Three Approaches to Determining Imaging Dose During Intrafraction CBCT in Radiotherapy

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INTRODUCTION

One of the parameters monitored during teleradiotherapy is patient positioning and internal organs motion. Pre- and post-treatment Cone-Beam Computed Tomography (CBCT) is typically performed for this purpose. Intrafractional CBCT (intraCBCT) allows for the assessment of set-up variations simultaneously with Volumetric Modulated Arc Therapy (VMAT) treatment. Introducing intraCBCT into clinical routine requires comparing it with CBCT. To this end, the computed tomography dose index (CTDI) is measured. This work proposes CTDI measurement paths for intraCBCT and the corresponding ranges of variability of CTDI values for intraCBCT ($CTDI_{intra}$) compared to CTDI for CBCT ($CTDI_{CBCT}$).

METHODS AND MATERIALS

CTDI determination was performed in accordance with IAEA recommendations [1]. Measurements were taken for the chest preset on two Elekta Versa HD linacs: V1 and V2. During $CTDI_{intra}$ determination, the dose rate (DR(ϑ)) was recorded at 0.5 second intervals for a full rotation (the angle ϑ ranges from 0 to 360 degrees) at constant gantry speed. DR(ϑ) measurements were performed under the following conditions: in a phantom (DR_r(ϑ)) and in air (DR_ra(ϑ)), both for a 20mm beam width, and in air for a standard beam (DR_a(ϑ)). Using a proprietary program, gantry angles (angles ϑ) and times corresponding to DR(ϑ) were extracted from the system files. For each angle ϑ with an accuracy of 1°, DR(ϑ) was determined according to the formula (1).

$$DR(\vartheta) = \frac{DR\_a(\vartheta)}{DR\_ra(\vartheta)} * DR\_r(\vartheta) \quad (1)$$

$CTDI_{intra}$ was determined for five plans with energies of 6MV and 6FFF, and MU ranging from 264.3 to 3920.5. For the selected beam, the angles ϑ which the kilovolt beam was exposed were extracted from the system file for each plan (formula 2).

$$CTDI = \int_0^T DR(\vartheta(t))\, dt \quad (2)$$

$CTDI_{intra}$ was calculated for five plans in the treatment and QA modes (mode QA, mode TREAT). For two plans (plan a, plan b), the measurements were repeated 10 times (once daily) and 3 times a day. The results were compared with the $CTDI_{CBCT}$ for both linacs. (plan a : 264.3 MU, 6 MV; plan b : 382.2 MU, 6 FFF)

RESULTS

$CTDI_{intra}$ compared to $CTDI_{CBCT}$ varied from 5.6% to 7.1% for V1 and from 10.8% to 15.4% for V2. All $CTDI_{intra}$ values were higher than $CTDI_{CBCT}$. Table 1 shows the $CTDI_{intra}$ determined under two-mode conditions for five different plans. $CTDI_{intra}$ values performed in the treatment mode and in the QA mode did not differ by more than 1% for both linacs. The $CTDI_{intra}$ value for all plans did not change by more than 0.6% for measurements 10 times once a day (Table 2) and 3 times a day (Table 3). The difference between $CTDI_{CBCT}$ for V1 compared to V2 was 12%.

Table 1. $CTDI_{intra}$ determined for 5 plans in TREAT and QA mode for V1 and V2 linacs.

			$CTDI_{CBCT}$ [mGy*cm]			
			V1		V2	
			19,91		17,83	
			$CTDI_{intra}$ [mGy*cm]			
beam modality	MU	mode	V1	percentage difference with respect to $CTDI_{CBCT}$	V2	percentage difference with respect to $CTDI_{CBCT}$
6 MV	535,6	TREAT	21,09	5,9	20,42	14,5
		QA	21,15	6,2	20,51	15,0
6 MV	264,3	TREAT	21,10	6,0	20,42	14,5
		QA	21,08	5,9	20,45	14,7
6 MV	3920,5	TREAT	21,63	8,6	20,58	15,4
		QA	21,63	8,6	20,49	14,9
6FFF	382,2	TREAT	21,03	5,6	20,33	14,0
		QA	21,02	5,6	20,30	13,9
6 FFF	2234,9	TREAT	21,33	7,1	19,75	10,8
		QA	21,16	6,3	19,85	11,3

Table 2. CTDIintra for two plans - daily measurement.

$CTDI_{intra}$ [mGy*cm]				
# fraction	V1		V2	
	plan a	plan b	plan a	plan b
1	21,03	21,02	20,48	20,43
2	21,03	21,04	20,50	20,47
3	21,11	21,00	20,46	20,53
4	21,06	21,02	20,43	20,42
5	21,02	21,02	20,43	20,43
6	21,05	20,99	20,43	20,43
7	21,07	21,01	20,43	20,42
8	21,03	21,05	20,36	20,43
9	21,16	21,04	20,47	20,40
10	21,01	21,09	20,40	20,47

Table 3. $CTDI_{intra}$ determined 3 times a day for 3 plans.

$CTDI_{intra}$ [mGy*cm]			
V1		V2	
plan a	plan b	plan a	plan b
21,03	21,05	20,36	20,43
21,03	21,04	20,47	20,40
21,16	21,09	20,40	20,47

CONCLUSIONS

The performed measurements made it possible to propose three approaches for determining $CTDI_{intra}$ with defined variability ranges.

Path 1: Performing $CTDI_{intra}$ measurements for a set of typical plans enables determination of $CTDI_{intra}$ with variation of less than 16% for a single intraCBCT compared to $CTDI_{CBCT}$. This result is comparable to difference between $CTDI_{CBCT}$ for twin machines.

Path 2: Performing a $CTDI_{intra}$ measurement for a single plan in QA mode allows assuming a $CTDI_{intra}$ variation of less than 2% compared to $CTDI_{CBCT}$. This takes into account the variability resulting from the measurement in QA mode and occurring in subsequent fractions.

Path 3: Performing a measurement in treatment mode allows for determining a $CTDI_{intra}$ with a variability of less than 1%, which results from the variability of CTDI during subsequent fractions.

Presented values may differ for different linac machines, but the research carried out allows for the selection of a course of action in order to adopt the appropriate procedure.

REFERENCES

[1] Status of Computed Tomography Dosimetry for Wide Cone Beam Scanners [IAEA 2011].

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