

Purpose or Objective

With the increasing use of imaging in radiotherapy processes, there is current interest in optimising radiotherapy imaging doses. Modern radiotherapy uses daily verification imaging as well as high-dose planning imaging such as 4DCT. The total imaging dose therefore has significantly increased with a resultant need to optimise all components in the therapy pathway.

DRLs are routinely used in diagnostic radiology but their application in radiotherapy is less straightforward because the image quality requirements (and hence patient dose) can be influenced by other parts of the treatment pathway. Treatment planning for highly modulated therapy often requires CT scans with narrower slices. This results in a higher patient dose in order to maintain image quality. Conversely, the use of image fusion during outlining may allow CT scan image quality (and hence patient dose) to be reduced.

This work has analysed dose received by patients during routine radiotherapy treatment planning CT acquisitions, for a range of treatment sites, at 3 regional radiotherapy centres in the UK.

Material and Methods

Radiotherapy planning CT scanners were surveyed in each of three regional centres. This comprised: Centre A - Philips Brilliance Big Bore, Centre B - Siemens Sensation Open, Centre C - Toshiba Aquilion Open.

Doses were recorded for 20 patients in each centre and included the following treatment sites: prostate, thorax, 4DCT thorax, breast, breast with SCF, head & neck and brain. Dose Length Product (DLP) and CT Dose Index_{vol} (CTDI_{vol}) were calculated for each body site at each centre. Data has been collected on the use of MRI and PET in the therapy pathway and the complexity of planning to assess the influence of these on CT dose.

Results

Mean DLP, CTDI_{vol} and effective dose have been analysed for each treatment site at each centre and the DLP comparison is shown in Figure 1.

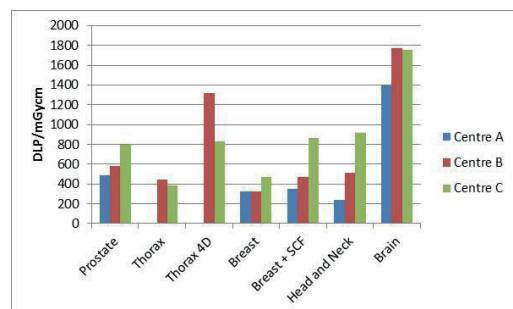


Figure 1: Mean dose length product for each treatment site and radiotherapy centre

A significant difference in dose between different centres is evident but analysis shows no significant correlation between dose and treatment complexity. A noteworthy finding is that although all three centres use similar breast planning and treatment processes, there is a 45% difference in dose between the highest and lowest dose centre.

Conclusion

This study suggests that while there appear to be considerable differences in planning scan dose for nominally the same treatment site, these do not seem to be as a result of intentional optimisation measures. The need for optimisation of therapy planning CT protocols is clear and would require to be completed before the secondary influences of treatment complexity can be identified. Therefore, the use of dose reference levels is appropriate in radiotherapy as a tool for identifying

significant, but potentially avoidable, differences in planning scan CT dose.

EP-1860 IGRT kV-imaging dose MC calculations validated in anthropomorphic phantoms using OSL

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Purpose or Objective

While in-room Magnetic Resonance Imaging starts becoming part of radiotherapy (RT) treatments, the use of X-ray imaging equipment in Image-Guided RT (IGRT) is still growing and with it the need to evaluate the additional dose-to-organs it delivers. This study aims at verifying the accuracy of Monte Carlo (MC) calculation of the patient dose-to-organs delivered by four commercially available kV imaging systems: the XVI CBCT (Elekta), the OBI CBCT (Varian), the ExacTrac 2D-kV system (Brainlab) and the 2D-kV CyberKnife imaging system (Accuray). Simulations were validated against OSL measurements in the pediatric anthropomorphic phantom Grant (CIRS, ATOM) performed in three different clinical sites.

Material and Methods

Each of the four kV-imaging systems was modeled as a Virtual Source Model (VSM) using the Penelope MC code. Such models were validated as part of a previous study using ionization chambers in water phantoms [G. Boissonnat et al., ESTRO 2017 Vienna].

