Collaborative roles of the multi-disciplinary team in Radiotherapy Imaging

Tim Wood, Hull University Teaching Hospitals NHS Trust

Imaging is fundamental to almost all Radiotherapy treatments undertaken in the UK. The technology and techniques used are constantly evolving, and include almost the full range available in diagnostic imaging departments. Hence, to make full use of this technology and to optimise those that use ionising radiation, a multi-disciplinary team approach is vital to ensure the best possible outcomes for the patient. A mix of Physicists (both from diagnostic imaging and radiotherapy), Radiographers and Clinicians, alongside other relevant disciplines for the task at hand are recommended. This approach is consistent with the recommendations of the Committee on Medical Aspects of Radiation in the Environment (COMARE) 16 Report, Recommendation 7 which promotes the idea of a team of radiation protection champions.

This talk will discuss some local implementations of these ideas, and the successes, failures and challenges that may be encountered. Audience participation and discussion will be actively encouraged!

Patient Safety in Radiotherapy Imaging

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Helen Best, Senior Clinical Officer – Radiotherapy, UKHSA
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Patient safety in radiotherapy (RT) has been defined as the absence of an unacceptable risk of harm when harm is excess morbidity or sub-optimal tumour control (Dunscombe 2012). There are known risks inherent in the planning and delivery of radiotherapy which might be loosely grouped into biological effects or procedural failures. This talk will focus on those associated with failures associated with radiotherapy on-set imaging.

The role of on-set imaging in contemporary practice will be explored.

Case studies of two significant radiotherapy on-set imaging incidents will be presented as learning opportunities and to highlight risk associated with on-set imaging. UK strategies to mitigate against these types of events will be highlighted.

Key learning from the *7th Safer Radiotherapy: Biennial radiotherapy error and near miss report* will be shared. This report is part of a series, series of two-year reports, providing an overview of Radiotherapy Error (RTE) data reported voluntarily to the National Reporting and Learning System (NRLS) at NHS England (NHSE) and directly to UKHSA between January 2020 until December 2021 (n=18,681). The report also contains aggregate data from January 2017 to December 2021 (n=45,282) and compares data with that from the preceding 2-year period (n=18,734). This report also contains data received from the inspectorates for the Ionising Radiation (Medical Exposure) Regulations for England, Wales, Northern Ireland and Scotland. This report has been written with the support of NHSE, Royal College of Radiologists, Society of Radiographers and Institute of Physics and Engineering in Medicine. The trend analysis includes severity of events, where along the patient pathway RTE occur, causative factors, safety barriers coding, methods of detection and brachytherapy related errors.

Incident trends associated with on-set imaging from this report will be presented and mitigations explored.

Whilst much has been done to improve patient safety in radiotherapy some error trends persist. It is time to consider new approaches to address these. In addition, when the opportunity for error is weighed against the reported occurrence of error, relative numbers of errors are low. This would suggest that there are many more opportunities to learn from where things have gone to plan as opposed to where they have gone wrong. Plans to address this and persistent on-site imaging incident trends will be shared.

Title of Study
Paediatric imaging in radiotherapy
4D CBCT optimisation

Abstract no more than 1 page in Arial 11 point, presenting speaker underlined

Invited talks – Abigail Bryce-Atkinson

Optimisation of radiotherapy image guidance requires consideration of the patient population, image purpose, and imaging dose. Use of phantom studies only provides limited value to evaluate image quality because in patients, image quality is affected by tissue texture, motion, and variation between patients. Simulation studies based on retrospectively acquired patient data are therefore a valuable tool to realistically assess image quality in patient images. Multidisciplinary collaborations (i.e. physicists, radiographers, clinicians and research teams) can boost the success of such studies, and allow images to be evaluated with methods directly related to the image purpose. These talks will summarise research aiming to optimise cone beam CT (CBCT) in image-guided radiotherapy (IGRT) for two patient populations (paediatric and adult lung cancer), highlighting methods that can be applied to evaluate images for the purpose of IGRT.

