COMPREHENSIVE EVALUATION OF PerFRACTION FOR *IN-VIVO* MONITORING USING DOSE MEASUREMENTS WITH TLD AND IONIZATION CHAMBERS IN 6 DIFFERENT PHANTOMS

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INTRODUCTION

In-Vivo dosimetry is strongly recommended in protocols and regulatory documents about radiotherapy [1]. PerFRACTION (Sun Nuclear) software is a software for *in-vivo* dosimetry and monitoring. It uses EPID measurements and linac treatment log files to calculate the planar dose in the portal and the volumetric dose in the planning CT or in the treatment session CBCT (Figure 1).

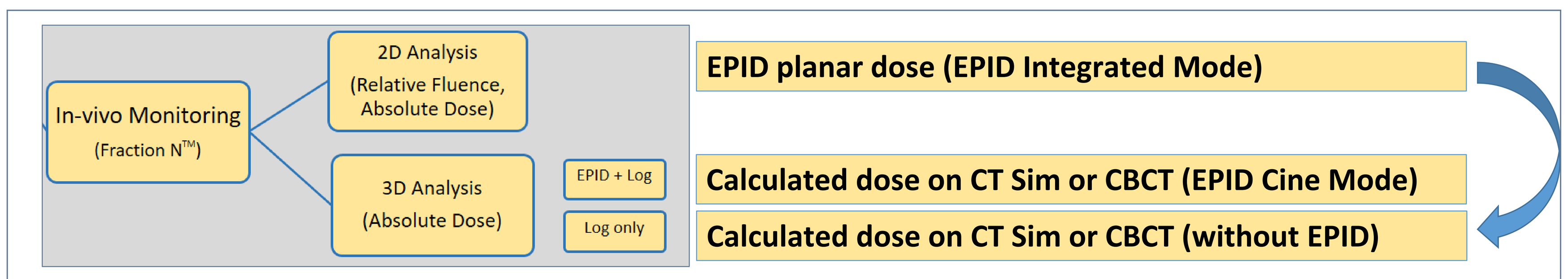


Figure 1. Modules available on PerFRACTION for *in-vivo* dosimetry and monitoring.

Whenever the image is acquired in the integrated / dosimetry mode, PerFRACTION calculates absolute planar dose in the EPID. In this case, the 3D dose distribution is also calculated based on in the planning CT or in the CBCT using the treatment log files. If an image is acquired in cine mode, for dose calculations, PerFRACTION uses the EPID MLC projection for each frame in addition to other treatment logs (method known as EPILOG). PerFRACTION calculates dose in the planning CT or CBCT even without the EPID exposure, using only the treatment log files (in this case including MLC log files).

Objective: To evaluate each PerFRACTION module through **sensitivity tests** and **end-to-end tests** using measurements with **TLDs and ionization chambers in 06 different phantoms**.

METHODS

We performed the tests using 6 and 10 MV photons beams of a TrueBeam linear accelerator (v2.7, Varian) and Eclipse TPS (Varian - versions and algorithms varied according to the test and are shown below). We used a source-EPID distance of 150 cm in all cases.

SENSITIVITY TESTS

We simulated two known errors to test the PerFRACTION sensitivity (see Figure 2):

- Variation of linear accelerator output: acrylic sheets were attached to the collimator for beam attenuation.
- Variation of the phantom thickness: reduction of 2 cm in the homogeneous phantom thickness during the irradiation.