In a second step, CT images of the phantom Grant were used to generate a voxelized phantom by converting the HU value of each voxel into the appropriate biological tissue (chemical composition and density). Then for each system, photons produced by the corresponding VSM were propagated in the voxelized phantom in order to obtain the 3D relative absorbed dose-to-medium map for three localizations (head, thorax and pelvis). MC-calculated doses were calibrated in amplitude using the ratio between the air kerma measured with an ionization chamber at the isocenter and the corresponding simulated value. After calibrating OSLs in air kerma at every beam quality, OSL measurements were performed in the anthropomorphic phantom at three localizations (head and neck, thorax and pelvis). After verifying that beam quality inside the phantom was impacting OSL corrections factors of less than 5%, they were neglecting. Therefore measured air kerma values were converted into absorbed dose-in-medium values using the incoming beam quality before being compared to simulated dose values.

Results

MC calculations were performed in 2 hours on a cluster of 40 CPUs with a MC uncertainty better than 5% in 1mm³ voxels.

The current study highlights the possibility to reproduce absolute dose measurements using VSM-driven MC simulations with an overall agreement better than 20 % (inside the irradiation field) for all four kV imaging systems and for the three anatomical localizations as presented in Table 1.

kV-System	Head and neck	Thorax	Pelvis
XVI (Elekta)	11.0 % ± 5.4 %	6.4 % ± 3.5 %	8.5 % ± 3.5 %
OBI (Varian)	17.1 % ± 8.0 %	12.3 % ± 5.6 %	
Cyberknife (Accuray)	8.8 % ± 3.8 %	10.4 % ± 6.0 %	
ExacTrac (Brainlab)	12.5 % ± 9.1 %		

Table 1: Relative dose deviation (mean ± standard deviation) between simulated and measured doses $\left\langle \left\| \frac{D_{\text{Simulated}}}{D_{\text{Measured}}} - 1 \right\| \right\rangle$.

Conclusion

This study demonstrates that MC calculations based on VSMs allow obtaining reliable absolute doses for kV imaging protocols in a reasonable computing time. All these developments are currently integrated into a dedicated software for imaging dose prediction, which will also include the Tomotherapy MVCT imaging system [V. Passal et al., MCMA 2017 Napoli]. This software will enable to study the magnitude of additional doses delivered by in-room X-Ray imaging positioning units during the course of a complete RT treatment.

EP-1861 Predicted reduction in fatal second cancers by proton therapy of childhood intracranial tumors

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Purpose or Objective

We hypothesized that the predicted lifetime attributable risk of a fatal subsequent malignant neoplasm, LAR, in children treated with intracranial photon therapy in a low- to middle-income country (LMIC) would not be reduced if they were instead treated with proton therapy in a high-income country (HIC).

Material and Methods

To test our hypothesis, we performed a virtual clinical trial on a sample of 7 pediatric patients of ages 2 to 14 years with intracranial tumors. These subjects' photon treatment plans were randomly selected from the clinical database of an academic hospital in a LMIC. Computed tomography images and contoured structures were transferred to an academic hospital in a HIC, where proton therapy plans were created and normalized to the same prescription dose as the photon treatment plans. Treatment planning systems of each institution were used to calculate equivalent dose in voxels representing patient anatomy from therapeutic fields. In photon therapy, a measurement-based analytical model was used to calculate equivalent dose from out-of-field radiation, and, in proton therapy, two Monte-Carlo-based analytical models were used to calculate equivalent dose from secondary neutrons. Missing anatomy and contours had been supplemented with those from size- and sex-matched patients of a previous study. Separately for photon and proton therapy, we applied a widely-accepted dose-effect model from the literature that is age-, sex-, and organ-specific to estimate LAR. Finally, we tested the null hypothesis that the ratio of LAR from proton therapy to that from photon therapy (LAR_{proton}/LAR_{photon}) was 1 versus the alternative hypothesis that it was less than 1.

