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The impact of PET/CT scanning on the size of target volumes, radiation exposure of organs at risk, TCP and NTCP, in the radiotherapy planning of non-small cell lung cancer

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ABSTRACT

Aim: To compare radiotherapy plans made according to CT and PET/CT and to investigate the impact of changes in target volumes on tumour control probability (TCP), normal tissue complication probability (NTCP) and the impact of PET/CT on the staging and treatment strategy.

Background: Contemporary studies have proven that PET/CT attains higher sensitivity and specificity in the diagnosis of lung cancer and also leads to higher accuracy than CT alone in the process of target volume delineation in NSCLC.

Materials and methods: Between October 2009 and March 2012, 31 patients with locally advanced NSCLC, who had been referred to radical radiotherapy were involved in our study. They all underwent planning PET/CT examination. Then we carried out two separate delineations of target volumes and two radiotherapy plans and we compared the following parameters of those plans: staging, treatment purpose, the size of GTV and PTV and the exposure of organs at risk (OAR). TCP and NTCP were also compared.

Results: PET/CT information led to a significant decrease in the sizes of target volumes, which had the impact on the radiation exposure of OARs. The reduction of target volume sizes was not reflected in the significant increase of the TCP value. We found that there is a very strong direct linear relationship between all evaluated dosimetric parameters and NTCP values of all evaluated OARs.

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Conclusions: Our study found that the use of planning PET/CT in the radiotherapy planning of NSCLC has a crucial impact on the precise determination of target volumes, more precise staging of the disease and thus also on possible changes of treatment strategy.

1. Background

In the current practice of radiotherapy planning and target volume determination in patients suffering from non-small cell lung cancer (NSCLC), a contrast-enhanced CT is usually used. Unfortunately, there are several clinical situations where we often encounter difficulties in contouring target volumes, as in the cases of tumour-related atelectasis, spiculated lesions and lesions close to the dystelectatic changes. Also, there are no adequate size-based criteria for nodal involvement assessment for these patients.[1]

Contemporary studies have proven that hybrid PET/CT examination has higher sensitivity and specificity in the diagnosis of lung cancer[2] and also leads to higher accuracy in the process of target volume delineation in NSCLC.

Although the prognosis of patients with NSCLC in stage III has become better in recent years, it is very difficult to improve the local control of the disease using conventional fractionation schedules and conventional doses (60 Gy).[3] This seems to be feasible by using accelerated hyperfractionated radiotherapy (HART,[4] CHARTWEL[5,6]), which increases toxicity, or by increasing the dose delivered to the target volumes, but it has been proven that the tolerance of surrounding organs at risk inhibits this effort.[7] On the other hand, reduction of the target volumes should lead to the possibility of delivering higher doses and thus to the increasing of tumour control probability (TCP) with acceptable normal tissue complication probability (NTCP). Nowadays, it seems that the way to reduce target volumes is to use the most precise imaging modality possible, optimally PET/CT.

Therefore, we proposed a representative study comparing radiotherapy plans made according to CT and PET/CT examinations in the same patient. For these comparative purposes we used different dose-volume parameters and sizes of target volumes. Furthermore, we investigated the impact of the changes in target volume sizes on TCP and NCTP and the impact of combined PET/CT examination on the staging of the disease and treatment strategy. According to our best knowledge, there has been no study published investigating the relationship between target volume changes that developed according to the use of PET/CT and NTCP values for all relevant organs at risk in the chest.

2. Patients and methods

2.1. Patients

Between October 2009 and March 2012, 31 patients (26 men and 5 women, with a median age of 68, see details in Table 1) suffering from histologically proven, inoperable, locally advanced NSCLC referred for radical radiotherapy – either as a single method or in combination with chemotherapy, sequential or concomitant – took part in our study.

Table 1 – Patients and disease characteristics.

	All patients ($n = 31$)
Sex	
Male	26 (83.9%)
Female	5 (16.1%)
Age at the time of diagnosis (median, range)	68 (56–80)
Side	
Right	21 (67.7%)
Left	10 (32.3%)
Histology	
Squamous cell carcinoma	24 (77.4%)
Adenocarcinoma	7 (22.6%)
Dose delivered (Gy; median; range)	66 (40.5–80)
Stage according to CT	
IA	0
IB	2 (6.4%)
IIA	1 (3.2%)
IIB	0
IIIA	18 (58.1%)
IIIB	6 (19.4%)
IV	4 (12.9%)
Stage according to PET/CT	
IA	0
IB	2 (6.4%)
IIA	0
IIB	3 (9.7%)
IIIA	17 (54.8%)
IIIB	6 (19.4%)
IV	3 (9.7%)
Radiotherapy purpose according to CT	
Radical	27 (87.1%)
Palliative	4 (12.9%)
Radiotherapy purpose according to PET/CT	
Radical	27 (87.1%)
Palliative	4 (12.9%)

2.2. Radiotherapy simulation and image acquisition

All patients underwent initial preparation at the Department of Oncology and Radiotherapy, University Hospital in Pilsen, according to our institutional standards, i.e. the choice of proper positioning and immobilization devices (we normally use WingBoard^R, MED-TEC, for immobilization of the upper arms when patients are in the supine position with both arms above the head), determination of the reference plane on X-ray simulator and drawing of the projection points of the simulated isocentre on the patient's skin. Planning PET/CT examination was carried out at the Department of Imaging