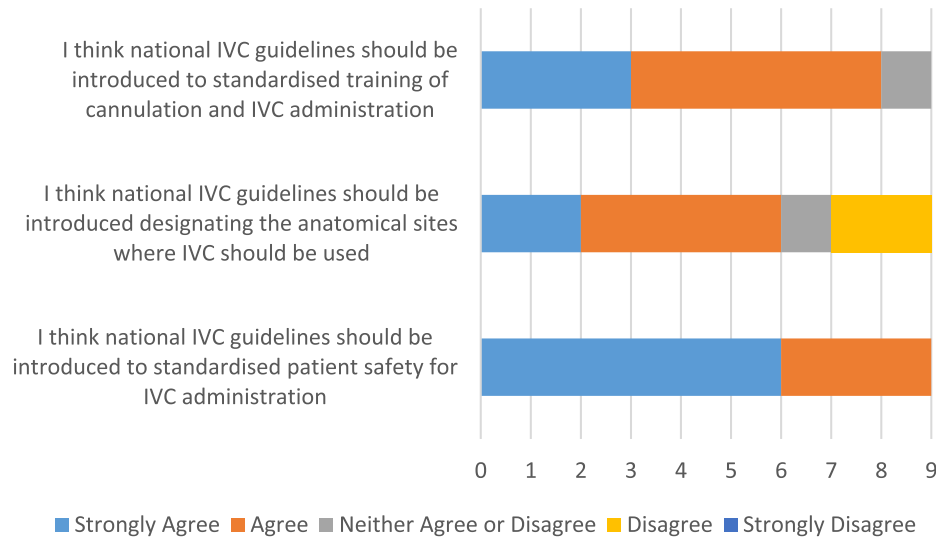


Fig. 4. Participants' response to guideline related questions.

programme. The duration of training varied, ranging from two days to two months with the training structure composed of a taught theory component followed by a period of supervised cannulations and administrations. The supervised cannulations ranged from 20 to 40 patients and the supervised administration ranged from 3 to 20 patients. When asked if the training they received was sufficient, 78% ( $n = 7$ ) of departments agreed. 78% of departments also agreed (strongly agreed = 5; agreed = 2) that they were confident in delivering IVC post the completion of training. When asked if guidelines are required for standardising IVC training five departments agreed and three departments strongly agreed (Fig. 4).

#### Guideline need

The response to questions relating to guidelines is shown in Fig. 4. All departments agreed ( $n = 3$ ) or strongly agreed ( $n = 6$ ) that guidelines are needed to standardise patient safety when administering IVC. Two-thirds for departments agreed that guidelines are needed to identify site where IVC should be used.

#### Discussion

IVC can enhance the IGRT capability of RTP CT imaging. Accurate TV and OAR delineation requires high quality imaging scans and many studies endorse the use of IVC in RTP scans reporting consistent and accurate structure delineation in a range of sites [7,8,26–28]. This study presents the current pattern of IVC practice in RTP scans in Ireland and identifies compliances and discrepancies with international recommended guidelines. This study can provide a practice comparison and learning for departments beyond Ireland.

The survey response rate (75%,  $n = 9/12$ ) is an adequate representation of current IVC practices in Ireland. Although each of the responding departments stated that they used IVC, there were inconsistencies in practice (Figs. 1–3). All of the Irish departments surveyed used IVC in clinical practice, which is similar to the UK use (98%) reported in 2014 [14].

No Irish department administered IVC to all nine of the RCR recommended tumour sites, while 6% of UK departments are fully compliant with these recommendations [14]. However, these results may not reflect poor compliance within Irish departments as small departments may refer less common disease sites (e.g. cholangiocarcinoma) to larger referral centres, thus not routinely imaging the range of RCR recommended sites. A third of Irish

departments administered contrast to six of the nine recommended sites, with all departments using IVC for head and neck nodes, which is also in line with current evidence based contouring recommendations [29]. Despite the RCR recommendations and evidence to suggest the benefit of IVC in TV and OAR delineation [13,29–31], IVC use was less routine in the stomach ( $n = 3/9$ ); pharynx ( $n = 5/9$ ) and oesophagus ( $n = 5/9$ ).

