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Proton Therapy Treatment Planning in the Case of Prostate Cancer

Proton therapy is a relatively recent form of radiation therapy, where the characteristics of the proton beam at least in theory allow for greater dose accuracy, sparing healthy tissue from unnecessary radiation. The method has gained popularity in the treatment of prostate cancer, but as protons are more sensitive to motion than photons, day-to-day movement of the target organ can be a challenge for effective treatment planning. Careful planning, daily control imaging, immobilization techniques and plan libraries are among the tools used to ensure appropriate dose distribution.

One of the most important differences between photon therapy and proton therapy is the sharp dose gradient of the Bragg Peak (Matsukawa et al. 2020). This means that the radiation energy can be distributed very locally, so that the tissues in front of and behind the target receive a much smaller dose (Mangan & Leech 2019). Thus, in the case of prostate cancer treatments, proton therapy should lead to improved dosimetry when organs such as the bladder and the rectum are concerned.

Proton therapy, however, is not entirely unproblematic. As its administered dose depletes sharply beyond the Bragg Peak, it is vitally important that the beam is targeted properly. Otherwise, the tumour may not receive the intended dose, whereas adjacent organs may be exposed to excessive radiation. This means that proton therapy is more sensitive to motion than photon therapy, which can be a challenge in the case of organs which are not in a fixed position, such as the prostate. Moreover, the density of the material that the proton beam travels through has a strong effect on the location of the Bragg Peak, and gaseous cavities are known to alter the dose distribution in a way that may expose healthy tissues to an unnecessarily increased dose (Mangan & Leech 2019).

Although bladder and rectal doses should be significantly lower with proton therapy, this does not necessarily seem to mean that patients encounter fewer gastrointestinal or genitourinary toxicities when they are treated with proton therapy. This may be due to the uncertainties in dose administration mentioned above, and improved treatment planning might yield improved results (Mangan & Leech 2019).

Compared to photon therapy, there are several factors in proton therapy that need to be taken into account when planning the treatment of prostate cancer. Most of these are related to the mobility of the prostate, as the motion sensitivity of the proton beam requires particular care in order for an adequate dose to be delivered to the target. In order to make accurate dose calculations, information on the relative proton stopping power ratio (RSP) is needed. Conventionally, RSP is estimated through a CT scan (Depauw et al. 2020).

Perhaps the main issue that requires attention is bladder and rectal filling, which causes both inter- and intra-fractionary movement of the prostate. It may not be enough even if the patient begins every treatment with an empty bladder and rectum, as the amount of rectal gas can vary daily and has the tendency to decrease towards the end of the treatment. Using an endorectal balloon to stabilize the volume of the rectum appears to be a viable method to reduce the intrafraction motion of the prostate in 90% of all fractions (Mangan & Leech 2019).

As for interfraction motion, it can be taken into account by using fiducial-based positioning (Mangan & Leech 2019). Of course, controlling the location of the fiducials may require daily imaging, which will increase the patient's radiation dose, if conventional CT scans are used for this purpose. However, studies indicate that MRI is also clinically applicable, and would of course result in a decreased overall dose for the patient (Depauw et al. 2020). It should be noted here that interfraction movement of the prostate is more likely with obese patients and that their immobilization can also be more difficult (Mangan & Leech 2019).

Finally, a group of researchers sought to account for organ motion and range uncertainties associated with proton therapy of locally advanced prostate cancer by creating a plan library with different positions of the prostate based on a population model. With the library, they were able to reduce the dose to the rectum and bladder while maintaining an adequate dose for the target (Pilskog et al. 2020).

In conclusion, it appears that while being an effective, modern treatment method of prostate cancer, proton therapy requires some extra consideration in order to account for its high sensitivity to motion combined with the inherent motility of the prostate and adjacent organs such as the bladder and the rectum. However, when appropriate measures are taken, effective and dosimetrically reasonable treatment can be administered, and thus proton therapy is considered as a promising, constantly developing form of external beam radiation therapy.

The list of references is available from the editorial office:
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