In paediatric radiotherapy, imaging dose reduction is of great importance, due to the long-term risks of radiation exposure, including the induction of second cancers later in life. Daily cone beam CT (CBCT) imaging allows for correction of setup errors and evaluation of internal anatomy. However, CBCT is more reluctantly applied in children due to dose concerns, and there is a lack of consensus regarding the optimal exposure settings to use for paediatric protocols. This talk will present research optimising paediatric CBCT protocols in radiotherapy, using simulation methods to create “ultra-low” dose CBCT scans from previously acquired data. Image quality was evaluated by determining the accuracy of CBCT-CT image registration, and qualitatively through visual grading analysis with experienced radiographers. The amount of image noise resulting from dose reduction was compared to “anatomical noise” arising from patient-related factors to define suggested protocols depending on the imaging purpose. Increasing CBCT dose above 1mGy held no benefit in improving image quality due to the presence of anatomical noise in abdominal sites, and CBCT dose could be reduced down to 0.125mGy whilst maintaining registration accuracy on bony anatomy.

In lung radiotherapy, breathing motion must be accounted for to ensure the tumour is fully treated. 4D CBCT is frequently used for patient setup when the tumour motion amplitude exceeds 1cm. Default 4D CBCT scan times are long (~4 minutes), which increases the total time the patient spends on the treatment couch, affecting their comfort and likelihood of drift away from their setup position. However, the acquisition time must be sufficient to capture enough breathing cycles to reliably evaluate breathing motion and provide sufficient image quality. This talk will discuss the feasibility of reducing 4D CBCT scan time using simulated and real patient images. Clinical usability of short scan time images was evaluated by assessing the accuracy of 4D CBCT-CT registration and definition of the tumour motion. 4D CBCT scan time could be halved to 2 minutes whilst maintaining accurate 4D tumour registration. Below 2 minutes, visual image quality and 4D registration was compromised.

Improving the quality of head and neck radiotherapy CT planning images by utilising a second image reconstruction set with reduced field of view and optimised reconstruction kernel.

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Background. CT planning images for head and neck radiotherapy typically have a large diameter field of view (FOV) to ensure the whole body region, including shoulders, can be visualised. In many centres head and neck scans are also imaged with reconstruction kernels intended for body imaging [Wood *et al*, 2018] which may give reduced image sharpness and contrast. This is contrary to the principal of image optimisation [Mutic *et al*, 2003] but arises from the valid concern that changing the kernel may change image CT numbers and the treatment plan dosimetry [Patel *et al*, 2018]. Unfortunately sub-optimal FOV and kernel choice will reduce the visibility of small details in the CT images with the associated adverse affect on the image contouring process of small organs [Brouwer *et al*, 2015]. Use of a second image reconstruction set, separate to that used for planning, allows image improvement without adversely affecting the planned dosimetry.

Methods. The head/neck scan protocol on a Canon Aquilion LB scanner was used with a Catphan image quality phantom. Alternative reconstruction kernels and diameter FOVs were selected and qualitative and quantitative measurements made to shortlist 4 kernels and the preferred FOV. Clinical images were then produced using the 4 kernels and the selected FOV and reviewed to choose the kernel and FOV combination which gave the best quality images. The workflow was adjusted to produce a second reconstructed image set for ten clinical scans and the contouring oncologists asked to comment on whether the image quality was routinely improved.

Results. Oncologists reported improved confidence in contouring all clinical scans and much preferred the quality of the second image set. Change of workflow routinely allowed contours to be merged onto the first image set to use for treatment planning. Figure 1 shows an example.

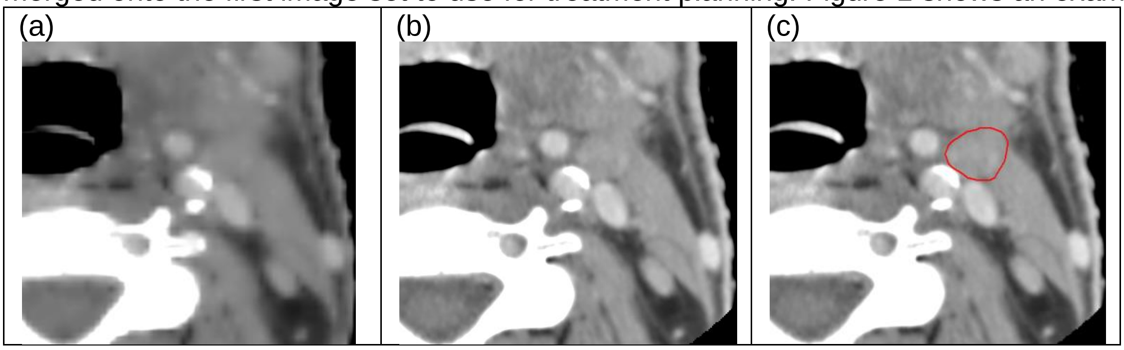

Figure 1. (a) Original image set using kernel FC13 and 550 mm diameter FOV, (b) second image set using kernel FC44 and 200 mm diameter FOV improving node visibility for (c) GTV contouring.