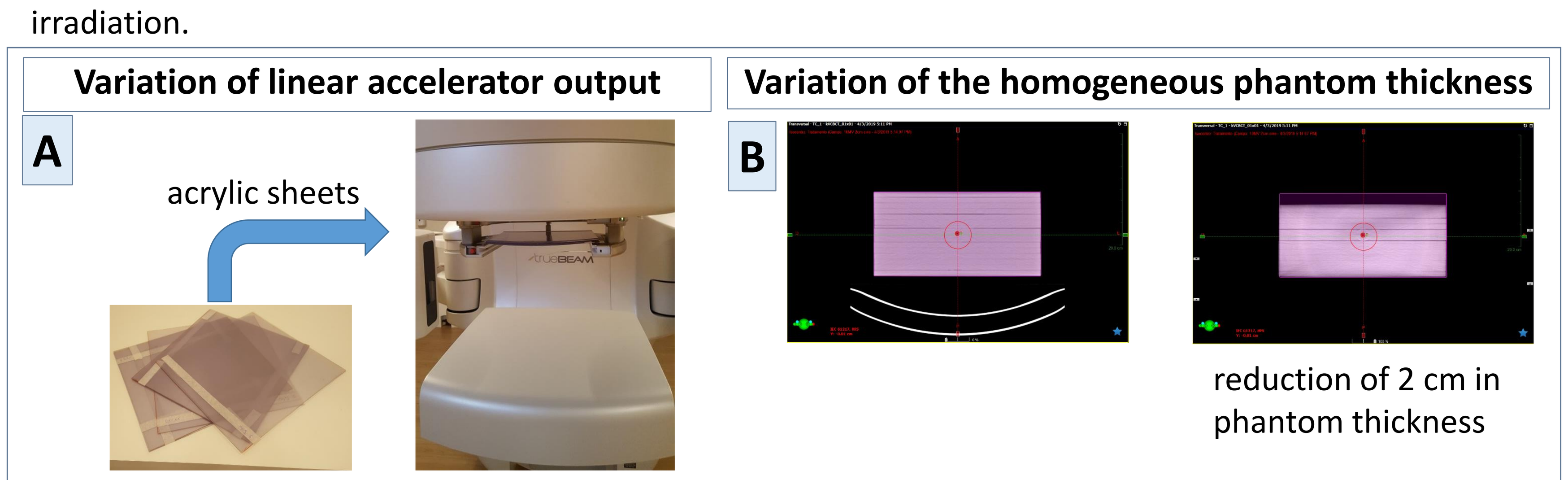
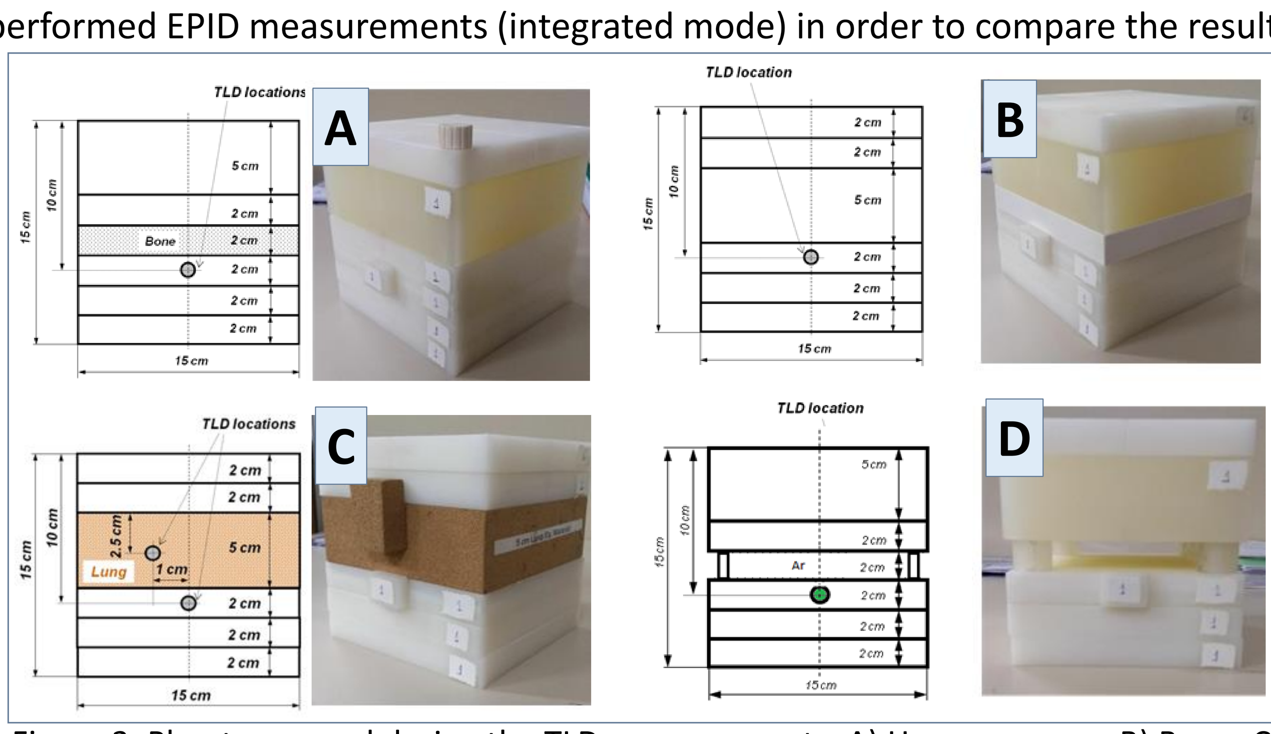


Figure 2. A) Setup used to attenuate the beam of the linear accelerator with acrylic sheets. B) Planning CT of the homogeneous phantom (on the left) and CBCT of the phantom with the thickness reduced by 2 cm (on the right).