Results

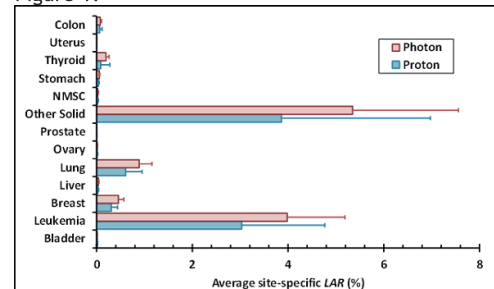
In either therapy, LAR generally decreased as age increased. The ratio of LAR was 0.75 ± 0.20 , reported at the 95% confidence interval. Our null hypothesis was rejected with a p-value of 0.011. That is, for this small sample set proton therapy in a HIC country reduced the

risk versus photon therapy in a LMIC, with statistical significance.

Table 1.

Organs and tissues	Mean organ equivalent dose (mSv): HIC proton therapy/LMIC photon therapy										Standard deviation
	8 y girl	8.5 y girl	4 y boy	8 y boy	12 y boy	12 y boy	12 y boy	12 y boy	Average		
Bladder	23/17	36/27	38/21	57/60	27/14	21/13	47/19	36/24	13/16		
Red bone marrow	2292/3500	4030/2825	5304/5682	2821/4495	1586/6400	2428/3204	750/1087	2730/3885	1491/1802		
Breast tissue	93/203	187/242	162/228	---	---	132/173	---	143/212	40/30		
Liver	59/127	115/167	101/147	123/186	75/107	92/108	118/131	98/139	24/30		
Lungs	76/188	194/239	134/210	191/300	127/197	171/205	213/229	158/224	48/38		
Ovaries	19/16	36/27	34/60	---	---	25/13	---	29/29	29/29		
Prostate	---	---	---	50/42	24/13	---	46/14	40/23	14/17		
Remainder	1167/2643	2105/1767	1564/1710	1804/3072	745/1380	936/1069	857/1072	1311/1816	521/772		
Skin	1522/1613	1646/892	1001/1114	839/1302	253/518	535/644	516/497	902/940	526/424		
Stomach	55/121	104/162	94/138	111/207	62/102	81/93	106/125	88/135	22/39		
Thyroid	155/246	346/1256	302/423	252/1935	251/352	631/727	422/1546	337/926	154/658		
Uterus	18/16	36/27	33/21	---	---	24/13	---	28/19	28/19		
Colon	42/85	68/92	68/76	78/129	41/29	44/38	69/52	59/70	16/32		

Figure 1.



Conclusion

In conclusion, our findings suggest that a reduction in the lifetime risks of fatal subsequent malignant neoplasms may be achievable for pediatric brain cancer patients in LMICs by making proton therapy available to them. This study also demonstrated the feasibility of applying dose calculation algorithms to existing or supplemental anatomy to quantify therapeutic and stray radiation doses in proton and photon therapy for the purpose of predicting late sequelae.

EP-1862 Consider the radiation dose to the kidneys during Intensity Modulated breast cancer treatment

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Purpose or Objective

The kidneys are dose-limiting organs for radiotherapy (RT) in abdominal cancers, with variety between centres in guidelines for kidney tolerances. Kost et al demonstrated 5% of irradiated kidneys developed renal abnormalities after receiving 3-6Gy in 15-30 fractions, independent of the volume irradiated [1,2]. Quantec guidelines suggest a mean kidney dose of <18Gy for an estimated risk of <5% [2]. Intensity Modulated Radiotherapy (IMRT) is sparingly used at Barts Cancer Centre (BCC) to treat selected breast cancer patients, due to a low dose delivered to a larger volume when compared with standard conformal CT planning. The kidneys have not routinely formed part of the organs at risk to be considered.

Material and Methods

Using Varian Aria, we identified 23 patients treated at BCC for breast cancer using IMRT without bolus between 2011 and 2017. The kidneys were contoured for each patient plan and patient age, treatment site, dose and bilateral maximum renal doses were recorded. We identified the 5 patients with highest renal doses, and re-planned these using an IMRT technique, including the kidneys within the optimisation process.

Results

Radiation dose to the kidneys were higher than expected, especially when treating the left side. This could be due to attempts to minimise dose to other organs at risk, particularly the heart. 11 out of 23 patients received