Conclusion. A second image set can be routinely used to improve contrast and sharpness, significantly improving the quality of head and neck images for contouring, with no adverse effects.

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Introducing AiCE Deep Learning Reconstruction Algorithm into a Radiotherapy Workflow

Jonathan Allred, Keith Langmack, Alex Taylor, Gavin Alexander

Background. Advanced intelligence Clear-IQ Engine (Canon, Japan) (AiCE) is a deep learning reconstruction that reduces the noise in CT scans in order to improve image quality[1]. Previously, AiCE has been used in diagnostic CT to considerable success, demonstrating improved SNR and qualitatively improved images when reviewed by Radiologists[2][3]. Despite this, there is not literature of AiCE being deployed in a Radiotherapy setting. In order to do this it is important to review the effect AiCE reconstruction has on HU in scans[4] and subsequently any difference in the calculated dose for patient treatment plans. Once AiCE has been introduced the department would then be able to optimise their CT imaging doses whilst maintaining a suitable SNR for clinical use[5].

Methods. In order to assess the effect of using AiCE on the HU of a CT scan an electron density phantom (Gammex) was scanned using clinical protocols for using the standard AIDR3D reconstruction and AiCE reconstruction at different mAs values. 19 patient scans were then reconstructed using AiCE reconstruction and the dose distributions of the clinical plans recalculated without altering the CT density table. The effect of recalculating on the dose on the AiCE reconstructed CT scans was measured by comparing the PTV clinical goals.

Results. In the electron density phantom the difference between the HU of water for AIDR3D and AiCE images was between 5-6HU depending on the mAs used. This was within the IPEM 91 tolerance for HU variation so was accepted. The greatest difference in HU was for dense bone with up to an 11HU maximum difference. When comparing the clinical goals of plans calculated using AIDR3D and AiCE reconstructed CT scans the dose difference was a maximum of 0.13Gy (0.2% of prescribed dose) for plans in soft tissue and 0.45Gy (1.1% of prescribed dose) for plans in bone. The median dose difference was a 0.02Gy difference.

Discussion. The difference in the HU between the AIDR3D and AiCE was acceptably small for all materials, with the larger difference in dense bone being accepted as that is known to vary considerably even when using the same reconstruction algorithm. The difference in the clinical goals was minimal for plans in soft tissue, demonstrating that for these plans it would not be necessary to introduce a new CT density table for these treatments. However, for the SRS treatment with a lot of bone overlapping, the higher dose difference suggests that a new CT density table would be useful for these plans. As a whole range of plans are required in our department a new CT density table for the planning system will be used when AiCE is used clinically.

Conclusion. AiCE has been evaluated to demonstrate HU stability that is suitable for use in Radiotherapy treatment planning. Through investigation of the dose differences in plans calculated using AIDR3D and AiCE reconstructions it has been established that the calculation is suitable using AiCE scans and that a new CT density table will be used due to the difference at high density.

Key references.

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Validity of Regular CBCT Commissioning Tests for use with Extended CBCT for a Varian TrueBeam© Linear Accelerator

Royal Devon University Healthcare NHS Foundation Trust: Adam Brookes, Rob Biggar, Rosemary Hakes

Background. Cone beam CT (CBCT) is frequently used on linear accelerators using the on board imager for 3D image verification prior to treatment. However, this can be limited by the length of the scan (17.6cm half-fan) [7] which can inhibit viewing the necessary patient anatomy for an accurate match and shift. To improve on this, extended CBCT can be used on the linac, in which two regular CBCTs are fused together using software in the image acquisition workspace to produce a larger singular image (length 33.2cm) with a 2cm minimum overlap region. The aim of the study was to enable on-set image verification for large area sites such as prostate, pelvic and PA nodes for the PEARLS[3] trial and for emergency palliative treatments.