The use of IVC has increased over the last decade based largely on consensus delineation guidelines and clinical trial protocols [14]. This is reflected in the usage reported in this study in the suggested RCR sites such as Non/Hodgkin's lymphoma; gynaecological disease sites; prostate; parotid and rectum, proposing that these sites should now have a definitive recommendation for IVC. There was a similar compliance in department IVC practice between the recommended and suggested RCR sites, this is also in line with the UK findings [32]. Sites where IVC was commonly given but not recommended or suggested in the RCR guidelines include prostate, brain and paranasal sinuses. The use of IVC at these sites reflects new evidence for its benefit in CT imaging [11,29] since the establishment of the RCR guidelines and is similar to the UK results [14]. These results may suggest a need to review and update the RCR recommended sites in view of evidenced based practice.

Two thirds of departments were in favour of the introduction of guidelines specifying the tumour sites where IVC is beneficial for TV and OAR delineation. UK RTTs also support this motion [14]. Such guidelines could facilitate the standardisation of IVC use in RTP scans. A more definitive list of sites where IVC use is warranted may support the increased use of contrast, for example by including the 11 suggested sites to the recommended list in the RCR guidelines. It can be argued that guidelines may not directly translate into a change in practice. However, there is evidence in the case of prostate, where consensus delineation guidelines for pelvic nodal volumes have recommended the use of IVC [11] and 67% ( $n = 6/9$ ) departments use contrast in this patient group. Collaboration at a multidisciplinary level may be key to developing consistent practice guidelines. The knowledge and experience of diagnostic radiographers; radiation oncologists and radiologists should be harnessed to create and optimise IVC protocols for RT planning scans.

RANZCR and ESUR guidelines recommend assessing renal function in patients at risk of PC-AKI only (Table 2). One department adhered to these recommendations while the remainder assessed renal functions in all patients. These inconsistencies may be due to following older RCR guidelines which recommended assessing



renal function for all non-emergency patients [33] and departments maintaining a cautious approach to patient safety. Assessing only high risk patients would streamline the pre-CT process by reducing the number of patients requiring biochemistry tests before IVC which requires a waiting period between taking blood and receiving results.

Inconsistencies were observed in the methods of assessing renal function across the different departments. Total glomerular filtration rate (GFR) is considered the best measure of kidney function, but it cannot be easily assessed in clinical practice, for that reason eGFR using serum creatinine levels is routinely used [17]. There are several different equations proposed to calculate eGFRs [17]. RANZCR and ESUR guidelines recommend measuring the eGFR using the Chronic Kidney Disease Epidemiology (CKD-EPI) proposed equation due to its accuracy across a wide variety of populations and clinical conditions when compared with other formulae issues [34–36]. Although 44% of departments used eGFR, different formulas were used to calculate this reading, with no department using the CKD-EPI equation. Four of the nine (44%) Irish department and 27% of UK departments [14] tested renal function using serum creatinine levels alone. Serum creatinine can fail to recognise patients with impaired kidney function in up to 92% of patient >70 years of age [36]. Indications for serum creatinine substitutes and formula specific eGFR measures can present as conflicting and possibly confusing. Highlighting these inconsistencies in renal function testing may help inform future policies and practice for departments.

The RANZCR and ESUR guidelines state that eGFR of less than 45 ml/min/1.73 m<sup>2</sup> is a risk factor for PC-AKI but above this level, the risk is likely to be non-existent and no intervention is required (Table 2). In addition, they state that IVC can still be considered at <30 ml/min/1.73 m<sup>2</sup> if the benefit outweighs the risk of PC-AKI on the patient [21] and preventive measures such as intensive hydration protocols prior to administration are followed [17,19] (Table 2). The reported results were inconsistent between departments and are more conservative than the recommendations; with a threshold of hydration intervention from 45 to 59 ml/min/1.73 m<sup>2</sup>. All departments that assess eGFR had a lower cut off for IVC use of 30–45 ml/min/1.73 m<sup>2</sup>. This conservative approach by departments is reasonable and may reflect clinical experiences and the balance of risk coming down on the side of preventing PC-AKI versus the benefit of image enhancement. The guidelines propose that if the benefits exceed the risk then IVC can be considered even at levels below 30 ml/min/1.73 m<sup>2</sup>, this approach may allow an increased number of patients benefit from contrast enhancement, especially in the context where 67% of departments did not use additional imaging methods to aid delineation when contrast was not used.

Risks of adverse reactions associated with IVC are well reported [18] and both the RANZCR and ESUR have an established escalation procedure in the event of adverse reactions [17,19,21]. The majority of departments (87%) provided patients with advice regarding delayed reactions and hydration post the IVC procedure. The safety of the patient is fundamental in any RT procedure including IVC use. In line with RANZCR recommendations, all RTTs should be trained in the signs and symptoms of early and late adverse reactions and the escalation procedures to address such reactions. This will ensure RTTs are competent in identifying and dealing with any safety issues that may arise during IVC process.

