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Alessandria*

# **Working Paper of Public Health**

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*Title:* TC simulation versus TC/PET simulation for radiotherapy in lung cancer: volumes comparison in two cases.

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*Abstract*

CT/PET is useful in early diagnosis, staging, follow-up and in radiotherapy treatment planning especially for tumors located in motion involved anatomic areas (chest and abdomen).

We analysed the treatment planning for radiotherapy of two pulmonary cancer patients.

A comparison was performed between GTV (Gross Tumor Volume) and PTV (Planning Target Volume) identified with CT images alone and GTV and PTV evaluated with CT/PET images.

CT/PET imaging was demonstrated to significantly modify the target volume if compared with CT imaging: volumes were reduced by 32-49%.

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### *Introduction*

Three-dimensional conformal radiotherapy (3D-CRT) or intensity modulation radiotherapy (IMRT) allows high precision cancer treatments.

The application of these techniques is based on the individuation of several volumes of interest like Gross Tumor Volume (GTV), Clinical Target Volume (CTV) and Planning Target Volume (PTV).

Biological target volume (BTV) is GTV derived from CT/PET images.

DVH (Dose Volume Histogram) summarizes 3D dose distributions. In modern radiation therapy, 3D dose distributions are typically created in a computerized treatment planning system based on a 3D reconstruction of a CT scan. The "volume" referred to in DVH analysis can be a target of radiation treatment, a healthy organ nearby a target, or an arbitrary structure (3).

PET imaging plays an essential role in oncology not only in patient's diagnosis, staging and follow-up but also in radio-therapeutic planning. In association with CT, PET can help to correctly localize irradiation target volume, to respect dose constraints for organs at risk and to reduce GTV determination (2).

CT/PET with gated respiratory acquisition mode (4D) represents an important evolution. The possibility to correct motion artefacts improves spatial resolution and increases examination sensitivity (9).

### *Materials and Methods*

A.O. SS Antonio e Biagio e C. Arrigo in Alessandria employs a 4D CT-PET scanner (GE Discovery 600). The equipment allows respiratory gating acquisition technique.

CT/PET simulation, with (18)F-FDG, for radiotherapy treatment planning is performed with the patient immobilized in the same positions applied during the following radiotherapy sessions. To ensure the reproducibility of the treatment, the same body supports and repositioning systems are employed. Nuclear medicine physician staff proceeds to identify tumour volume and to contour uptaking lesions on the CT/PET images (Advantage GE workstation). Images containing the defined BTV are then sent to the treatment planning system (Oncentra MasterPlan), where radiotherapy physician staff completes the contouring of GTV, CTV and organs at risk (Healthy lungs, Esophagus, Spinal Cord, Heart) on the CT images, to define the treatment planning.

We analysed the case of two pulmonary cancer patients, treated with radical radiotherapy and chemotherapy for non-small cell lung cancer (NSCLL), too advanced for primary surgical treatment. (Figure 1)

The characteristics of the patients were:

Patient 1: Female, 47 years old, stage IIIB (T4 N2) NSCLL of right upper lobe.

Patient 2: Male, 58 years old, stage IIIA (T4 N1) NSCLL of right upper lobe.

The treatment, in both patients, consisted of induction chemotherapy with Platinum 75 mg/m<sup>2</sup> and Docetaxel 75 mg/m<sup>2</sup> (two courses every 21 days) followed by radical radiotherapy at a dose of 66 Gy in 33 fractions and concomitant weekly chemotherapy with Platinum 25mg/m<sup>2</sup> and Docetaxel 25 mg/m<sup>2</sup>.