We used a Farmer ionization chamber as reference to measure the introduced dose variations. Both sensitivity tests used EPID in integrated mode. In the case of phantom variation thickness, dose variations in the central axis of the EPID (absolute 2D) were analyzed, as well as the 3D dose calculation using the treatment log files in the CBCT (3D only with logs).

END-TO-END TEST (EPID 2D ABSOLUTE DOSE)

Transmission dosimetry has the advantage of not interfering with treatment/test dose distributions. Therefore, we tested PerFRACTION during the annual independent auditing program provided by Brazilian government. This voluntary program is based on postal delivery of 4 phantom kits with TLDs to be irradiated. Its measurements were compared with our TPS dose calculation. During the irradiation of the TLDs, we performed EPID measurements (integrated mode) in order to compare the results (Fig. 3).



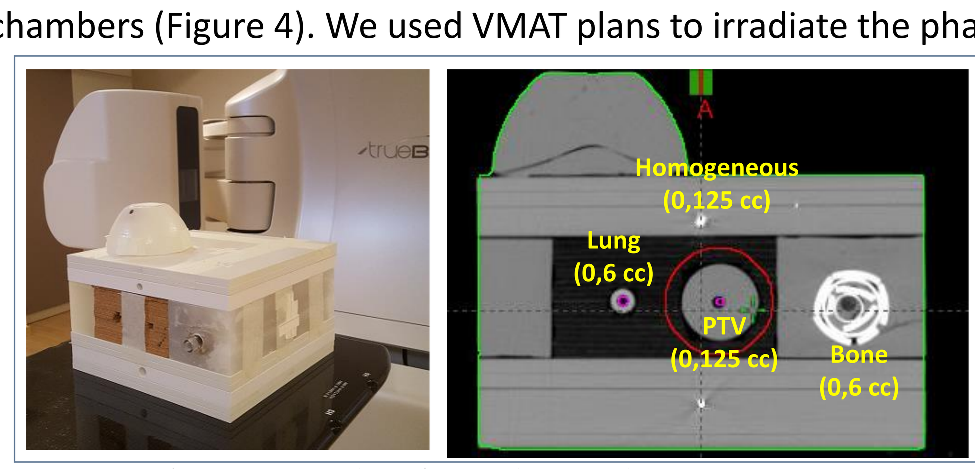
Setup:
- Open-square field
- UM calculated by the TPS to delivery 200 cGy on TLD
- Algorithm AAA, v15.1
- EPID operating on integrated/dosimetry mode

Phantoms:
A) Homogeneous
B) 01 slab simulating bone
C) 01 slab simulating lung
D) 01 region with air

Figure 3. Phantoms used during the TLD measurements: A) Homogeneous, B) Bone, C) Lung and D) Air.

END-TO-END TEST (3D EPILOG + CBCT)

We performed an end-to-end test using a homemade heterogeneous phantom, which simulates lung (cork), bone (PVC) and water equivalent medium (solid water slabs). The phantom has 4 spots for ionization chambers (Figure 4). We used VMAT plan to irradiate the phantom with the EPID exposed in Cine Mode.



Setup:
- VMAT Plan
- 400 cGy on PTV (inside the cork) and 200 cGy on PVC (Bone structure)
- Algorithm Acuros, v15.5
- EPID on cine mode (3D evaluation – EPILOG)

04 ionization chambers:
02 SNC125c: Homogeneous Region and PTV
02 SNC600c: Lung and Bone

Figure 4. Phantom used in the End-to-end test to compare doses measured with 4 ionization chambers. Mean doses were calculated on sensitive volumes of the detectors by PerFRACTION using EPILOG method on CBCT image.