Cannulation and IVC administration is largely RTT led, with RTTs cannulating patients in 67% of departments and administering IVC in all departments. Inconsistencies were reported in many aspects of IVC training (duration, number of supervised cannulations and administrations), similar to findings from other countries [14]. The majority of participants felt the training was sufficient and were confident in administering IVC post training. One department

reported the theoretical component of the training was inadequate and one department referred to staff training as a barrier to the expansion of IVC use. Training programmes in Ireland are delivered by and for diagnostic radiographers. The programmes have a strong focus on the practical aspects of cannulation as it is assumed that participants have prior knowledge of the theoretical aspects of IVC, as a result, they may not meet the educational needs of RTTs.

Advanced techniques such as saline chaser and bolus tracking were used routinely in a third of departments. The two departments who reported achieving consistent image enhancement with IVC routinely use bolus tracking and saline chaser. Both techniques are cost effective, reduce risk of CI nephropathy and are beneficial in CT enhancement when used correctly [37–39]. While it is positive that cannulation and IVC administration is largely RTT led, inconsistencies exist in training received in optimisation techniques in IVC administration. Throughout their careers, RTs may work in several departments bringing with them their own cannulation and IVC practices. This could lead to a department where practices may be dependent on the RTT completing the cannulation and IVC administration. Eight of the nine departments were in favour of guidelines to standardise IVC training programmes, which is to be expected based on the variations reported. Lack of standardisation and inconsistencies in practice may prove difficult for new staff training and building competencies in this area potentially jeopardising the effectiveness and safety of this procedure. A standardised training programme focused on RT practice may provide the basis for much needed consistency in cannulation practices and guidelines for maximising IVC function and capabilities thus optimising image quality.

#### Limitations

A limitation of this study was the lack of full participation of all departments ( $n = 9/12$ ). Departments without IVC facilities may have assumed the survey was not applicable to them. Full participation in the study would provide a fully comprehensive picture of IVC use throughout Ireland. Departments were not asked to provide their clinical IVC protocol. It is also possible respondents may not have clearly understood or have been biased by the wording in this survey. Given the small sample of centres ( $n = 12$ ) it was not practical to pilot the questions on RTTs from other centres. There may be discrepancies between what was captured in the survey and the implemented clinical protocol. The use of IVC may be physician dependent, rather than site/protocol dependent, this point was not captured in the survey.

#### Conclusion

IVC is used routinely in clinical practice in Ireland but there are inconsistencies in its application. There is heterogeneity in terms of: the disease sites where IVC is warranted; the assessment of patients' renal function prior to contrast administration and the RTT IVC training. A lack of definitive guidelines may mean the proven benefits of IVC in facilitating TV and OAR delineation is not being fully maximised. The findings of this study are based on the Irish context, however the insights offered into IVC practice can provide learning for departments in other countries.

Recommendations to departments using IVC include:

- IVC should be implemented into routine clinical practice for all sites where its use has shown superior image interpretation thus facilitating accurate TV and OAR delineation. In the absence of other evidence, the 20 sites identified by the UK RCR 'imaging for Oncology' publication provides guidance on appropriate IVC use [13].
- eGFR levels can be checked for patients 'at risk' of PC-AKI only. This 'at risk' group can be identified by reference to the EURL guidelines [20].

- Standardised RTT training for IVC cannulation and administration should provide RTTs with the skills to implement image enhancement techniques and maximise benefits of IVC where required.

#### Declaration of Competing Interest

None of the authors listed have any conflicts of interest to declare.

#### Appendix A. Questionnaire

1. If IVC is not used routinely within the department what are the reasons for this?

- |  |                                       |
|--|---------------------------------------|
| <input type="radio"/> Financial reasons      | <input type="radio"/> Hospital policy |
| <input type="radio"/> Staff training         | <input type="radio"/> Not applicable  |
| <input type="radio"/> Lack of resources      |                                       |
| <input type="radio"/> Other (please specify) |                                       |

