Virtual Simulation and Verification in Total Body Irradiation Using AcQSim and an EPID with Extended Image Detection Unit


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Introduction
Total body irradiations (TBI) for conditioning patients with leukemia prior to bone marrow transplantation (BMT) require precise adjustment and verification of shielding block positions. Kidney shielding for patients, whose kidneys are preexposed by radio immuno therapy, represents a special request to our treatment procedure.

Methods and Material
A Varian Clinac 2300C/D is used for conventional therapy and for TBI. For TBI the patient is treated in a second treatment room at a distance of 510 cm above the focus of a vertical beam. Each fraction is given with ap (patient prone) and pa (patient supine) beams.
TBI treatment planning is performed by means of Multiplanar Reconstruction (MPR) and Virtual Simulation (fig.1). For localization the kidneys are segmented on the CT slices. The Digitally Reconstructed Radiograph (DRR) is used for production of shielding blocks at a computerized block cutting device and serves as reference image for verification of the block positions (fig. 2).

Fig. 1: (a), (b) The patient dimensions for monitor unit calculations and production of compensators are determined at several representative slices. (c), (d) For estimation of lung dose the distribution of the Hounsfield units in a freely definable area is consulted and the mean value is used for determining lung tissue density. From this dose value the thickness of the lung transmission blocks are determined.
Online matching of kidney blocks is performed as part of treatment. Since kidneys cannot be detected in portal images, the verification is done by matching of kidney block positions and segmented kidneys in the DRR. In order to make the DRR available for online matching, it is exported to the DICOM node of the Varian VARiS Vision network. An Electronic Portal Imaging Device with Extended Image Detection (PortalVision XL, Varian) provides a sufficiently large sensitive area for our TBI setup. Thus the region of the lungs together with that of the kidneys are shown in a single image. The matching procedure is based on structure template drawings on the reference DRR. Artificial markers, placed on the patients anterior skin, and the outline of the kidneys are used as structures of interest (fig 3a). The complete structure template is overlayed onto the portal image and the external markers are aligned to their actual position on the portal image. As a result, we get the planned positions of the kidney blocks displayed in the treatment image (fig. 3b) In case of block displacement, an easy mouse guided measurement at the computer screen yields the needed shifts to get the planned positions. The images are scaled to distances at the level of the block tray; so the block positions can be adjusted immediately according to the measurement (fig 3c).

Results
Virtual Simulation facilitates beam setups with extended source-skin-distances, that are far beyond the possibilities of a conventional simulator. Visualization by means of CT segmentation permits localization of soft tissue organs that cannot be detected in conventional simulation. Consequently, this allows more appropriate adjustment of shielding blocks, regarding complete coverage of sensitive structures. The presence of the patient is necessary only during the CT scan. The actual simulation can be done at any later point in time when schedule permits. The DICOM interface makes AcQSim an integrated part of the VARiSVision network. This allows fast and easy provision of reference DRR for electronic online verification and matching, which is an essential part in our course of TBI treatments.
Fig. 3 (a) Reference DRR with structure drawings of segmented kidneys and external markers (yellow). The shielding blocks for lungs are also included, but not used for online matching (green). (b) Electronic Portal Image with lung and kidney shielding blocks along with matched structure overlay. (c) Measurement for block adjustment in case of displacement.