Diameter-independent Computer-Aided Classification of Mesorectal Lymph Nodes in Rectal cancer: Preliminary Results

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INTRODUCTION: Rectal cancer is the third leading cause of death in the United States [1]. Metastatic mesorectal lymph nodes are essential predictors of disease prognosis in rectal cancer. However, clinical MRI assessment has limited sensitivity to predict the malignant potential of lymph nodes, with sensitivity as low as 45% when the >5 mm diameter criterion is applied [2]. Given that others [2] have identified qualitative characteristics such as border irregularity and MR signal heterogeneity as potential sensitive predictors of malignancy, we hypothesized that there are quantitative and diameter-independent features that can delineate malignant from benign lymph nodes. To this end, we extracted several quantitative morphological and textural features [3-6] from conventional contrast enhanced T1-weighted MR images of mesorectal lymph nodes in patients with rectal cancer.

MATERIALS AND METHODS: A total of seven patients with rectal masses and mesorectal lymph nodes present were included in this retrospective analysis (median age 61 years, range 47-87 years; n=7 males). All studies were performed at 3.0-T (Siemens MAGNETOM Trio, Tim system) and included a contrast-enhanced volumetric interpolated breath-hold T1-weighted fast GRE sequence ('VIBE': flip angle/TR/TE/slice thickness/in-plane resolution = 12°/3.49 ms/1.28 ms/2 mm/1.09 mm; 6-10 ml Gadovist, Bayer Health Care, Canada). The size of each mesorectal lymph node was assessed and manually segmented offline by an experienced radiologist using ImageJ (NIH, http://rsbweb.nih.gov/ij/). Lymph nodes were subsequently grouped according to size, with nodes ≤ 3 mm designated 'low malignant potential' and ≥ 6 mm 'high malignant potential.' Nodes of intermediate size were deliberately excluded to minimize bias. Node contours and segmented contrast-enhanced T1 node regions of interest were utilized to derive a total of 73 morphologic features and 70 textural features (MaZda software version 4.6, P.M. Szczypiński, Institute of Electronics, Technical University of Lodz, Poland)[7]. We excluded any morphologic features that appeared to depend directly on lymph node diameter from further analysis. Remaining shape-related descriptors were related to the smoothness or spiculation of node borders, circularity or eccentricity, and topology of the lymph nodes [8]. The latter were determined by finding the medial axes and branch-points of the nodes, as well as the number of 'cavities' identified by the software. The textural features computed included second-order grey-level and run-length statistical features, as well as descriptors related to multi-scale signal intensity patterns (wavelet transform features) [7]. For each candidate feature, Mann-Whitney U tests were used to compare low-malignant from high-malignant potential lymph nodes. The most discriminative features ($P<0.05$) were then used to train an artificial neural network (ANN) classifier. Cases were divided into equally sized train- and test-sets and the process repeated by systematically repartitioning and repeating the train/test procedure (10-fold cross validation [4]). The performance of the ANN classifier was averaged to arrive at sensitivity, specificity and accuracy values.
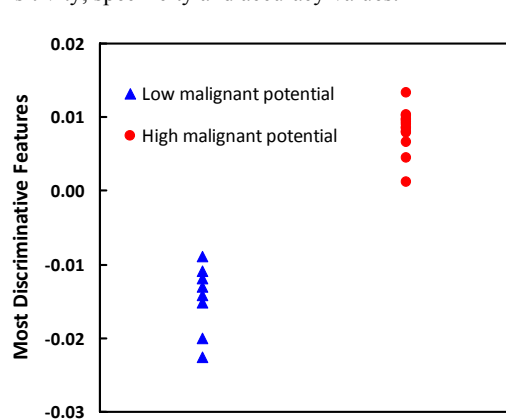
(a) **(b)**

FIGURE 1: Scatter plot depicting the most discriminative diameter-independent features for lymph nodes of low and high malignant potential, P =0.0001.
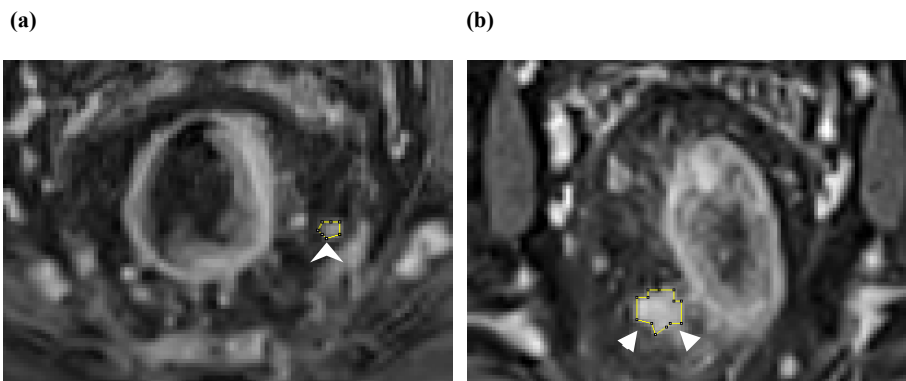
FIGURE 2: Contrast-enhanced T1W images obtained from two patients with rectal cancer. Mesorectal nodes with low (a, 3mm diameter) and high (b, 12 mm) malignant potential illustrate other differences beyond node size, eg, border irregularity and gray-level heterogeneity (b).

RESULTS: A total of 22 mesorectal lymph nodes were included in the analysis and ranged from 2-12 mm (2-3 mm, n=8; 6-12 mm, n=14). We identified 14 diameter-independent features that delineated lymph nodes with high malignant potential (8 morphological and 6 textural, each with $P<0.05$, Mann Whitney U; Figure 1). Representative contrast-enhanced T1-weighted images acquired from two patients with rectal cancer are provided in Figure 2 and illustrate differences between low (a) and high (b) risk lymph nodes beyond diameter, including greater contour irregularity and lower gray-level homogeneity in (b). The most discriminative morphological and textural features were combined (Figure 1) and used to train and test an ANN classifier. The average sensitivity, specificity and accuracy of the 10-fold cross-validation were 89%, 78%, and 85%.

DISCUSSION: In this preliminary study, several diameter-independent morphological and textural features were identified that enabled identification of lymph nodes with high malignant potential. With sufficient cases, this computer-aided classification approach promises to provide improved sensitivity compared to conventional radiologic methods.

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