2. Which sites is IVC used for within the department?

- |   |  |
|---|--|
| <input type="checkbox"/> Brain                  | <input type="checkbox"/> Colon               |
| <input type="checkbox"/> Spinal cord            | <input type="checkbox"/> Rectum              |
| <input type="checkbox"/> Pharynx                | <input type="checkbox"/> Cervix              |
| <input type="checkbox"/> Paranasal sinuses      | <input type="checkbox"/> Endometrium         |
| <input type="checkbox"/> Larynx                 | <input type="checkbox"/> Vulva               |
| <input type="checkbox"/> Parotid                | <input type="checkbox"/> Bladder             |
| <input type="checkbox"/> Thyroid                | <input type="checkbox"/> Prostate            |
| <input type="checkbox"/> Head and neck nodes    | <input type="checkbox"/> Testis              |
| <input type="checkbox"/> Lung                   | <input type="checkbox"/> Soft tissue sarcoma |
| <input type="checkbox"/> Liver                  | <input type="checkbox"/> Breast              |
| <input type="checkbox"/> Pancreas               | <input type="checkbox"/> Primary bone        |
| <input type="checkbox"/> Kidneys                | <input type="checkbox"/> Hodgkin's           |
| <input type="checkbox"/> Adrenals               | <input type="checkbox"/> Non Hodgkin's       |
| <input type="checkbox"/> Oesophagus             | <input type="checkbox"/> Cholangiocarcinoma  |
| <input type="checkbox"/> Stomach                |  |
| <input type="checkbox"/> Other (please specify) |  |

3. Who administers the IVC?

- Radiation therapist
- Nurse
- Other (please specify)
- Doctor
- Health care assistant

4. What are your IVC protocols based on?

- Diagnostic Protocols
- Other (please specify)
- Manufacturers Recommendations

5. What training must be undertaken prior to cannulation and administration of using IVC?

Cannulation-please specify:

Duration of this training:

Administration- please specify:

Duration of this training:

6. I think national IVC guidelines should be introduced to standardised patient safety for IVC administration.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

7. Who cannulates the IVC patients?



8. After completing the required training, I feel confident in delivering IVC.

- Strongly agree  Disagree
- Agree  Strongly disagree
- Neither agree nor disagree

9. Do you think the training received is sufficient?

- Yes  No
- Other (please specify)

10. Do I think my institutions current protocols are adequate?

- Strongly agree  Disagree
- Agree  Strongly disagree
- Neither Agree Nor Disagree

11. I think national IVC guidelines should be introduced designating the anatomical sites where IVC should be used?

- Strongly agree  Disagree
- Agree  Strongly disagree
- Neither agree nor disagree

12. I think national IVC guidelines should be introduced to standardised training of cannulation and IVC administration?

Strongly agree

Disagree

Agree

Strongly  
disagree

Neither agree nor disagree

## 13. Is kidney function routinely checked prior to administration of IVC?

 Yes, for every patient No Yes, high risk patients only If High risk please specify what factors are considered:

## 14. Who is responsible for checking kidney function?

Radiation Therapist

Doctor

Diagnostic radiographer

Health care assistant

Nurse

Other (please specify)

## 15. If kidney function is assessed, what method is used?

GFR

EDTA

eGFR Wright Formula

Not applicable

eGFR Cockcroft Gault

Unknown

eGFR MDRD

Other (please specify)

16. If kidney function is assessed, what threshold limits/bands do you use prior to administration?

17. In your opinion, is the enhancement achieved from using current IVC protocols sufficient?

- Always
- Most of the time
- Sometimes
- Never

18. Are additional administration techniques used?

- Bolus tracking
- Saline chaser
- Other (please specify)
- None used

19. What procedure is used if contrast cannot be delivered?

- Planning scan merged with secondary diagnostic scan
- No action take
- Other (please specify)

20. Is post injection advice given to the patient?

- Yes
- No
- If yes please specify

21. What advice is given if extravasation occurs?

22. Are any future developments planned within the department to improve/ extend the use of

IVC?

Yes

No

Other (please specify)

