European Journal of Radiology 84 (2015) 228–234

Contents lists available at ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Evaluation of dual energy spectral CT in differentiating metastatic from non-metastatic lymph nodes in rectal cancer: Initial experience

Huanhuan Liu [a,d], Fuhua Yan [a], Zilai Pan [a], Xiaozhu Lin [a], Xianfu Luo [a], Cen Shi [a], Xiaoyan Chen [b], Baisong Wang [c], Huan Zhang [a,*]

[a] Department of Radiology, Ruijin Hospital Affiliated to Shanghai Jiaotong University, School of Medicine, Shanghai 200025, China
[b] Department of Pathology, Ruijin Hospital Affiliated to Shanghai Jiaotong University, School of Medicine, Shanghai 200025, China
[c] Department of Biomedical Statistics, Shanghai Jiaotong University, School of Medicine, Shanghai 200025, China
[d] Department of Radiology, Xinhua Hospital affiliated to Shanghai Jiaotong University School of Medicine

ARTICLE INFO

Article history:
Received 30 July 2014
Received in revised form
13 November 2014
Accepted 17 November 2014

Keywords:
Rectal cancer
Lymph node
Computed tomography
Dual energy spectral imaging
Monochromatic image

ABSTRACT

Objectives: To investigate the value of dual energy spectral CT (DEsCT) imaging in differentiating metastatic from non-metastatic lymph nodes in rectal cancer.
Methods: Fifty-five patients with rectal cancer underwent the arterial phase (AP) and portal venous phase (PP) contrast-enhanced DEsCT imaging. The virtual monochromatic images and iodine-based material decomposition images derived from DEsCT imaging were interpreted for lymph nodes (LNs) measurement. The short axis diameter and the normalized iodine concentration (nIC) of metastatic and non-metastatic LNs were measured. The two-sample *t* test was used to compare the short axis diameters and nIC values of metastatic and non-metastatic LNs. ROC analysis was performed to assess the diagnostic performance.
Results: One hundred and fifty two LNs including 92 non-metastatic LNs and 60 metastatic LNs were matched using the radiological-pathological correlation. The mean short axis diameter of metastatic LNs was significantly larger than that of the non-metastatic LNs (7.28 ± 2.28 mm vs. 4.90 ± 1.64 mm, $P < 0.001$). The mean nIC value for metastatic LNs was significantly lower than that of non-metastatic LNs (0.24 ± 0.08 vs. 0.34 ± 0.21, $P = 0.001$ in AP; 0.47 ± 0.18 vs. 0.64 ± 0.17, $P < 0.001$ in PP). Combining nIC (PP) with the short axis diameter, the overall accuracy could be improved to 82.9%.
Conclusions: With the combination of nIC value in PP and conventional size criterion, dual energy spectral imaging may be used to differentiate metastatic from non-metastatic lymph nodes in rectal cancer.

1. Introduction

Colorectal cancer is the third most prevalent cancer and the third leading cause of cancer-related death in the United States and its incidence is increasing [1]. Management is particularly challenging technically for surgeon and local recurrence within the pelvis is a common result of treatment failure [2]. As reported in previous publications, the local recurrence following rectal cancer surgery varies from 3% to 45% [3]. Since the introduction of total mesorectal excision (TME) which is considered as the standard approach for primary rectal cancer nowadays, the high local recurrence rate is reduced to less than 10% [4]. However, the local recurrence risk increases when the circumferential resection margin (CRM) is involved from the tumor and the lymph nodes (LNs) metastasis is present which predicts a poor prognosis. Therefore, neoadjuvant treatment is needed for those patients. There is evidence that preoperative radiotherapy may further reduce the rate of local tumor recurrence. The benefits of neoadjuvant treatment seem most marked in patients with T3, T4 or LN positive disease [2]. Hence, accurate preoperative staging is essential for the selection of patients for further therapies.

Nowadays, noninvasive radiological modalities such as endoluminal ultrasonography (US), computed tomography (CT), and magnetic resonance (MR) imaging have been widely used in the assessment of the depth of cancer invasion and LNs involvement. Many studies demonstrate that MRI is a promising diagnosis method for assessing the depth of tumor invasion superior to CT scan and almost equal to the endorectal ultrasound [5]. The LNs assessment, however, remains a burdensome task for the radiologists [1,5–7]. With LN size as a criterion, the sensitivity varies from 55% to 71% [5,6]. Due to the high soft tissue contrast on MRI, previous studies have demonstrated improved sensitivity and

* Corresponding author. Tel.: +86 21 64370045 600320; fax: +86 21 54665108.
E-mail address: huanzhangy@126.com (H. Zhang).

http://dx.doi.org/10.1016/j.ejrad.2014.11.016
0720-048X/

specificity with the use of border and/or signal criteria relative to size alone [8,9]. However, such criteria can be more subjective and less reliable among different observers [10]. Recently, the benefit of adding functional imaging techniques such as diffusion-weighted MR imaging to improve the performance of LNs assessment is the focus of many research projects. However, the diagnostic value was controversial [1,7]. Furthermore, access to MR imaging is restricted in many countries [11]. Though many diagnosis standards including size, border and/or signal and apparent diffusion coefficient (ADC) value of LNs were used in different studies, so far, the evaluation of LN involvement mainly relies on node size as a criterion in clinical work. What is more, there is no uniform diagnosis standard for differentiating metastatic LNs from non-metastatic LNs.

