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White Paper

Low-dose radiotherapy of inflammatory joint diseases with Halcyon.

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Introduction

Analgesic radiotherapy of inflammatory joint diseases is of high importance in the ambulatory care of benign diseases using linear accelerators. The deep integration of therapy devices into oncology information systems achieves high quality standards in terms of dose logging, therapy and follow-up documentation.
The Halcyon system (Varian, Palo Alto, USA) is a compact ring-gantry mounted linear accelerator system with a CT-like aperture of 100 cm diameter. A classical light field with laser isocenter for direct adjustment of standing fields is not available. The collimation of the flattening filter free (FFF) 6MV treatment beam as IMRT or VMAT treatment is performed by a dual-layer MLC (28 x 28 cm^2) with a virtual leaf width of 5 mm. Mandatory upstream of each fraction is imaging in terms of IGRT, either as kV-CBCT or orthogonal 2D-MV images.

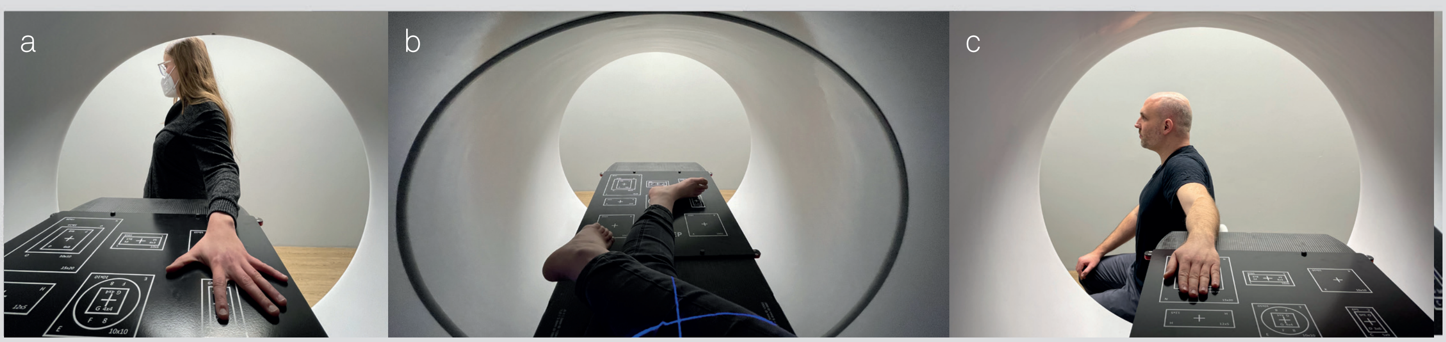
Thus, the challenge is to implement technically simple radiotherapy of benign diseases for a state-of-the-art IGRT linear accelerator system without light field adjustment within a bore with inhomogeneous 6MV-FFF treatment fields.
We report on the implementation of the BEAM technology (**Be**nign **A**pplication **M**odule), at Halcyon linear accelerator for the treatment of inflammatory joint diseases and first clinical results.

Method

The BEAM concept for Halcyon linear accelerators utilizes the BeamSTEP and BeamPLAN components. To avoid the typical light field guided adjustment of the treatment localization, a special carbon table support (BeamSTEP) with imprints of clinically used standing fields at a focal surface distance of 100cm is used. This can be placed on the IGRT couch top of the Halcyon in a few simple steps using the index system.
For distal localizations such as finger, hand or elbow, the patient is behind the Halcyon system and, standing or sitting, brings the region to be irradiated to the planned image in the bore (Fig. 1. a,b,d). Foot and knee localizations are set lying on the treatment couch, feet-first in an analogous manner (Fig. 1. c).

Fig. 1:

Typical treatment situations with the BeamSTEP (carbon support) for analgesic treatments of:
Index finger (a), heel spur (b), entire hand (c).



Since Halcyon always requires an image-based workflow (MV/MV) with reference CT and 3D-RT plan, individual DICOM 3D-RT plans (corresponding to the BeamSTEP tabletop, Fig. 2. center) are calculated for RT planning based on synthetic CTs of different thicknesses to the patient (Fig. 2. right). This is done using the BeamPLAN application which is integrated into ARIA ECLIPSE to generate opposing and single field plans (Fig. 2 left). BeamPLAN takes all necessary parameters from the physician's prescription and combines them with predefined treatment fields to create a 3D CRT plan. For this purpose, the user selects the position and required field size by mouse click on the BeamSTEP table top shown. BeamPLAN then creates 3D CRT treatment plans with correct table positions and homogeneous 6MV treatment fields (ventral or dorsoventral).