Methods. To commission extended CBCT for clinical use a number of measurements were carried out to compare the extended CBCT image to a regular CBCT using tolerances derived from IPEM 81[2]. To assess the image quality, Catphan 504[5] and Rando anthropomorphic phantoms[1] were imaged and reviewed with SNC Machine[4]. To confirm the geometric accuracy of the extended CBCT, known distance markers on the phantom were measured in the software and compared against the Catphan specifications[5]. Catphan and a daily imaging cube were offset by known distances using reference markers and a 3D/3D match performed. Additional measurements were carried out to assess the suitability of pre-CBCT topograms, including changing topogram imaging protocol, CBCT imaging protocol and time taken between topogram and CBCT.

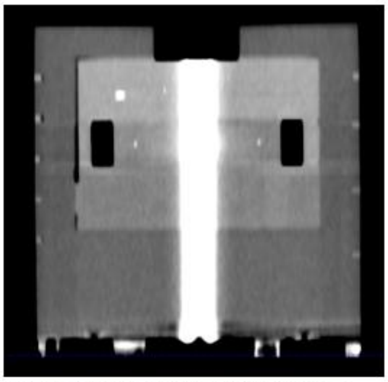

Figure 1: Artefact in extended CBCT of a CatPhan phantom

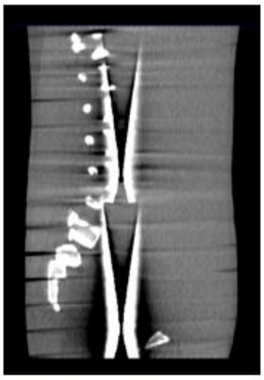

Figure 2: Artefact in extended CBCT of a Rando phantom

Results. Comparison between extended CBCT and normal CBCT showed that measurements of image quality, geometry and 3D/3D match complied with IPEM 81 tolerances. During the initial measurements with the Rando phantom and Catphan, some torpedo artefacts[6] were noted when performing a kV topogram before the CBCT. This presented as a bright region through the centre of the phantoms as seen in figures 1 and 2.

Discussion. Extended CBCT was successfully commissioned and determined to be clinically suitable for large area site image verification. Investigations into the artefacts showed that these occurred exclusively when using a phantom and performing a kV topogram before the CBCT. This was determined to be unlikely to happen during clinical use, as the panel would not be overexposed due to the dose being mostly attenuated by the patient rather than a small phantom. Measurements showed that the artefact was more likely to occur when using a high dose topogram protocol.

Conclusion. All of the commissioning tests carried out passed. Investigations into the artefact determined this was not a concern, and was related to the amount of charge trapped in the panel by the initial kV topogram[6,7]. Using solely extended CBCT with no topogram was found to be acceptable and the imaging modality was handed over for clinical use. Care would need to be taken when using topograms beforehand in the absence of a CT scanner for emergency palliative treatment. Commissioning tests for standard CBCT were deemed to be similarly valid for extended CBCT measurements.

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Working Party Updates: CBCT survey and CT planning DRLs

Tim Wood, Anne Davis, James Earley, Rebecca Lindsay, Rosy Plaistow, Matthew Williams
IPEM Imaging in RT Working Party

In June 2016 and following on from the first ‘Imaging in Radiotherapy’ scientific meeting, a working party was formed by IPEM to audit typical imaging doses and image quality for the full range of X-ray imaging procedures undertaken in Radiotherapy departments. This includes planning CT scans and on treatment CBCT imaging

The aims of this working party were to publish a range of typical doses for common procedures undertaken in most UK Radiotherapy Centres (in much the same way as PHE do with national reference doses in diagnostic imaging). It was hoped that making this data available to the UK Radiotherapy community would enable better optimisation of imaging to ensure doses are ALARP, whilst maintaining image quality that is sufficient for the clinical task (so in some cases, doses in some centres may need to increase!). It was hoped this work would identify best practice that will ultimately benefit patients.

This talk will discuss the background to project and an overview of the results of these audits. The first ever national dose reference levels (NDRLs) for planning CT scans were published in 2018, and the results and issues identified from this study will be discussed. There will also be an update on the results of the national audit of CBCT doses in Radiotherapy, which is pending publication very soon. For a number of examinations, a wide range of clinical practice has been observed when it comes to exposure settings. This is both dependent on the type of system being used and how variations in the local population of patients are accounted for (or not, as the case may be).

CBCT optimisation on the Halcyon/Ethos platform

David Carnegie, Clinical Scientist, NHS Grampian

We present our work on optimising image quality of cone-beam CT's on Varian's Halcyon/Ethos platform. Using measurements of noise and contrast-noise-ratio on phantom material, the image quality was optimised to match or exceed that on our existing Truebeam LINACs without compromising dose.

