How strongly does tissue decelerate the therapeutic heavy ion beam?

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Physikalisch-Technische Bundesanstalt has developed a method for the more exact dosing of heavy ion irradiation in the case of cancer.

Irradiation with heavy ions is suitable in particular for patients suffering from cancer with tumours which are difficult to access, for example in the brain. These particles hardly damage the penetrated tissue, but can be used in such a way that they deliver their maximum energy only directly at the target: the tumour. Research in this relatively new therapy method is focussed again and again on the exact dosing: how must the radiation parameters be set in order to destroy the cancerous cells "on the spot" with as low a damage as possible to the surrounding tissue? The answer depends decisively on the extent to which the ions can be decelerated by body tissue on their way to the tumour. Scientists of the Physikalisch-Technische Bundesanstalt (PTB) have established an experiment for the more exact determination of the stopping power of tissue for carbon ions in the therapeutically relevant area which is so far unique worldwide. Although the measurement data so far available must still become more exact, the following can already be said: The method works and can, in future, contribute to clearly improving the dosing for cancer therapy with carbon ions. The first results have recently been published in the magazine "Physics in Medicine and Biology".

Human tissue mainly consists of water. It can, therefore, be simulated well in liquid water in which form accelerated ions can be stopped on their way and at which target they deliver their maximum energy quantity – at least theoretically, because up to now experimental data has

existed only for water vapour. Scientists, however, assume: If the aggregate state is neglected, the data determined for the determination of the radiation dose become too imprecise.

Within the scope of the doctoral thesis of J. M. Rahm, PTB scientists have now succeeded for the first time in determining the stopping power of liquid water for carbon ions with kinetic energies in the range of the maximum energy dissipation by experiment. The first results actually indicate that carbon ions are less strongly stopped in liquid water, related per molecule, than in water vapour. As soon as more exact data are available, the findings will be included in the calibration of ionization chambers which are used to determine the dose in therapy planning. At present, the Heidelberg Ion-Beam Therapy Center (HIT) is the only institution in Europe which irradiates patients with heavy ions.

The procedure applied by the researchers is based on a method which originates from nuclear physics: the Inverted Doppler Shift Attenuation Method. While the carbon ions excited by a nuclear reaction move through the water volume, they are stopped and fall back into their ground state. The energy distribution of the gamma quanta emitted thereby is recorded with the aid of an ultra-pure germanium detector. The Doppler effect, which leads to the displacement of the gamma energy, and the exponential-decay law allow the development of the velocity of the carbon ions with time to be pursued and, thus, conclusions on the stopping process to be drawn.

More information: J. M. Rahm, W. Y. Baek, H. Rabus and H. Hofsäss: "Stopping power of liquid water for carbon ions in the energy range between 1 MeV and 6 MeV." *Phys. Med. Biol.* 59 3683 (2014)

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