ORIGINALARBEIT

Dosimetry intercomparison of four proton therapy institutions in Germany employing spot scanning

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Abstract

Aim: *To verify the consistency of dose and range measurement in an interinstitution comparison among proton therapy institutions in Germany which use the pencil-beam scanning technique.*

Methods: *Following a peer-to-peer approach absorbed dose and range have been intercompared in several missions at two hosting centers with two or three visiting physics teams of participating institutions using their own dosimetry equipment. A meta-analysis has been performed integrating the results of the individual missions. Dose has been determined with ionization chambers according to the dosimetry protocol IAEA TRS-398. For determination of the depth of the distal 80% dose the teams used either a scanning water phantom, a variable water column or a multi-layer ionization chamber.*

Dosimetrischer Vergleich zwischen vier Protonentherapiezentren in Deutschland im Nadelstrahl-Bestrahlungsmodus

Zusammenfassung

Ziel: *Die Konsistenz der Messung von Energiedosis und Protonenreichweite soll in einem Ringvergleich zwischen Protonentherapieinstituten in Deutschland, welche die Bestrahlungstechnik des magnetisch ausgelenkten Nadelstrahls anwenden, experimentell geprüft werden.*

Methoden: *Die Energiedosis und Reichweite wurden in mehreren Messkampagnen auf kollegialer Ebene verglichen. Im Rahmen von Treffen an zwei verschiedenen gastgebenden Protonentherapiezentren führten zwei oder drei Physikdelegationen mit ihrer jeweiligen*

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Results: *The systematic deviation between measured doses of the participating institutions is less than 1%. Ranges differ systematically less than 0.4 mm.*

Conclusions: *The match of measured dose and range is better than expected from the respective uncertainties. As all physics teams agree on the assessment of absorbed dose and range, an important prerequisite for a start of joint clinical studies is fulfilled.*

Keywords: Proton therapy, pencil-beam scanning, dosimetry, ionization chamber, range

Dosimetrieausrüstung Messungen der gleichen Felder durch. Die Ergebnisse der einzelnen Treffen wurden in einer Metaanalyse zusammengefasst. Die Dosismessungen erfolgten gemäß dem Standard IAEA TRS-398. Zur Bestimmung der Tiefe, an der die Dosis auf 80% des Maximums abfällt, wurden Ionisationskammern verwendet. Diese wurden im Wasserphantom oder innerhalb einer variablen Wassersäule bewegt, oder befanden sich innerhalb eines mehrschichtigen Detektors mit Vielkanalauslese.

Ergebnisse: *Die systematische Abweichung der gemessenen Dosiswerte zwischen den Physikdelegationen ist kleiner als 1%. Reichweiten differieren um maximal 0,4 mm.*

Schlussfolgerung: *Die Übereinstimmung von gemessener Dosis und Reichweite ist besser als die Unsicherheiten der einzelnen Dosimetriegeräte erwarten lassen. Durch die gezeigte Konsistenz von Dosis und Reichweite ist eine wesentliche Voraussetzung für den Start gemeinsamer klinischer Studien erfüllt.*

Schlüsselwörter: Protonentherapie, Nadelstrahlverfahren, Referenzdosimetrie, Ionisationskammer, Reichweite

1 Introduction

An increasing number of patients receives radiation therapy with protons and carbon ions due to potential clinical benefits in terms of normal tissue sparing. In Germany, this has been accomplished by the start of operation of new particle therapy centers. German particle therapy centers built in the last few years include the option of beam delivery in the pencil-beam scanning (PBS) mode. In PBS irradiations the longitudinal dose distribution is controlled by the beam energy which is set at accelerator level. In lateral directions a narrow particle beam is magnetically steered across the clinical target.

Having launched the particle therapy facilities evidence for the benefit of particle treatment has to be provided. Some clinical studies have already started and more are in preparation. For particle therapy, joint clinical studies are particularly important, because for some tumor sites only the collaboration of centers can reach the necessary cohort size [1]. In particular, the German cancer consortium DKTK provides the framework for such kind of medical research.

A prerequisite for clinical studies in radiation therapy is that absorbed dose determined by the individual institutions is directly comparable [1–3]. For this purpose, codes of practice (CoP), which recommend ionization chambers (ICs) for reference dosimetry, have been established [1,4]. However, implementation of the CoPs in PBS mode is not trivial, because the high instantaneous local dose rates might cause artifacts in ICs through recombination effects [2]. Similarly, the dosimetry equipment for depth–dose curves requires careful characterization, because the control of the depth of dose depositions is directly linked to the benefit of particle therapy. Range is the most important parameter of the depth–dose curve.

In order to enable joint clinical studies and to gain confidence in the dosimetry equipment and procedures, in this work, mutual intercomparisons of measured dose and range have been carried out between physics teams of all clinically operating German particle therapy centers treating deep seated tumors before May 2015: Rinecker Proton Therapy Center (RPTC)/München, Westdeutsches Protonentherapiezentrum (WPE)/Essen, Heidelberger Ionenstrahl-Therapiezentrum (HIT)/Heidelberg, and Universitäts Protonen Therapie Dresden (UPTD). In total three missions have been conducted in the frame of clinical commissioning of the first PBS based treatment room in Essen and Dresden, respectively. Every mission encompassed bilateral or trilateral (teams of three institutions participating) intercomparisons of the key quantities absorbed dose and range.

A number of proton dosimetry intercomparisons have been reported in the past. These were either performed at a single site with more than ten physics teams participating [5,6] or by a single auditor team traveling to the participating proton therapy centers [3]. For the current study a physics delegation