Fig. 2:

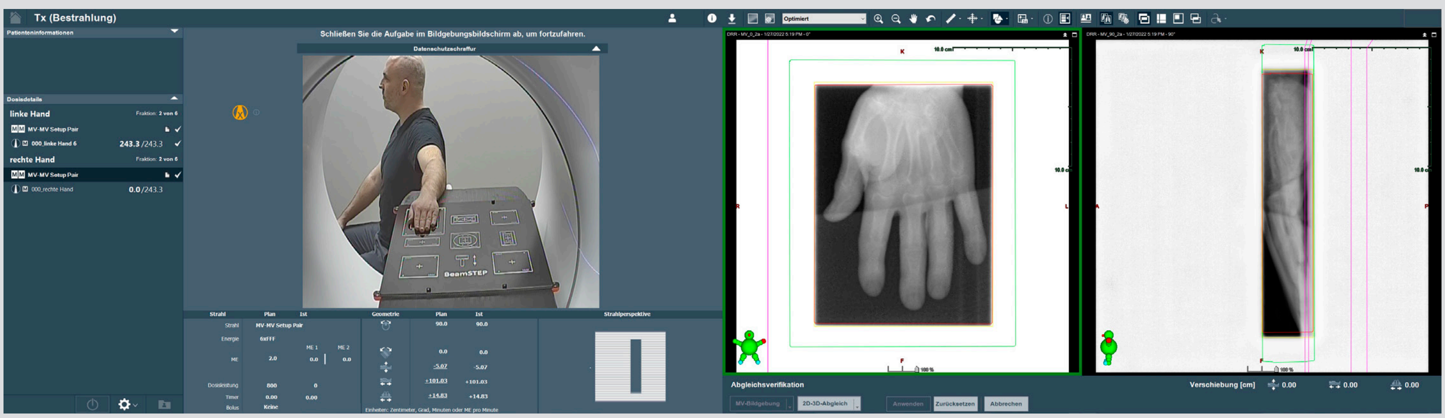
BeamPLAN application in ARIA (left) for RT planning of different field sizes based on synthetic CTs (right). The physician's prescription can be used to generate the treatment plan. 6MV-FFF fields are „smoothed" in BeamPLAN by an IMRT sequence. The field shapes shown correspond directly to the carbon BeamSTEP table support (center) used at Halcyon and can be activated via mouse click.

For treatment, Halcyon's Move-to-Position maneuver automatically moves the treatment table so that the patient's treatment region is easily brought into alignment with the imprinted virtual light field by the RTTs. Mandatory Halcyon MV imaging prior to RT ensures correct positioning by the RTT.

The efficiency of this treatment method was investigated using osteoarthritis-related degeneration of the left hand as an example. Circulation times of Halcyon treatments on the device of the RNS Wiesbaden as well as TrueBeam and Clinac DHX of the Radiologische Allianz Hamburg were compared. The turnaround time per fraction includes transfer from the locker room to the linear accelerator, positioning, MV imaging, treatment, and transfer from the linear accelerator back to the locker room.

Fig. 3:

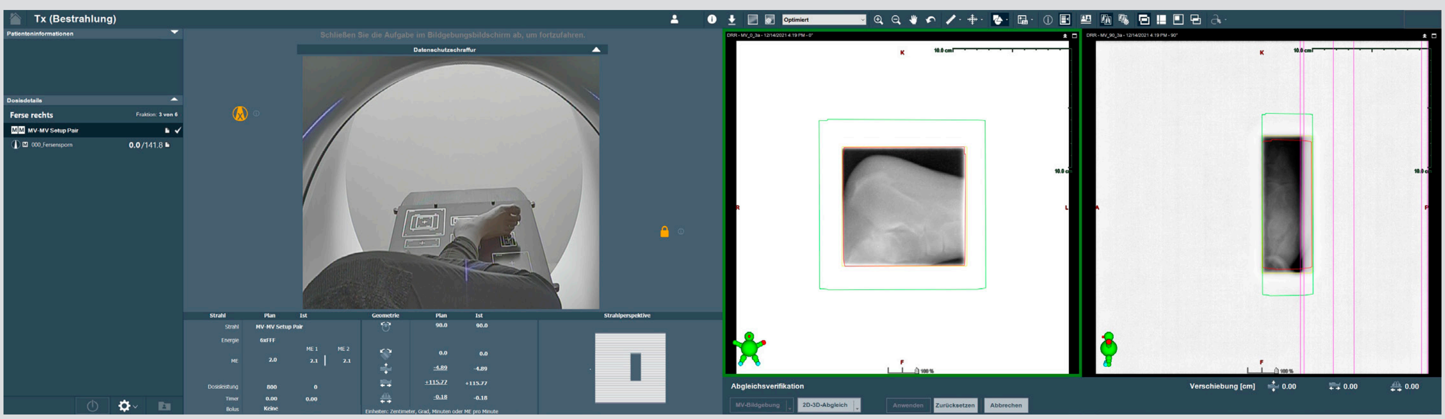
Typical treatment situation in the area of the left hand. The patient stands or sits behind the gantry and places his hand in the predefined virtual light field of the BeamSTEP table support.



