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Original research article

Influence of the type of imaging on the delineation process during the treatment planning

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ABSTRACT

Aim: The aim of this study was to compare the intra- and interobserver contouring variability for structures with density of organ at risk in two types of tomography: kilovoltage computed tomography (KVCT) versus megavoltage computed tomography (MVCT). The intra- and interobserver differences were examined on both types of tomography for structures which simulate human tissue or organs.
Materials and methods: Six structures with density of the liver, bone, trachea, lung, soft tissue and muscle were created and used. For the measurements, the special water phantom with all structures was designed. To evaluate interobserver variability, five observers delineated the structures in both types of computed tomography (CT).
Results: Intraobserver variability was in the range of 1–14% and was the largest for the liver. The observers segmented larger volumes on MVCT compared with KVCT for the trachea (79.56 ccm vs.74.91 ccm), lung (87.61 vs. 82.50), soft tissue (154.24 vs. 145.47) and muscle (164.01 vs. 157.89). For the liver (98.13 vs. 99.38) and bone (51.86 vs. 67.97), the volume on MVCT was smaller than KVCT. The statistically significant differences between observers were observed for structures with density of the liver, bone and soft tissue on KVCT and for the liver, lung and soft tissue on MVCT. For the structures with density of the trachea and muscles, there were no significant differences for both types of tomography.
Conclusions: During the contouring process the interobserver and intraobserver contouring uncertainty was larger on MVCT, especially for structures with HU near 80, compared with KVCT.

1. Background

Precise delineation of target volume and organs at risk is dictated by a high quality of imaging and experience of the observer. Generally, all contours for radiotherapy planning are delineated on kilovoltage computed tomography (KVCT) scans without contrast. Improvements in KVCT technology allow accurate contouring, planning of radiation therapy (RT) and individualization of therapy for each patient. Although

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in some cases only simple two-dimensional (2D) images are required, the three-dimensional (3D) kilovoltage scan allows to visualize structural details of tissues without any invasion and has become the gold standard in radiation therapy. For patients with dental fillings or metal prosthesis, megavoltage computed tomography (MVCT) is used.[1] However, the alternative to MVCT can be dual energy CT (DECT) which allows to reduce metal artifacts and may significantly enhance the diagnostic value in the evaluation of metallic implants and the region around the implants. In DECT, the simultaneous adaptation of two different energies allows the differentiation of materials according to density. Familiarity with the capabilities of DECT may improve diagnostic performance.[2] New technologies are surely an immense technological leap forward, although not without certain risks.[3,4] The second type of imaging used in this study is MVCT acquired by the TomoTherapy machine. Helical TomoTherapy (HT) is dedicated for the intensity modulated radiation therapy (IMRT) followed by the image guidance (IG) procedures. From the technical point of view, HT is a combination of a computed tomography scanner and a linear accelerator which allows to work in two independent modes – treatment and imaging.[5] The 6 MV X-ray beam is used in the treatment mode, while imaging mode uses the energy of the X-ray beam decreased to 3.5 MV.[6,7] At the Greater Poland Cancer Centre, for accurate positioning of patients, the registration procedures of megavoltage (MV) CT scans on HT are performed every day and adjusted to the pre-treatment kilovoltage (KV) CT scans from the diagnostic CT.

One of them is manual delineation which is time-consuming and varies between the operators.[8] It is reasonable to expect the contouring variability in MVCT scans to be larger than in conventional KVCT scans because of increased noise and reduction of soft-tissue contrast associated with megavoltage beams used for image reconstruction.[9]

In this study, the uncertainty of delineation process was evaluated and compared between kilovoltage and megavoltage scans. Authors compared the inter- and intraobserver variability in contouring on KVCT used for radiotherapy planning with MVCT acquired with helical TomoTherapy.

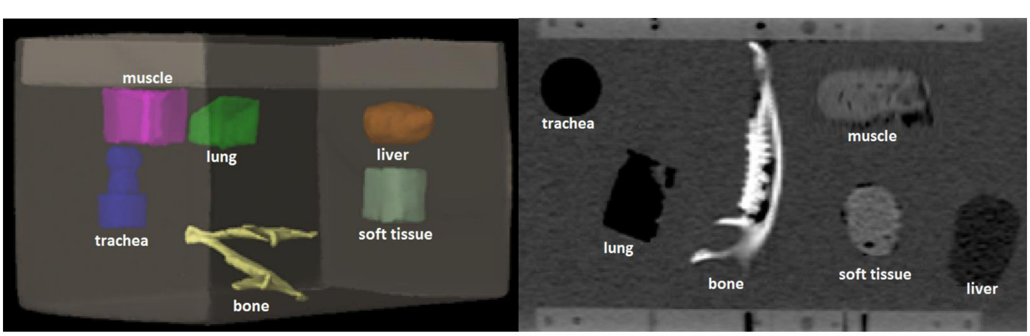
A major uncertainty, which could potentially limit the benefit of radiotherapy accuracy in radiation delivery to the prescribed volume and thereby the treatment outcome, however, is the interobserver and intraobserver variability in contouring the target and organs at risk. The reduction of soft-tissue contrast while using energy in megavoltage imaging could obviously affect the observer's ability to recognize the precise borders of the analyzed structure. That is why the variability of contours in MVCT is expected to be greater than in KVCT.[8] Additionally, the increased interest in the use of MVCT data for treatment planning requires knowledge of the electron density of the tissues and checking how the structures of different densities are delineated by different observers.[10]

2. Materials and methods

In the first step, a special water phantom was designed and created. Inside a water phantom of 60 cm × 30 cm × 35 cm six structures were immersed. Each of these structures had different volume, shape and electron density. All structures were placed inside the phantom according to the protocol specially developed for this study. For this protocol, the authors designed three configurations of structure location. In each configuration, the same structures were located in different places of the phantom. This represented an additional task for the observers who every time identified the structure on their own. These structures were set on the special fence, some of the fences remained empty (without any structure) just to distract the observer or check out his attention.

Fig. 1 presents the location of structures in the phantom and scans from KVCT.

The structures correspond to the Hounsfield Units (HU) of the liver, bone, trachea, lung, soft tissue and muscle. The phantom was scanned using the Somatom Sensation Open 20 CT scanner (Siemens AG, Erlangen, Germany) in the following conditions: 120 kV and 60 mAs with 2 mm slice thickness. Then, the images were exported to the treatment planning system. In order to determine the HU of the homemade structures in the treatment planning system, a calibration curve was used. Calibration curve defines the relationship between the electron density and Hounsfield Units. KVCT calibration curve was determined using Cheese Phantom (Quality Assurance Kit for the TomoTherapy® System, Accuray). The phantom with different density plugs was scanned using 120 kV, with mAs adjusted automatically. Next, in the computer system, the regions of interest were chosen and Hounsfield Units for each plug were automatically calculated. Based on the readings, the KVCT calibration curve was marked.



A B

Fig. 1 – Homemade phantom with immersed structures. (A) The first configuration of the structures. (B) The view of the phantom from computer tomography with different density of the structures.