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Stereotactic body radiation therapy for liver metastasis – The linac-based Greater Poland Cancer Centre practice

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ABSTRACT

Aim: The main purpose of this work is to give a technical description and present the properties of the liver SBRT protocol implemented in the Greater Poland Cancer Centre (GPCC) in Poznan, Poland.
Background: Stereotactic body radiation therapy (SBRT) for liver metastasis is a non-invasive therapeutic option which enables irradiation of a small target in the body with a high dose.
Materials and methods: This study presents details of our linac-based liver SBRT protocol. Special emphasis has been placed on fiducial implantation, patient preparation (CT scanning, immobilization), treatment planning, and its implementation.
Results: The liver SBRT treatment course implemented in the GPCC consists of three fractions to deliver a total of 45 Gy. Fraction delivery details with description of patient positioning (localization of liver metastasis) are presented below.
Conclusions: The literature validation of the assumptions concerning the steps of the GPCC linac-based liver SBRT procedure show their potential for an effective and patient friendly implementation.

1. Background

Most of the cancers: colorectal, breast, kidney, lung, pancreas cancers, often present solitary metastasis or oligometastases in the liver. A surgical resection provides a long term survival in approximately 30% of patients with the colorectal carcinoma liver metastases, but only a limited (10–25%) percentage of patients is amenable to surgery. Non-surgical ablation methods include cryotherapy, laser-induced interstitial thermotherapy, and radiofrequency ablation which is the most frequently used method. Stereotactic body radiation therapy (SBRT) is a non-invasive therapeutic option, which enables irradiation of a small target in the body with a high dose.[1–4] The use of SBRT is rapidly increasing.[5–8]

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2. Aim

The aim of the study is to present the SBRT treatment for liver metastases using a conventional linear accelerator.

3. Materials and methods

At the Greater Poland Cancer Centre (GPCC), for the SBRT purposes, we classify patients into those with metastases in one organ (liver metastases); those with a histopathologically proven colorectal adenocarcinoma; those after a radical resection of the primary tumor; inoperable; or those with a recurrence after an operation on the liver. The maximum accepted diameter of the largest metastasis is 6 cm. If two lesions of metastases are close to each other, the maximum diameter is greater (up to 8–9 cm with the lesions contoured as one connected target). One to four metastases are accepted while a tumor is visible on CT scans.

The patient should have status 2 WHO/ECOG; chemotherapy is allowed before and after the study treatment, but the last chemotherapy must be within one month before the SBRT.

Exclusion criteria: an uncontrolled extrahepatic disease and an uncontrolled primary cancer, a liver cirrhosis.

Before the treatment begins, all patients are discussed at a meeting of a multidisciplinary team consisting of surgeons, medical oncologists, radiation therapists, radiologists and hepatologists. At the GPCC, preparation for the stereotactic treatment starts by conducting an operation. For the treatment, internal fiducial markers are implanted near the liver tumor to allow monitoring the tumor movement during the treatment. While the fiducial markers are typically implanted under CT-guidance or ultrasound guidance, at the GPCC the fiducial markers are implanted during the operation. The tumor at the time of treatment may turn out to be larger than estimated through CT or ultrasound examinations. The surgeon or radiation oncologist visually implants 2–4 fiducial markers in healthy tissues, in a strategic, non-planer geometric relationship among one another. The operator can observe the tumor, measure it if necessary, and can easily observe the distance between the tumor and the healthy tissue. The implantation process becomes easier than the one conducted through the CT guidance. A CT scan treatment planning with contrast and slice thickness of 3 mm is conducted about ten to fourteen days after the fiducial placement. An appropriate preparation for the SBRT treatment is started by forming the vacuum pillow on which the patient is positioned frameless in a standard supine position, the patient's arms are abducted alongside the head, and knee support is utilized.[9,10] The CT images are acquired at 3 mm slice spacing in different breathing conditions:

- free shallow breathing for planning purpose[10,11];
- deep breathing while maintaining position;
- free shallow breathing with contrast enhancement.[10]

All CT scans are transferred to the Eclipse V.10.0 Treatment Planning System (Varian Medical Systems, Palo Alto, California, USA). A gross tumor volume (GTV) and organs at risk (OARs) are delineated by a physician on the free breathing CT scan.[10,30] The gross tumor volume is considered to be identical with the clinical target volume (CTV) and expanded by 5 mm margin (the exception being by 10 mm in the cranio-caudal direction) to create the planning target volume (PTV)[11–13] for the respiratory motion observed at the time of simulation. The OARs may include healthy organs (liver for which the PTV volume is subtracted, kidneys, spinal cord, stomach, esophagus, bowel, heart). The dose delivered to the organs is presented in Table 1. Dose constraints to OARs are adopted to the clinical protocol as proposed by the International Liver Tumor Group.[31,32]

Table 1 – Dose constraints to organs at risk.

Organ at risk	Dose constraint
Liver (healthy) (liver-PTV)	$D_{700\,ml} < 15$ Gy
Kidneys (both)	$D_{35\%} < 15$ Gy for kidneys volume (sum of both kidneys) $D_{50\%} < 15$ Gy for the kidney receiving the highest dose
Spinal cord	$D_{max} < 18$ Gy
Stomach	$D_{1CC} < 21$ Gy
Esophagus	$D_{1CC} < 21$ Gy
Bowel	$D_{1CC} < 21$ Gy
Heart	$D_{1CC} < 30$ Gy
Duodenum	$D_{1CC} < 21$ Gy

$D_{700\,ml}$ – dose received by 700 ml of the analyzed organ.
$D_{X\%}$ – dose delivered to x% of the analyzed organ.
D_{1CC} – dose delivered to 1cc of the analyzed organ.

According to numerous literature findings, the dose is normalized to prescribe 100% of the dose to the mean GTV. At the same time, jaws and a multileaf collimator (MLC) should be adopted and fitted to encompass the GTV and PTV volumes by at least 95% and 67% isodose, respectively.[13,26,33]

In our treatment protocol (the liver SBRT), we use 15 Gy in 3 fractions (the total dose 45 Gy).[9] The protocol assumes that the treatment plan is prepared by a three dimensional conventional conformal radiotherapy technique with 6 MV photons and the dose rate of 600 MU/min. A dosimetric calculation is conducted using the Anisotropic Analytical Algorithm with heterogeneity correction.[14–16]

The geometry of the plan should be proposed taking into account the tumor size, medical location, boundary, and vasculature projection in the treated area.[17,30] To enhance dose homogeneity, field weighting and wedges can be used.

At the GPCC, we use the Varian environment: the Eclipse v. 10.0 Treatment Planning System. The patients are treated in a Clinac 2300CD linear accelerator with the On-board Imager, OBI and 120 Millennium MLC with 0.5 cm width in the isocenter.[9]

4. Results

In our SBRT protocol three fractions are delivered according to two proposed schemes: irradiation every second day with the treatment starting on Monday; or the treatment starting on Tuesday and ending on Monday. Both schemes are applied in different cancer centers with three dose fractions delivered in one week (Erasmus). The total course of the SBRT is completed