SIMULATION OF PATIENT EXPOSURE AT RADIUS FRACTURE DIAGNOSTICS USING 2D AND 3D IMAGING TECHNIQUES

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Abstract

Patient dose is one major aspect for quality assurance in medical imaging. This study shows how Monte Carlo simulations can be used to calculate patient exposure for all X ray-based imaging techniques. The calculated doses can also be used to compare exposure between 2D and 3D imaging systems.

1. PURPOSE

Patients under suspicion of having a radius fracture conventionally undergo a two-plane projection 2D X ray imaging (AP and LAT). This examination often leads to no clear diagnostic findings. Then, further – 3 dimensional – examinations are done. Most patients undergo a conventional CT examination. Since late 2011 dedicated extremity scanners are available. These machines deliver high image quality at relatively low investment costs. The dose aspect indeed is discussed controversially. Manufacturers postulate patient exposures comparable to conventional 2D projection images. Critics talk about factors of 2 to 5 compared to conventional CT. However dose comparisons are difficult in this case. The main exposure value used for patient dose calculations in conventional 2D X ray is the dose area product (DAP). In conventional CT it is the computed tomographic dose index (CTDI) and for a whole scan the dose length product (DLP). These values are measured using CTDI phantoms. The CTDI head phantom with 16cm in diameter and the CTDI body phantom with 32cm in diameter. Which phantom was used for the corresponding protocol in conventional CT seems to be the manufacturers' best treasured secret. The extremity scanners gantry is very small so that only the 16cm head phantom fits into it. From this it follows that shown CTDI values at the extremity scanners only correspond to the 16cm head phantom. If the conventional CT scanner shows a value corresponding to the 32cm body phantom there is no comparability. To compare 2D and 3D examinations we used Monte Carlo simulations. This study shows step 1 towards objective dose comparisons between 2D projection and 3D volume imaging using a dedicated extremity scanner.

2. MATERIAL AND METHODS

To compare absorbed dose at 2D and 3D imaging a Monte Carlo simulation system was used. Therefore the geometries of a projection workplace (Philips Healthcare Systems) and a H22e extremity scanner (SCS GmbH, Planmed Oy) were implemented. The used simulation software GMCTdospp was developed in house and provides a graphical frontend for the EGSnrc user code CTdospp. This software package calculates radiation transport through given geometries. For this study we used the right arm of the ICRP adult male Voxel phantom. The examinations were simulated using the standard protocols for radius fracture provided by each manufacturer (Table I)

For each examination (2D and 3D) the absorbed dose in each structure of the voxel phantom was calculated. 2D examinations are always performed in 2 planes (pa and lat). Therefore the absorbed doses for both projections were added. All patients that undergo a 3D examination using the Planmed Verity had a previous two plane projection examination. For this case the absorbed structure doses received from projection and 3D imaging were added.

TABLE I. STANDARD PROTOCOLS FOR RADIUS FRACTURE PROVIDED BY MANUFACTURER

Exam type	Used device	Field size	kV	mAs
Radius pa	Philips DR	18×24 cm^2	55	2
Radius lat	Philips DR	18×24 cm^2	57	3
Radius pa and lat	Philips CR	18×24 cm^2	50	5
Radius 3D	Planmed Verity		90	36

3. RESULTS AND DISCUSSION

Table II shows the absorbed structure doses for the projection workplaces, the Verity and the added structure doses for projection and 3D imaging.

TABLE II. ABSORBED DOSE FOR PROJECTION AND 3D IMAGING

Structure name	Absorbed dose (mGy)				
	Philips DR	Philips CR	Verity	Verity + DR	Verity + CR
Ulnae and radii, cortical	0.58	0.5	0.73	1.31	1.23
Ulnae and radii, spongiosa	0.35	0.32	1.34	1.69	1.66
Wrists and hand bones, cortical	1.63	1.46	3.08	4.71	4.54
Wrists and hand bones, spongiosa	1.14	0.96	3.18	4.32	4.14
Cartilage, arms	0.28	0.22	1.24	1.52	1.46
Muscle, arms	0.08	0.06	0.15	0.23	0.21
Residual tissue, arms	0.14	0.12	0.2	0.34	0.32
Skin, arms	0.2	0.18	0.24	0.44	0.42

Table II shows that a 3D exam using a dedicated extremity scanner delivers in mean about 2 to 3 times more dose compared to a two-plane projection examination. Looking at conventional two plan radius X ray images the diagnoses is mostly unclear. Therefore most patients undergo further examinations. One of these could be the Scaphoid Quartet. This means that four further projection images are acquired that cause even more dose. Another option is to perform a conventional CT scan or acquire a 3D volume image using a dedicated extremity scanner, which causes additionally more dose. All these structure doses must be added and then compared to the dose given by the modality that answers the question, “Is there a radius fracture or not?”

4. CONCLUSION

This first study shows that Monte Carlo Simulations are an easy way to compare dose between imaging techniques that are not comparable using shown exposure parameters. However a lot of manufacturer or modality specific information is needed to perform correct simulations. All calculated dose values correspond to acquisition parameters defined as standard protocols by the manufacturer. There is an optimization potential in 2D as well as in 3D imaging. Further studies must be done firstly to optimize imaging techniques with respect to dose minimization, and, secondly, to compute the resulting dose values. Independent of these future studies, the diagnostic pathway of patients with potential radius fractures should be reconsidered. It may save enormous dose if patients are directly scanned with dedicated extremity scanners.

REFERENCES

[1] WULFF, J., SCHMIDT, R., FIEBICH, M., et al., Fast kerma-based patient dose calculations in diagnostic radiology using EGSnrc, In *51st AAPM Annual Meeting*, Anaheim, California (2009).

[2] SCHMIDT, R., WULFF, J., KÄSTNER, B., et al., Monte Carlo based calculation of patient exposure in X ray CT-examinations, In *4th European Conference of the International Federation for Medical and Biological Engineering* (2009) 2487-2490.

[3] SCHMIDT, R., WULFF, J., KAESTNER, B., et al., Patient individual equivalent dose calculations for CT examinations, In *World Congress on Medical Physics and Biomedical Engineering, September 7 - 12, 2009, Munich, Germany,* Springer (2009) 632-634.