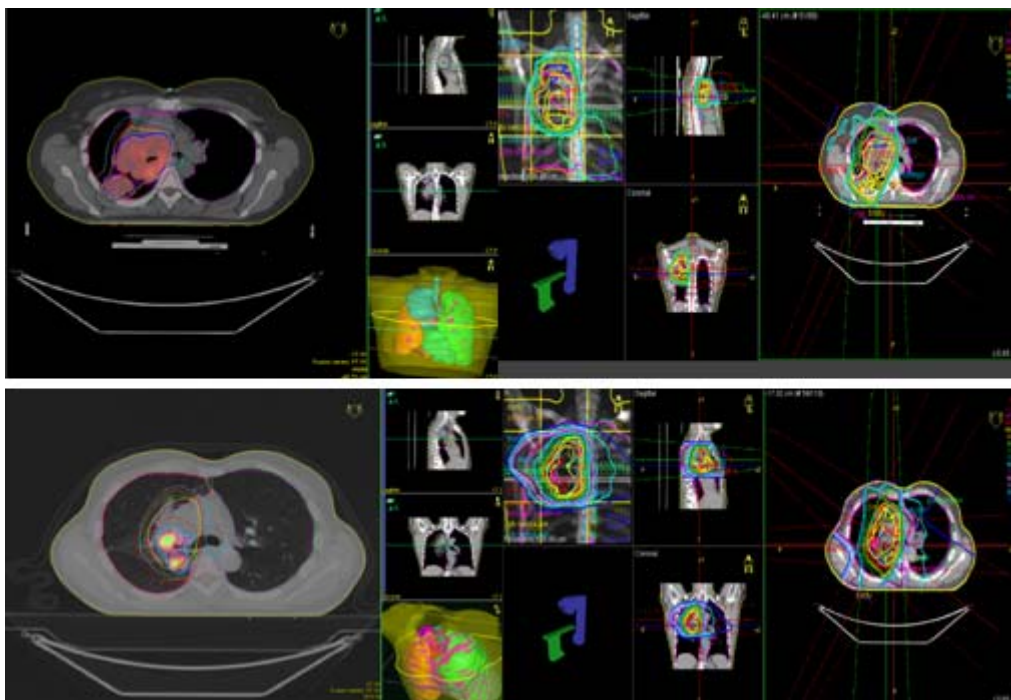


Figure 1: CT/PET imaging end treatment planning for patient 1 (top) and 2 (bottom)

CTV was defined by using CT window for parenchyma. PTV was obtained adding one 10 mm margin in every direction but medially (5 mm), because both neoplasms were central and very near to the vertebral body. The radical treatment included a dose of 66 Gy with 3D conformal technique and 6 MV photons, generated by Linac equipped with multileaf collimator.

## Results

A comparison was performed between GTV and PTV identified with CT images alone and GTV and PTV evaluated with CT-PET images. In both cases PET-defined GTVs resulted significantly smaller (31.6% and 48.7% respectively). PTVs were smaller too (22.7% and 42.6% respectively).

In patient 1 it was possible to spare atelectasis regions that would have been diagnosed as neoplastic and treated accordingly, if only CT images had been considered. In patient 2 a suspect secondary pleural lesion was excluded from radiation area: it was visible in the CT images but absent in the PET scans, because of its metabolic silence.

	CT		CT/PET		CT/PET	CT/PET
	GTV (cm <sup>3</sup> )	PTV (cm <sup>3</sup> )	GTV (cm <sup>3</sup> )	PTV (cm <sup>3</sup> )	GTV Reduction	PTV Reduction
Patient 1	535.5	1015.4	367.1	785.3	31.6%	22.7%
Patient 2	361.7	757.0	185.5	434.4	48.7%	42.6%

Table 1: comparison between GTV and PTV for patient 1 and patient 2.

Figure 2 and Table 2 show an analysis of dose distribution and of dose-volume histograms (DVH) for both cases.