RESULTS AND DISCUSSION

SENSITIVITY TEST

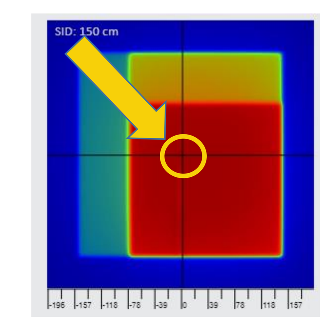
Variation of linear accelerator output

6 MV	EPID - 2D (Integrated Mode) Attenuation (%)	Difference (%)	10 MV	EPID - 2D (Integrated Mode) Attenuation (%)	Difference (%)
Reference	1.6	-	Reference	3.0	-
PerFRACTION	2.0	0.4	PerFRACTION	1.8	1.2

Variation of the phantom thickness

6 MV	EPID - 2D (Integrated Mode) Attenuation (%)	Difference (%)	10 MV	EPID - 2D (Integrated Mode) Attenuation (%)	Difference (%)
Reference	5.5	-	Reference	4.3	-
PerFRACTION	5.8	0.3	PerFRACTION	3.5	0.8

Dose evaluated in the central pixel



Variation of the phantom thickness

6 MV	LOG CBCT – 3D (Integrated Mode) Attenuation (%)	Difference (%)	10 MV	LOG CBCT - 3D (Integrated Mode) Attenuation (%)	Difference (%)
Reference	5.5	-	Reference	4.3	-
PerFRACTION	4.9	0.6	PerFRACTION	4.8	0.5

Calculated on CBCT using information from the EPID log files in integrated mode

In our sensitivity tests, PerFRACTION accurately detected variations of linear accelerator output in the in-vivo monitoring. Analogous results were obtained for the simulated variation of the patient's thickness. There is an excellent agreement between ionization chamber measurements and EPID measurement at central axis. The larger difference we found was 1.2%.

END-TO-END TEST (EPID 2D ABSOLUTE DOSE)

PHANTOMS (6 MV)	TLD Difference to reference (%)*	EPID 2D (Integrated Mode) Difference to reference (%)**	PHANTOMS (10 MV)	TLD Difference to reference (%)*	EPID 2D (Integrated Mode) Difference to reference (%)**
Homogeneous	-1.2	0.0	Homogeneous	-1.5	0.3
Bone	2.9	3.7	Bone	-0.1	**3.2**
Lung	-2.1	-1.7	Lung	-0.4	0.0
Air	-1.3	-1.7	Air	-1.6	0.0

**Dose calculated by Eclipse TPS on TLD*
***Dose expected at EPID's central axis, according to PerFRACTION*

Using TPS calculations as reference, the table above shows the deviations of the TLDs measurements, as well those of dose calculated by PerFRACTION on the EPID. Variations detected by TLDs measurements and by PerFRACTION calculation were very close. Among the 16 points analyzed (TLDs and EPID), 12 had variations less than 2%, 2 points with variation between 2% and 3%, and only 2 points with deviations greater than 3%. The major deviations were observed for PerFRACTION calculation in the phantom region that simulated bone. However, for 6 MV, the TLD also showed a high deviation to TPS, similar to those detected by PerFRACTION. This finding suggests that an investigation of TPS dose calculation in high-density mediums should be performed.

END-TO-END TEST (3D EPILOG + CBCT)

6 MV	PTV Dose (cGy)	PTV Diff. (%)	BONE Dose (cGy)	BONE Diff. (%)	LUNGS Dose (cGy)	LUNGS Diff. (%)	HOMOGENEOUS Dose (cGy)	HOMOGENEOUS Diff. (%)
Measured	400,3	-	208,0	-	180,6	-	215,3	-
PerFRACTION	424,0	5,9	220,0	5,8	193,0	6,9	215,0	-0,1

10 MV	PTV Dose (cGy)	PTV Diff. (%)	BONE Dose (cGy)	BONE Diff. (%)	LUNGS Dose (cGy)	LUNGS Diff. (%)	HOMOGENEOUS Dose (cGy)	HOMOGENEOUS Diff. (%)
Measured	399,3	-	197,4	-	166,9	-	203,9	-
PerFRACTION	418,0	4,7	204,0	3,3	179,0	7,3	202,0	-0,9

Challenging issues :
- Highly modulated plan
- Very heterogeneous phantom
- Dose calculation performed in CBCT

Using ionization chamber measurement as reference, the table above shows the deviations of the dose calculated by PerFRACTION using the EPILOG file in the CBCT image. In the homogenous region, we observed good agreement for both energies (deviation less than 1,0%). In other regions, the deviations were higher, however, end-to-end tests can be tricky and deviations up to 8,0% occurred in previous studies [2,3] that investigated similar complex situations.

CONCLUSION

Our tests indicate that PerFRACTION dose calculation in different situations have good agreement with standard measurements. Therefore, considering the variety and complexity of the tests in this study, the PerFRACTION system can be considered effective to increase patient's safety through *in-vivo* monitoring.

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