Included were the last 30 treatments of different patients at the time of data retrieval per linear accelerator. Rectangular shaped single fields (100 cm² – 150 cm²) were prescribed with single doses of 0.5 Gy or 1 Gy in six fractions with dose depths between 1.5 cm and 3 cm. TrueBeam and Clinac DHX treatments used unmodulated 6MV photons, Halcyon used intensity modulated 6 MV FFF photons.

Fig. 4:

Typical patient positioning for heel spur treatments with Halcyon.
For foot and knee localizations, the patient is positioned lying on the treatment couch, feet-first.

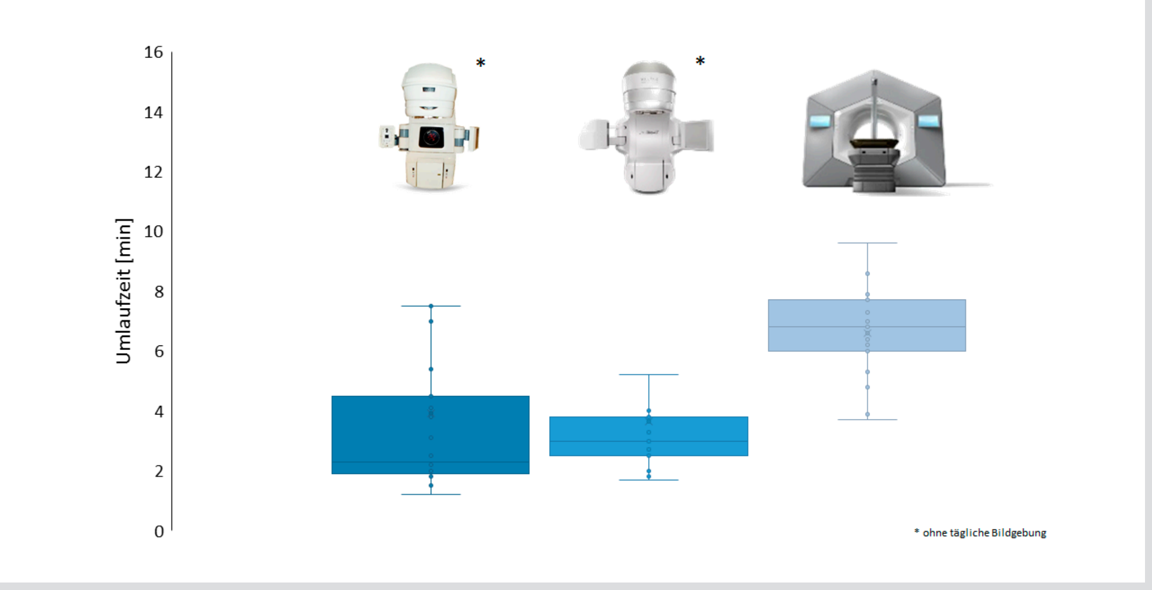


Results

The described workflow for the treatment of benign joint diseases could be successfully implemented for typical peripherally located localizations such as knee joint, foot, elbow, hand and finger at the Halcyon linear accelerators of RNS Wiesbaden. The installation and training of the BEAM technology took about 4 hours. Using the BeamPLAN application integrated in ARIA, individual 3D irradiation plans could be created in less than 2 min by taking over the physician's prescription. The circulation times per fraction and patient were 6.6 ± 1.4 min (mean ± standard deviation) for Halcyon, 3.6 ± 2.2 min for TrueBeam, and 3.9 ± 3.3 min for Clinac DHX (Fig. 5). Image guidance on the TrueBeam and Clinac was performed only once during the initial setup. The dose of 2MU/fraction required for MV image guidance is included in the RT plan.

Fig. 5:

Boxplots of rotation times of the localization „left hand“ of different Varian linear accelerator types (from left to right: Clinac DHX, TrueBeam and Halcyon). The boxplots show the minimum, lower quartile, mean marked as X, median as horizontal line, upper quartile and maximum.



Discussion

BEAM technology extends the range of applications of Halcyon linear accelerators to include treatment methods for analgesic radiotherapy in inflammatory joint diseases. With the BeamPLAN application integrated in ARIA or ECLIPSE, single field or opposing treatment plans are created in an uncomplicated and patient-specific manner, which can be applied efficiently using virtual light fields for positional alignment of the irradiation region on the Halcyon. Radiation therapy for the finger, hand, elbow, foot and knee localizations is possible within typical treatment timeslots. The only slightly increased turnaround time of less than 7 min compared to classical linear accelerators by about 3 min, is negligible considering the extension of the therapy spectrum of Halcyon. The additional time required by the upstream MV imaging directly contributes to an improvement of the treatment documentation.

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