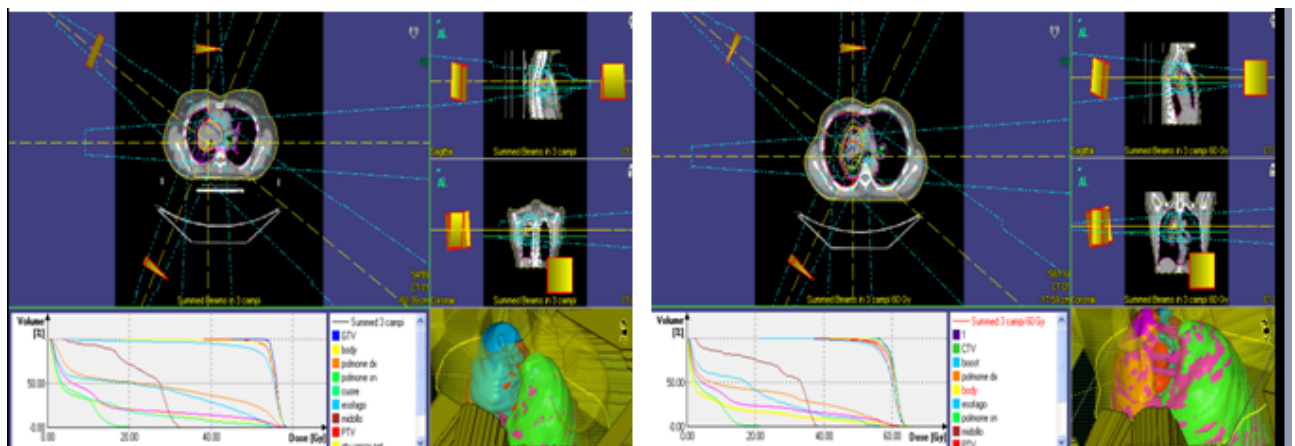


Figure 2: Dose distribution for patient 1(left) and for patient 2 (right)



Simulation	Patient 1		Patient 2	
	CT/PET	CT	TC/PET	CT
Lungs V 13 Gy	30%	34.3%	29.1%	32.6%
Lungs V 20 Gy	18%	18.3%	23.7%	24.4%
Lungs V 25 Gy	16.5%	16.5%	22.3%	23.1%
Lungs V 30 Gy	15.3%	15.1%	20.4%	21.7%
Esophagus V 35 Gy	38.7%	51.7%	18.1%	23%
Esophagus V 50 Gy	18.1%	32.6%	7.8%	10.8%

Table 2: DVH for patient 1 and 2

We reported only data about DVHs of healthy lungs and esophagus: in fact in these organs we have found more difference in dose distribution between CT/PET planning and CT planning.

About DVH for healthy lungs, in patient 1, V13 was more favourable with CT/PET simulation respect to CT simulation; V20, V25 and V30 were almost similar. In patient 2, V13, V20 and V30 were instead better with CT/PET simulation respect to CT simulation; V20 only was similar.

About DVH for esophagus, in both patients, there was a big difference in V35 and in V50 between CT/PET simulation and CT simulation (38.7% vs. 51.7%, 18.1% vs. 32.6% respectively for V35 and V50 in patient 1 and 18.1% vs. 23%, 7,8% vs. 10.8% respectively for V35 and V50 in patient 2).

### Discussion and Conclusions

CT/PET in treatment planning may improve accuracy and reproducibility of GTV contouring, may identify on the basis of signal intensity functional subvolumes for dose boosting (dose painting by contours) and in future might be used to shape the dose distribution according to the voxel intensity (dose painting by numbers).

Several studies in more than 700 patients have shown that the use of PET image data leads to an advantage for the patient.

Different methods are described in literature for volume delineation in PET, like visual contouring (8), absolute thresholds (7) and thresholds by fixed percentage of SUV (1). The threshold contour level affects the tumor size. The appropriate threshold level depends on lesion size and image reconstruction parameters. These effects should be carefully considered when using PET contour and/or volume information for radiotherapy applications (4).



Despite the limitations associated with the interpretation of the functional signal, CT/PET contouring of BTV offers potential gains for improving local control reducing delineation variations and for giving better protection of healthy tissue (5-6).

CT/PET may distinguish the tumor from collapsed lung tissue (atelectasis) and may let lymph-node staging with higher accuracy.

In our two cases CT-PET imaging was demonstrated to significantly modify the target volume if compared with CT imaging: volume was reduced by 32-49%.

A smaller GTV allows smaller PTV and dose distributions sparing organs at risk of irradiation (lung, esophagus), reducing post irradiation complications.

In both cases there was an improvement in lung DVHs with CT/PET simulation, compared with CT simulation. However the improvement of lung DVHs is, in percentage, lower in respect to reduction in GTV and PTV, the reason being that volume reduction is near the pulmonary apex and mediastinum, where the volume of lung parenchyma is more limited.

Esophageal DVHs are instead better when CT/PET was employed in treatment planning.

Finally, CT-PET with gated respiratory acquisition mode (4D) improved the organ motion control, limiting potential geographic miss due to respiratory movements during radiotherapy.





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