1. Introduction

In the tumor related morbidity lung cancer is the leading death cause, both in the male and female population. In the treatment of lung cancer local control is a crucial question the possibility of tumor recurrence is very high, even in early stage disease. In the 3D conformal radiotherapy for PTV (planning target volume) definition many factors have to be taken in account (e.g.: microscopic spread of the tumor cells, daily set up errors, tumor motions). In the common practice standard safety margins are added to clinical target volumes (CTV) which are derived from a spiral CT scan. These safety margins are estimated arbitrarily, potentially resulting in either excessive exposure of normal tissues (especially in case of combined chemo-radio therapy) or insufficient target volume coverage. Overestimation of the PTV can cause higher side effect profile- especially in combined treatment settings. With the use of inadequate PTV volume the delivery of an adequate tumor destroying dose becomes doubtful.

According to International Commission on Radiation Units and Measurements (ICRU) Report, Recommendation No. 50 and 62, the planning target volume (PTV) has to include the uncertainties arising from internal organ motion, patient movements and positioning errors. Uncertainty resulting from tumor movement must be considered in 3D therapy planning especially in case of IMRT or stereotactic therapy.

In 2004 a complex study was initiated in our institute to detect tumor movements, to analyze uncertainties in treatment planning arising from tumor motions and to detect the effectiveness of the fixation system used in our institute for lung cancer radiotherapy.

2. Purposes:

2.1. Dynamic MR based analysis of tumor movement

As a first step a dynamic MR based movement analysis was delivered. The aim of our dynamic MR based study was to make a high precision characterization of tumor movements in upper and mid-lobe localized tumors (as high patient number as possible), and to calculate numerical data for safety margins to be considered in 3D planning of lung cancer patients.

2.2. The role of the tumor movements in the treatment planning

The next aim of our program was to detect the possible uncertainties rising from tumor movements in the daily treatment planning, in extreme breathing conditions. We used CT fusion for the characterization of tumor motion and we adapted the coverage index to give exact numerical data.

2.3. The influence of thermoplastic patient fixation on tumor motions

Finally we analyzed the effects of our patient positioning system on the chest wall and tumor motions under extreme breath conditions using multislice CT.

3. Materials and methods:

3.1. Dynamic MR based analysis of tumor movement

Twenty-four patients with newly diagnosed stage II-IV lung cancer were enrolled into the study. According to tumor localization in the right S1-S3 segments 9, in the right S4-S10 segments 2, in the left S1-S3 segments 9 and in the left S4-S10 segments 4 lesions were detected. In normal treatment position individual dynamic MR examinations were performed in axial, sagittal and coronal planes (100 slices/30 sec). For tumor motion analysis E-RAD PACS software was used.

3.2. The effect of the tumor movements for the treatment planning

Ten patients with lung cancer were enrolled into the study. According to tumor localization five patients had periferial and five had central tumor. After the normal planning CT scan two more scans were made with the same CT parameters in maximal exhalation and in maximal inhalation. For planning the normal breathing scans were used with the fusion of the maximal inhalation and maximal exhalation scans. After the fusion in all breathing phases the gross tumor volumes were contoured (GTV1,GTV2,GTV3). Around the GTV1 (normal breathing phase GTV) 3 planning target volume (PTV) were generated with the margin of 0,5cm, 1,5cm and 2,5cm (PTV1,PTV2,PTV3). Individual plans were generated to all PTV.

3.3. The influence of thermoplastic patient fixation on tumor motions

Ten patients with stage II-IV lung cancer were enrolled into the study. According to tumor localization, 5 patients had peripheral, 5 patients central lung cancer (T2-T4). Totally six series of measurements were made with multislice CT-scanner, both with and without mask fixation, in normal breathing, at maximal tidal volume inhalation and at maximal tidal volume exhalation.

4. Results:

4.1. Dynamic MR based analysis of tumor movement

Movements of the tumor under normal breathing conditions were registered in the three main directions. The mean antero-posterior deviation was 1,09 mm (range: 0,63 mm-2,04 mm), the mean medio-lateral deviation was 1,14 mm (range: 0,6 mm- 2,44 mm). The greatest deviation was measured in cranio-caudal direction (mean: 2,7 mm, range: 0,79 mm- 8,15 mm). The mean direction independent deviation was 1,8 mm (range: 0,9 mm- 4,8 mm).

4.2. The effect of the tumor movements for the treatment planning

All GTV volumes were registered. In all cases volume deviations were administered in different breathing phases (min:1,5%, max:35,6%). For GTV coverage comparison Coverage Index (CI) was used. In case of extreme breathing conditions using 0,5cm margin was enough to reach good coverage for central tumors. For peripheral tumors 1,5 cm margin had to be used for the acceptable coverage (CI: 0,85-1,00).

4.3. The influence of thermoplastic patient fixation on tumor motions

Movements of chest wall, diaphragm and tumor, with and without mask, under different breathing conditions were registered. With the use of the immobilization system, no significant difference was found in the diaphragmatic movements (mean deviation of diaphragm: 41.7-40.5mm-right side, mean deviation of diaphragm: 40.5-36.8mm-left side) and in the tumor motions (mean deviation in craniocaudal direction: 15.3-12.4 mm, mean deviation in posteroanterior direction: 11.5-8.8mm, mean medial deviation: 4.6-4.1mm, mean lateral deviation: 7.2-5mm). Significant difference were found concerning tumor motions in anteroposterior direction (mean: 8.9-6.3mm) and the transverse chest movements in anteroposterior direction.

5. Conclusions:

5.1. Dynamic MR based analysis of tumor movement

Dynamic MR is a sensitive and well tolerated method for tumor motion monitoring in high precision 3D therapy planning of lung cancer patients. Our results demonstrate that tumors located in the upper and mid lobes have moderate breath synchronous movements. The greatest deviation occur in cranio-caudal direction.

5.2. The rule of the tumor movements in the treatment planning

In our study extreme breathing conditions were analyzed. According to our results CT scans, used in the daily rutin, don't exactly represent the tumor midposition and the true tumor volume. Due to breathing synchron tumor movements 0,5cm margin must be used for planning in central localization. In peripheral tumors wider margin should be used.

5.3. The influence of thermoplastic patient fixation on tumor motions

Besides the advantage of optimal patient positioning, the movements of the bony chest wall can be considerably reduced by using of the immobilization system. However, this fixation system has its limitation concerning its suitability for minimizing the tumor motions.