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Review

Extracranial stereotactic body radiotherapy. Review of main SBRT features and indications in primary tumors

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ABSTRACT

Aim: Review of main SBRT features and indications in primary tumors.
Background: Stereotactic body radiotherapy has been developed in the last few years. SBRT allows the hypofractionated treatment of extra cranial tumors, using either a single or limited number of dose fractions, and resulting in the delivery of a high biological effective dose with low toxicity.
Material and methods: SBRT requires a high level of accuracy for all phases of the treatment process: effective patient immobilization, precise target localization, highly conformed dosimetry and image guided systems for treatment verification. The implementation of SBRT in routine requires a careful considering of organ motion. Gating and tracking are effective ways to do so, and less invasive technologies "fiducials free" have been developed. Due to the hypofractionated scheme, the physician must pay attention to new dosimetric constraints in organ at risk and new radiobiological models are needed to assess the optimal fractionation and dose schemes.
Results: Currently, SBRT is safe and effective to treat primary tumors, which are otherwise untreatable with conventional radiotherapy or surgery. SBRT has quickly developed because of its excellent results in terms of tolerance and its high locoregional control rates. SBRT indications in primary tumors, such as lung primary tumors, have become a standard of care for inoperable patients. SBRT seems to be effective in many others indications in curative or palliative intent such as liver primary tumors, and novel indications and strategies are currently emerging in prostate cancer, head and neck tumor recurrences or pelvis reirradiations.
Conclusion: Currently, SBRT is mainly used when there is no other therapeutic alternative for the patient. This is due to the lack of randomized trials in these settings. However, the results shown in retrospective studies let us hope to impose SBRT as a new standard of care for many patients in the next few years.

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1. SBRT overview and requirements

Over the last decades stereotactic cranial radiosurgery has been successfully used for the treatment of intracranial lesions as it can precisely deliver a high dose of radiation to a tumor with very low dose to surrounding critical tissues. The good results obtained in intra-cranial localizations have led to the development of extra-cranial stereotactic radiation therapy known as stereotactic body radiation therapy (SBRT). SBRT, as a precise external beam radiation technique, allows the hypofractionated treatment of extra cranial tumors, using either a single or limited number of dose fractions, and resulting in the delivery of a high biological effective dose, often above 100 Gy which could be considered as “ablative” dose (stereotactic ablative body radiotherapy “SABR” is another suggested name for this technique). As in intracranial stereotactic radiosurgery, SBRT requires a high level of accuracy for all phases of the treatment process and organ and patient motion must be considered in the treatment planning. Recommendations and treatment quality control guidelines have also been established for SBRT.[1,2]

Accuracy in SBRT requires effective patient immobilization, precise target localization with the integration of modern image systems (CT, MRI, PET-CT) in order to properly define the tumor area for treatment and to further minimize radiation dose to healthy surrounding tissues; treatment planning also requires highly conformed dosimetry and isotropic dose fall-off (Fig. 1). Dose calculations should be carried out with algorithms which can account for the effects of tissue heterogeneities. Therefore, in order to deliver these accurate doses, linear accelerators must be equipped with micromultileaf collimators, the possibility of using multiple non overlapping beams of radiation and even intensity modulated radiation therapy.

One of the key challenges and requirements of SBRT is to reach the same “stereotactic accuracy” for extra cranial treatment as is achieved for cranial treatments. SBRT requires new image-guided verification techniques (IGRT), such as cone beam imaging or stereoscopic X-ray imaging, that allow a precise treatment of non-moving lesions (spine, prostate, etc.). For moving lesions such as lung and liver tumors, problems with accuracy still remain a challenge, and the assessment of tumor motion can be approached in different ways. Quantification of tumor motion can be measured and an ITV (internal target volume) can be deduced using a 4D-CT scan during the different respiratory phases. To reduce the target treatment area and spare healthy tissue more effectively, restrictive techniques, such as “dampening” with abdominal compression, can be used. Other methods called “compensating techniques” can not only quantify tumor motion but also have an intra-fraction control of tumor position and can treat the tumor exactly at the place where it is located, by visualizing its motion during the treatment. These techniques allow a precise delivery of high dose of radiation to the tumor with minimal dose to surrounding critical tissue (Fig. 1).

Novalis Exactrac Adaptive Gating® technique has been developed as a method that improves the accuracy of SBRT for lung and liver lesions, by monitoring organ tumor motion and irradiating within a selected area of the respiratory cycle. The tumor can be irradiated in this selected area by using internal markers previously implemented close to or directly into the tumor. Based on external markers, internal tumor motion is correlated with the external respiratory signal. During patient setup, infrared markers track the respiratory cycle. The Exactrac image guided system localizes the internal marker by X-rays and quantifies the tumor motion by correlating the external marker motion to the internal marker position. A selected area of this cycle is defined as the “beam on area” of irradiation. The validity of this model is verified in real time by ExacTrac X-Rays[3,4] (Fig. 2).

“Tracking” is another compensating technique, and the tumor can be followed by “tracking” these fiducials or even by tracking certain tumors visible in the guidance X-ray image system. The CyberKnife system can track the tumor during the treatment using fiducials. However, transthoracic fiducials implantation under CT guidance can be responsible for pneumothorax (24–45%).[5,6] A fiducial-free tracking system, Xsight® Lung Tracking System (XLTS), has therefore been designed. This system requires that the tumor is wider than 15 mm and that it is visible in the orthogonal X-ray images (the tumor must be distant of at least 15 mm from any major vascular structures and its projection on the spine must be different from 45°). The system also uses a correlation model between external markers and the internal tumor positions to attain a millimetric precision. Both tracking systems can be combined

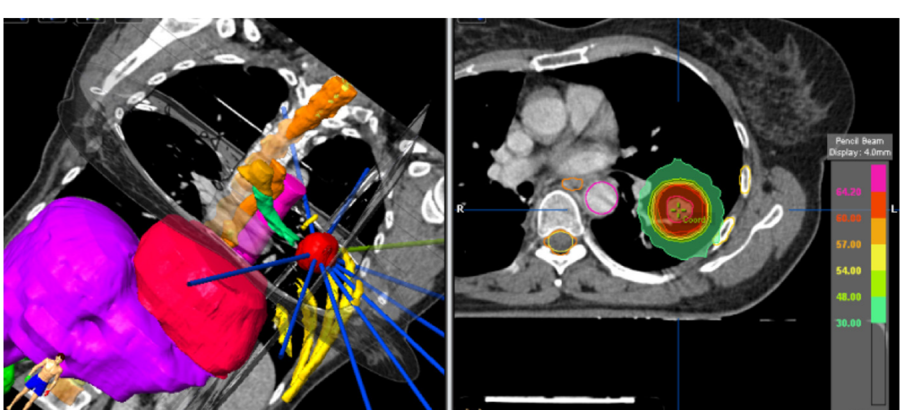

Fig. 1 – SBRT treatment for early stage peripheral NSCL cancer. Highly conformed dosimetry with multiple beams. Dose prescribed: 60 Gy in 3 fractions of 20 Gy.