The advent of muti-detector row CT has allowed a quick one stop shop examination of the chest and abdomen including distant metastasis for the local and distant staging [12]. With the introduction of dual energy spectral CT (DEsCT), the imaging mode based on the rapid switching between high and low energy data sets to produce both the virtual monochromatic spectral images at energy levels ranging from 40 to 140 keV and the material decomposition images, the functional imaging aspect of CT has also been added in the clinical applications. The spectral CT scanning method has demonstrated its benefits in different clinical applications such as the detection of insulinomas, diagnosis of pulmonary embolism, differentiating hepatocellular carcinoma (HCC) from focal nodular hyperplasia (FNH) and hepatic hemangioma, and gastric cancer staging [13–16]. However, to the best of our knowledge, there are few studies about the value of DEsCT imaging in the N staging of rectal cancer. The aim of our study was to investigate whether the DEsCT imaging could improve the accuracy of N staging of rectal cancer and discriminate metastatic LNs from non-metastatic ones.

2. Materials and methods

2.1. Patients

The study was approved by our institutional ethics committee and all patients provided written informed consent. From March 2012 to March 2013, 88 consecutive patients suspected of primary rectal cancer underwent non-enhanced and dual-phase pelvic enhanced CT scans. Among them, a total of 33 patients were excluded from the study because of the following reasons: transanal resection ($n = 4$), long interval between CT and surgery over three weeks ($n = 5$), dual-phase pelvic enhanced CT scans without DEsCT mode ($n = 15$) and inoperability or refusal of operation ($n = 9$). The other 55 patients (39 men, 16 women; median age, 59 years [ranging from 33 to 82 years]) underwent surgical resection within two weeks (ranging from 2 to 14 days). The body mass index (BMI) of patients ranged from 18.4 to 28.3 and the average BMI of patients was 22.6 ± 2.0. A preoperative therapy (radiotherapy and/or chemotherapy) was not performed in any patient. All patients were histopathologically confirmed as having rectal adenocarcinoma. The case accrual process was performed by a radiologist with 2 years of experience in abdominal imaging.

2.2. Dual energy CT imaging

All patients underwent the enema with 500–1000 ml of water the night before CT examination. If the cleaning effect was not satisfactory, Glycerine Enema 40 ml (H34022079, Shanghai, China) could be used. No rectal distension or antispasmodic medication was performed.

All patients were scanned craniocaudally in supine position. Dual-phase pelvic contrast-enhanced scans were performed on a High Definition CT system (Discovery CT750 HD, GE healthcare, Milwaukee, Wisconsin, USA). First, a non-enhanced scan covering the whole pelvic cavity from the anterior superior iliac spine to the symphysis pubis was acquired following scout imaging with the conventional helical mode at a tube voltage of 120 kVp. 70–120 ml (1.5 ml/kg) of a nonionic iodinated contrast agent (370 Ultravist, Schering, Berlin, Germany) was then administered via the antecubital vein at a flow rate of 3 ml/s using 20-ga needle through an automatic injector. The arterial phase (AP) scan covering the pelvis and the portal venous phase (PP) scan covering the abdomen and pelvis from the dome of the diaphragm to the symphysis pubis were performed at 35 s and 70 s after the administration of contrast agents.

The dual-phase contrast-enhanced scans were performed using the DEsCT mode (GSI mode) with a single tube, fast tube voltage switching between 80 and 140 kVp on adjacent views during a single rotation. Other imaging parameters were as follows: acquisition slice thickness 1.25 mm, tube current 600 mA, rotation speed 0.6 s, and helical pitch 0.984:1. The CT images were reconstructed by using projection-based material decomposition software and a standard recon kernel. Three types of images were reconstructed from the single spectral CT acquisition for analysis: conventional polychromatic images obtained at 140 kVp, iodine-based material decomposition images, and a set of virtual monochromatic images with energy values ranging from 40 to 140 keV.

2.3. Quantitative analysis of LNs

2.3.1. Size and iodine concentration of LNs

All the measurements were performed on an advanced workstation (AW 4.4, GE healthcare, Waukesha, WI, USA) with the Gemstone Spectral Imaging (GSI) viewer. First, to get the best contrast-to-noise ratio (CNR) between the LN and normal rectal wall, an optimal energy level (keV) was obtained from the set of virtual monochromatic images. To perform it, a circular region of interest (ROI) was placed in the LN and the normal rectal wall separately. The GSI viewer software automatically calculated CNR values for LNs over all photon energies and displayed the corresponding CNR-energy curve (Fig. 1) from which the optimal keV level for the highest CNR was selected. Then, the optimal keV images were used to measure the short axis diameter of each regional LN by two radiologists (both with 12 years of experience in staging of gastrointestinal tumors). The average optimal energy level for all LNs was (70 ± 4) keV. Meanwhile, the location and the numbers of LNs in each group were recorded. Within the mesorectal fascia, the distance between the LNs and the tumor was also recorded in order to facilitate comparison between pathology and CT findings.

The iodine concentration (IC, in milligrams per milliliter) of each LN was measured on the iodine-based material decomposition images by the same two radiologists. The ROI for IC measurement was the same as the ROI on the optimal keV images by using the copy and paste function. Circular ROIs were placed in the LNs and external iliac artery on iodine-based material decomposition images of arterial and portal venous phase independently. The circular ROIs were located near the center of each LN to reduce the measurement error. The LNs with the short axis diameters less than 2 mm were excluded from analysis because it is technically challenging to position the circular ROI in these small LNs [1]. The GSI viewer software package automatically calculated the IC values from the iodine-based MD image and CT values at each energy level (40–140 keV) from the virtual monochromatic image for LNs and external iliac arteries. The IC value of each LN was normalized to that in the external iliac artery to obtain the normalized IC value ($nIC = IC_{LN} / IC_{artery}$) to minimize variations in patients.