Unlike Truebeam, the Halcyon/Ethos platform has many fewer options available to the physicist to customise imaging protocols and these limitations are discussed.

Results presented include tables of exposure factors, image quality metrics, and dose as measured on a CTDI phantom and how these differ from the manufacturer's data.

Table 1: Comparison of image quality and dose between Ethos and Truebeam.

		Image Quality		Dose	
Protocol	**mAs**	**CNR**	**Noise (HU)**	**CTDI (mGy)**	**DLP (mGycm)**
Head	138.90	10.48	20.19	3.97	110.87
	115.75	8.69	23.22	3.31	92.40
	Truebeam	10.58	23.43	3.41	61.36
Pelvis	1074.00	11.31	18.42	24.16	674.06
	805.50	10.43	19.37	18.12	505.55
	Truebeam	10.73	20.52	18.07	325.17
Pelvis Fast	592.00	8.73	22.88	13.64	380.50
	769.60	10.43	18.86	17.73	494.65
	Truebeam	10.73	20.52	18.07	325.17
Thorax	300.60	10.04	19.89	7.14	199.18
	214.75	7.80	25.86	5.10	142.29
	Truebeam	8.65	32.06	4.87	87.75
Thorax Fast	294.60	7.89	25.01	7.06	197.03
	208.68	6.15	31.31	5.00	139.57
	Truebeam	8.65	32.06	4.87	87.75

Table 2: Optimised CBCT settings

Protocol	kV	mAs	Anode Heat for eFOV
Head	100	115.75	<60%
Pelvis	125	805.5	<30%
Pelvis Fast	125	769.6	<30%
Breast	125	49.10	<60%
Thorax Fast	125	208.68	<60%

As a centre using the OmniBoard immobilisation system from MacroMedics, we show how the high density components present in the board negatively impact image quality and produce unavoidable artefacts using the iterative reconstruction algorithm that comes as standard on the Halcyon/Ethos platform.

A discussion of the consequences and compromises that had to be made will conclude this presentation. This work will be of interest to centres currently using or considering purchasing a Halcyon/Ethos machine.

Evaluation of Optimisation Methods for Pelvis CBCT

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Background. Studies suggest that Pelvis CBCT dose reductions can be achieved in multiple ways through manipulation of 1) reconstructed slice thickness[1], 2) default exposure parameters[2,3] and 3) scan length[4]. At CGH, a local optimisation exercise was carried out for Varian Truebeams in which each of these approaches was explored and evaluated as a means to reduce dose and/or improve image quality in Pelvis CBCT.

Methods. 1) Seven clinical (2mm) CBCTs were retrospectively re-reconstructed at 3mm slice thickness for visual assessment and to quantify noise reduction. CBCTs were acquired of an anthropomorphic pelvis phantom at various offsets using 2mm, 3mm and 4mm reconstructions. These were automatched to a 3mm reference CT image and the shifts recorded. 2) Patients were grouped into size-based categories according to planning CT CTDI. Representative phantoms were constructed using in-house bolus and scanned with varying exposure parameters. Image noise was measured to inform selection of size-based optimised parameters. 3) PTV length and isocentre position were reviewed for 11 prostate patients, from which two reduced scan length protocols were agreed for pilot. Dose reductions were measured and quantified in terms of DLP and effective dose using a wide-beam CT methodology.

Results. 1) Mean noise reduction for 3mm reconstructions was 10.5%. In optimisation, this was exchanged for dose reductions of 25%. Automatch shifts for 3mm and 4mm slice thicknesses showed discrepancies of <0.2mm in all directions when compared with the 2mm default.

