Development of An Inguinal Lymph Node Clinical Target Volume with Ferumoxtran-10 Enhanced Magnetic Resonance Imaging for Precision Radiotherapy Treatment

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Background

Primary and adjuvant inguinal nodal radiotherapy is utilized in the treatment of genitourinary, gynaecologic and gastrointestinal malignancies. Intensity modulated radiotherapy may permit the delivery of escalated dose to the nodal basins at risk while maintaining or reducing the risk of lymphedema and fibrosis of the organs at risk within the treatment field. Adequate delineation of the nodal Clinical Target Volume at risk is predicated upon a sound knowledge of the lymphatic anatomy of the groin and pelvis. Unfortunately, the topography of the inguinal lymph nodes has not been well defined and inguinal nodal radiotherapy volumes are typically defined in reference to the femoral vascular anatomy or bony landmarks as surrogates.

Purpose

To develop anisotropc margins of expansion using magnetic resonance lymphography with ferumoxtran-10 for the purposes of nodal Clinical Target Volume delineation. Nodal frequency and topography will be analysed on ferumoxtran-10 magnetic resonance images of the lower pelvis and inguinal region to define the radiotherapy treatment volumes.

Methods:

A single center trial was undertaken in patients with histologically confirmed cancer. All patients underwent pre- and post- contrast MRI studies over two consecutive days. Ferumoxtran-10 (Combidex®: Advanced Magnetics, Inc, Cambridge, MA) was administered on the first day. Axial images were obtained at 3 mm intervals through the pelvis. The pulse sequences performed consisted of T2w FSE (TR/TE 4500/80; flip angle 90°; field of view 24-28 cm; matrix 256 x 256; number of excitations 3), T2*w GRE (TR/TE 2100/24; flip angle 70°; field of view 26-28 cm; matrix 160 x 256; number of excitations 2). The pelvic vasculature and lymph nodes were delineated beginning at the femoral artery at the level of the inguinal ligament using 3D modeling and image processing software (3D-DOCTOR®: Able Software Corp., Lexington, MA). Lymph node frequency, size and location relative to the adjacent vascular segments were analyzed in addition to the distance from the skin surface to the most posterior aspect of each lymph node. The x-y-z coordinate boundary descriptors for the pelvic vasculature and lymphatics were compiled in one data file for each study subject and analyzed. Each lymph node volume was divided into a nodal volume element representing its position within the 3-dimensional space within the lymph node and in relationship to the adjacent vascular structures. Each volume element measured 0.5 (x-axis) x 0.5 (y-axis) x 3 (z-axis) mm in dimension. Pair distances were determined from the centre of each nodal volume element to the closest vascular edge (arterial or venous) for each vascular segment. To account for variable vascular topography, pair distances were generated for each individual element across all axial planes. A distance histogram describing the centre of each nodal volume element to the nearest vessel edge for varying bin sizes was generated.

Results:

20 patients have been analyzed with a median age of 64 (range 39-82). A median of 8 lymph nodes was identified on both the right and left side (Range: 3-14) with a median depth of 26.4 (9.4-49.5) on the right and 27.3 (8.1-52.9) on the left. The median short axis diameter of the lymph nodes was 6 mm (range 2-12). Table 1. depicts the distance of the nodal volume elements from the closest vessel edge and Figure 1. depicts the scatterplot distribution of these elements around the femoral vessels. The anisotropic vascular margin of expansion required to encompass all of the nodal tissues for all 20 patients was 37.2mm Anteriorly, 45.3mm Laterally, 5.3mm Posteriorly and 16.4mm Medially.

Conclusions:

The use of ferumoxtran-10 facilitates nodal delineation within the pelvis and groin. The lymph nodes are observed to be distributed radially around the anterior aspect of the femoral vessels. The femoral vessels may provide a suitable surrogate for the determination of depth of the associated lymph nodes and would be capable of defining the volume within which the nodal tissue of interest lies for the purpose of generating a precision radiotherapy target volume.

Percentile	50^{th}	80^{th}	90^{th}	95^{th}	99^{th}	100th
Median (mm)	13.5	17.6	20.1	21.9	24.2	25.8
Range (mm)	4.8-21.5	6.0-36.8	6.5-39.5	6.9-41.3	7.3-44.0	7.4-45.3

Table 1: Percentile distances of the node elements (0.5x0.5x3mm^3) from the closest vessel edge in mm.

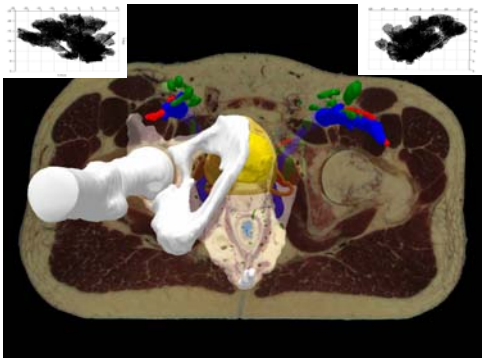

Figure 1: Scatter plot of lymph node elements for the right and left inguinal region overlain upon an axial rendering demonstrating the medial to lateral radial distribution of each nodal volume element (0.5 x 0.5 x 3 mm^3) to the closest vessel edge.