23. If you have any additional comments, please specify:

24. Per month, approximately how many patients receive a planning CT scan in your department?

25. Per month, approximately how many IVC scans are acquired in your department?

## References

- [1] Skrzynski W, Zielinska-Dabrowska S, Wachowicz M, Slusarczyk-Kacprzyk W, Kukolowicz PF, Bulski W. Computed tomography as a source of electron density information for radiation treatment planning. *Strahlenther Onkol* 2010;186(6):327–33.
- [2] Yohannes I, Kolditz D, Langner O, Kalender WA. A formulation of tissue- and water-equivalent materials using the stoichiometric analysis method for CT-number calibration in radiotherapy treatment planning. *Phys Med Biol* 2012;57(5):1173–90.
- [3] Landry G, Reniers B, Granton PV, van Rooijen B, Beaulieu L, Wildberger JE, et al. Extracting atomic numbers and electron densities from a dual source dual energy CT scanner: experiments and a simulation model. *Radiother Oncol* 2011;100(3):375–9.
- [4] Nasrollah J, Mikaeil M, Omid E, Mojtaba SS, Ahad Z. Influence of the intravenous contrast media on treatment planning dose calculations of lower esophageal and rectal cancers. *J Cancer Res Ther* 2014;10(1):147–52.
- [5] O'Neill BD, Salerno G, Thomas K, Tait DM, Brown G. MR vs CT imaging: low rectal cancer tumour delineation for three-dimensional conformal radiotherapy. *Br J Radiol* 2009;82(978):509–13.
- [6] Karlsson M, Karlsson MG, Nyholm T, Amies C, Zackrisson B. Dedicated magnetic resonance imaging in the radiotherapy clinic. *Int J Radiat Oncol\*Biophys* 2009;74(2):644–51.
- [7] Giraud P, Kantor G, Loiseau H, Rosenzweig KE. Target definition in the thorax and central nervous system. *Semin Radiat Oncol* 2005;15(3):146–56.
- [8] Helou J, Karotki A, Milot L, Chu W, Erler D, Chung HT. 4DCT simulation with synchronized contrast injection in liver SBRT patients. *Technol Cancer Res Treat* 2016;15(1):55–9.
- [9] Goodman KA, Regine WF, Dawson LA, Ben-Josef E, Haustermans K, Bosch WR, et al. Radiation therapy oncology group consensus panel guidelines for the delineation of the clinical target volume in the postoperative treatment of pancreatic head cancer. *Int J Radiat Oncol\*Biophys* 2012;83(3):901–8.
- [10] Scher ED, Ahmed I, Yue NJ, Jabbour SK. Technical aspects of radiation therapy for anal cancer. *J Gastrointest Oncol* 2014;5(3):198–211.
- [11] Harris VA, Staffurth J, Naismith O, Esmail A, Gulliford S, Khoo V, et al. Consensus guidelines and contouring atlas for pelvic node delineation in prostate and pelvic node intensity modulated radiation therapy. *Int J Radiat Oncol Biol Phys* 2015;92(4):874–83.
- [12] Zhou S-M, Bentel GC, Lee CG, Anscher MS. Differences in gross target volumes on contrast vs. noncontrast CT scans utilized for conformal radiation therapy treatment planning for prostate carcinoma. *Int J Radiat Oncol\*Biophys* 1998;42(1):73–8.
- [13] *Imaging for Oncology*. In: *Oncology FoC*, editor. London: The Royal College of Radiologists; 2004.
- [14] Williams K, Probst H. Use of IV contrast media in radiotherapy planning CT scans: a UK audit. *Radiography*. 2016;22:S28–32.
- [15] Kim S, Russell W, Price P, Saleem A. Suboptimal use of intravenous contrast during radiotherapy planning in the UK. *Br J Radiol* 2008;81(972):963–9.
- [16] The Royal College of Radiologists. Standards for intravascular contrast agent administration to adult patients. 2nd ed. London: The Royal College of Radiologists; 2010.
- [17] van der Molen AJ, Reimer P, Dekkers IA, Bongartz G, Bellin M-F, Bertolotto M, et al. Post-contrast acute kidney injury – Part 1: Definition, clinical features, incidence, role of contrast medium and risk factors: recommendations for updated ESUR Contrast Medium Safety Committee guidelines. *Eur Radiol* 2018;28(7):2845–55.
- [18] Hunt CH, Hartman RP, Hesley GK. Frequency and severity of adverse effects of iodinated and gadolinium contrast materials: retrospective review of 456,930 doses. *AJR Am J Roentgenol* 2009;193(4):1124–7.
- [19] van der Molen AJ, Reimer P, Dekkers IA, Bongartz G, Bellin M-F, Bertolotto M, et al. Post-contrast acute kidney injury. Part 2: risk stratification, role of hydration and other prophylactic measures, patients taking metformin and chronic dialysis patients: recommendations for updated ESUR Contrast Medium Safety Committee guidelines. *Eur Radiol* 2018;28(7):2856–69.
- [20] European Society of Urogenital Radiology. Guidelines on Contrast Media. Available from: <http://www.esur.org/guidelines> [accessed 5th Nov 2019].
- [21] The Royal Australian and New Zealand College of Radiologists. Iodinated Contrast Media Guideline. 2018. Available from: <https://www.ranzcr.com/search/ranzcr-iodinated-contrast-guidelines> [accessed 5th Nov 2019].
- [22] Cope LH, Drinkwater KJ, Howlett DC. RCR audit of compliance with UK guidelines for the prevention and detection of acute kidney injury in adult patients undergoing iodinated contrast media injections for CT. *Clin Radiol* 2017;72(12):1047–52.
- [23] Irish Institute of Radiography and Radiation Therapy. Intravenous Cannulation/Administration for Radiographers/Radiation Therapists: Guidelines on Best Practice 5th ed.; 2017.