2) *Table 1: Dose reductions from size-based exposure parameter optimisation*

Patient group	% Population	CTDI current (mGy)	CTDI optimised (mGy)	% Dose Reduction
Small	28.2	16.0	6.0	62.5
Medium	44.7	16.0	14.0	12.5
Large	11.5	16.0	20.0	-25.0
Large	8.0	36.8	20.0	45.7
X-Large	7.6	36.8	36.8	-

3) *Table 2: Dose reductions for reduced scan length protocols*

Scan Range (cm)	CTDI (mGy)	DLP (mGy.cm)	Effective Dose (mSv)	% Dose Reduction
17.5	16.0	344	4.4	-
12.0	16.0	246	3.2	28.5
10.0	16.0	210	2.7	39.0

Discussion. 1) Optimising with an increased CBCT slice thickness of 3mm delivered dose reductions of 25% for all patients. Automatching was unaffected but reduced longitudinal spatial resolution was available for manual matching. 2) Size-based optimisation led to dose reductions and increased image noise for the majority of patients. Consistency of image quality across the patient cohort was much improved, however this was the most resource intensive optimisation approach. 3) By reducing scan lengths, large dose reductions were achieved with no compromise in image quality for a subset of patients.

Conclusion. This study confirms there are multiple approaches to optimising Pelvis CBCT, each of which has scope for significant dose reductions to be achieved. Methods can be combined according to a centre's particular processes, requirements and available resource.

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Impact of IGRT protocols on imaging dose for radiotherapy patients over ~20 years

Chris Hayes, Dr Christina Agnew, Dr Louise Belshaw

Background

Image Guided Radiotherapy (IGRT) includes verification imaging of the patient treatment position in comparison to the planning position in order to reduce systematic and random treatment delivery errors [6, 9]. There are several modalities within IGRT, with most centres using kV and MV imaging (planar and volumetric) [3-4, 8-11]. Each modality has inherent advantages and disadvantages, however, most IGRT modalities will expose patients to an additional dose of radiation (concomitant dose). Whilst these imaging exposures are lower than treatment exposures, they can irradiate a larger area and add a substantial concomitant dose over a patient's treatment, depending on the imaging frequency, imaging modality and the number of treatment fractions [2, 7, 12]. This study investigated the change in concomitant dose patients received at the Northern Ireland Cancer Centre (NICC) based on imaging frequency and imaging modality and how that has changed over the past 20 years.

Methods

At the NICC, patient treatment data is stored in the ARIA database. The ARIA database is an array of categorised databases (patient records, treatment records, etc.), which are linked through unique identifiers such as patient IDs or course serial numbers. This study used Structured Query Language (SQL) to interrogate the ARIA database to determine the use and development of IGRT in NICC since 2003. Parameters extracted from the database included imaging modality, fractionation regimes and imaging frequency. The dose per image modality was taken from the literature [5].The change over time of average imaging dose per patient and the use of IGRT across different anatomical sites were assessed.

Results

Average doses for MV planar, kV planar and CBCT imaging modalities were taken as 3.04Gy, 0.12cGy and 1.43cGy respectively [5]. Investigations demonstrated fluctuations in the average patient contaminant dose over time, which can be seen in Figure 1. This was due to the varied use of different imaging frequencies, imaging modalities and the variation in fractionation regimes over time.

Conclusion

Additional exposure associated with IGRT changes over time relating to changes in technology, clinical practice and imaging protocol.

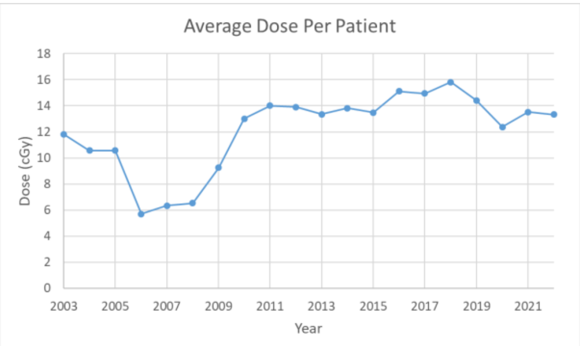

Figure 1- Average imaging dose per treatment course to patients over time at NICC.

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Investigations into DirectDensity^{TM}: a Novel CT Reconstruction algorithm that allows image acquisition at multiple kVp for treatment planning

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Background.

The Hounsfeld Unit – density (HU-d) calibration curves, required by treatment planning systems, have traditionally been limited to image acquisition using a single accelerating potential of around 120kVp. HU have an energy dependence (particularly at high densities) and also have a well reported discontinuity at soft tissue like densities [1]. Optimisation of kVp allows for improved image quality but traditionally comes with a high quality assurance burden and a risk of confusion within the treatment planning process [2]. The implementation of DirectDensityTM (Siemens Healthineers GmBh, Germany) remedies this by allowing one HU-d curve application to all kVp [3, 4]. This work reports on our investigations into the linearity, robustness and effect on image quality of implementation of DirectDensity^{TM}.