- [24] Jefferies S, Taylor A, Reznick R. Results of a national survey of radiotherapy planning and delivery in the UK in 2007. *Clin Oncol (R Coll Radiol)* 2009;21(3):204–17.
- [25] A.R. Medical Imaging and Radiotherapy Research. Skills and strategies. Livingstone EC, editor. London; 2010.
- [26] Senan S, De Ruysscher D, Giraud P, Mirimanoff R, Budach V. Literature-based recommendations for treatment planning and execution in high-dose radiotherapy for lung cancer. *Radiother Oncol* 2004;71(2):139–46.
- [27] Rasch C, Steenbakkers R, van Herk M. Target definition in prostate, head, and neck. *Semin Radiat Oncol* 2005;15(3):136–45.
- [28] Villeirs GM, Van Vaerenbergh K, Vakaet L, Bral S, Claus F, De Neve WJ, et al. Interobserver delineation variation using CT versus combined CT + MRI in intensity-modulated radiotherapy for prostate cancer. *Strahlenther Onkol* 2005;181(7):424–30.
- [29] Grégoire V, Evans M, Le Q-T, Bourhis J, Budach V, Chen A, et al. Delineation of the primary tumour Clinical Target Volumes (CTV-P) in laryngeal, hypopharyngeal, oropharyngeal and oral cavity squamous cell carcinoma: AIRO, CACA, DAHANCA, EORTC, GEORCC, GORTEC, HKNPCSG, HNCIG, IAG-KHT, LPRHHT, NCIC CTG, NCRI, NRG Oncology, PHNS, SBRT, SOMERA, SRO, SSHNO TROG consensus guidelines. *Radiotherapy Oncol* 2018;126(1):3–24.
- [30] Matzinger O, Gerber E, Bernstein Z, Maingon P, Haustermans K, Bosset JF, et al. EORTC-ROG expert opinion: radiotherapy volume and treatment guidelines for neoadjuvant radiation of adenocarcinomas of the gastroesophageal junction and the stomach. *Radiother Oncol* 2009;92(2):164–75.
- [31] Christianen MEMC, Langendijk JA, Westerlaan HE, van de Water TA, Bijl HP. Delineation of organs at risk involved in swallowing for radiotherapy treatment planning. *Radiotherapy Oncol* 2011;101(3):394–402.
- [32] Mendenhall NP, Meyer J, Williams J, Tebbi C, Kessel S, Laurie F, et al. The impact of central quality assurance review prior to radiation therapy on protocol compliance: POG 9426, a trial in pediatric Hodgkin's disease. *Am Soc Hematol* 2005.
- [33] The Royal College of Radiologists. Standards for intravascular contrast administration to adult patients. In: Royal, editor. London: The Royal College of Radiologists; 2015.
- [34] Thomsen HS, Morcos SK. In which patients should serum creatinine be measured before iodinated contrast medium administration? *Eur Radiol* 2005;15(4):749–54.
- [35] Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro 3rd AF, Feldman HI, et al. A new equation to estimate glomerular filtration rate. *Ann Intern Med* 2009;150(9):604–12.
- [36] Kappel J, Calissi P. Nephrology: 3. Safe drug prescribing for patients with renal insufficiency. *CMAJ* 2002;166(4):473–7.
- [37] Bae KT. Intravenous contrast medium administration and scan timing at CT: considerations and approaches. *Radiology* 2010;256(1):32–61.
- [38] Shibamoto Y, Naruse A, Fukuma H, Ayakawa S, Sugie C, Tomita N. Influence of contrast materials on dose calculation in radiotherapy planning using computed tomography for tumors at various anatomical regions: a prospective study. *Radiother Oncol* 2007;84(1):52–5.
- [39] Dorio PJ, Lee Jr FT, Henseler KP, Pilot M, Pozniak MA, Winter 3rd TC, et al. Using a saline chaser to decrease contrast media in abdominal CT. *AJR Am J Roentgenol* 2003;180(4):929–34.