Methods.

HU-d calibration curves were generated using the Gammex Advanced Electron Density Phantom for both the standard Qr40 reconstruction and the DirectDensity Sm40 (mass density) reconstruction kernel at kVp of 70, 80, 90, 100, 110,120, 130, 140kVp. The dependence of the HU numbers for the Sm40 reconstruction were investigated for 7 inserts ranging from LN-300 (0.299g/cc) to Cortical Bone (1.925g/cc). This was done using a 2cc region of interest centrally located on each insert and recording the average HU value.

Modulation Transfer Function (MTF) measurements were conducted on the Sm40, Sd40 (electron density) and Qr40 reconstructions using SPICE-CT (ImageJ) and AutoCT imaging software.

Results.

DirectDensity produced linear HU-d calibration curves with greatly reduced energy dependence. Inspection of the individual inserts HU values with kVp found that although there was still some energy dependence, the variation would not lead to a dosimetric impact for soft tissues. For the lung insert, the variation in density measured over all the kVp was within 0.02g/cc and for adipose the variation in density measured over all kVp was within 0.024g/cc. For bone, the variation in density over all kVp was 0.122g/cc and an incidental finding where the HU values decreased was observed at 110kVp. This was seen with all the bone type inserts but not for other tissue types. The MTF measurements showed a decrease in spatial resolution with the Direct Density reconstructions compared with the Standard reconstruction.

Conclusion. DirectDensity generates a HU-d calibration curve that is more linear and less energy dependent compared to standard HU-d curves however spatial resolution decreases when it is used which should be considered when implementing this technology.

Key references.

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Standardisation and Optimisation of Paediatric kV Planar Imaging Protocols on Varian TrueBeam Linacs

Purpose

Radiotherapy treatment position can be verified using planar kV images or volumetric CBCT images, with planar kV images providing lower dose than CBCT imaging.
No paediatric planar kV default settings are available on Varian TrueBeam linacs. A review of paediatric patients from January 2019 to March 2021 who underwent kV planar image verification on Varian TrueBeam Linacs in the Northern Ireland Cancer Centre (NICC) was carried out (n=28). This showed that a range of kV planar protocols were being used for a range of patient sizes. The age range of the patients was 11 months-17 years (median 7 years). After this review, a standardisation of the paediatric kV planar protocols was proposed based on patient site, from which to further optimise these protocols.

Methods

The kV planar protocol optimisation was radiographer led through a reduction of mAs. For the patient's first fraction, small adult protocols were used and the image quality was rated from 4 (good quality, easy to use) to 1 (poor quality, not useable). If the radiographers rated the planar image quality as sufficient, the subsequent fraction could have the mAs lowered in steps of 1mAs, until a change in image quality was noted, which made the match difficult. The relationship between image quality and mAs reduction was investigated, along with the relationship between patient size, patient weight and image quality for each treatment site. Patient size was determined from the height and width of the body contour on the isocentre slice of the treatment planning CT dataset.

Results

Over the past 12 months, 10 paediatric patients were imaged using the standardised protocols (including 2 CNS patients, age range 2-18 years, median 8 years). For head and extremity patients (n=5), 100% of images were assigned a rating of 4, despite the reduction of imaging mAs to the minimum possible for these patients. This demonstrates that image quality can still be maintained while reducing the mAs for these protocols. For the pelvis protocol patients (n=7), there was slightly more variation in image quality ratings. 6 patients had a mAs reduction while maintaining image quality ratings of 3 or 4. However, radiographers found that for one patient, suitable image quality was more difficult to achieve with the standard settings. This resulted in a rating of 2 or 3 for their treatments, with no mAs reduction possible.

Analysis showed no strong correlation between image quality and patient size ($r = 0.202$) or image quality and patient weight ($r = 0.132$) for any site. More patients would need to be included in the review for further analysis.

Conclusion and Future Work

Standardisation of paediatric kV planar protocols has been implemented in the NICC based on treatment site. Over 12 months, 10 patients were imaged using the standard protocols. Further optimisation of the standard protocols was possible for all but 1 patient by a reduction of mAs throughout the patient's treatments, while maintaining image quality. To further optimise planar kV image protocols, a radiographer led method has now been introduced to reduce the kV exposure in a 5kV step with a subsequent reduction of mAs throughout the patient's treatment.