

● Original Contribution

THREE-DIMENSIONAL TRANSVAGINAL TOMOGRAPHIC ULTRASOUND IMAGING FOR CERVICAL CANCER STAGING

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Abstract—The objective of this study was to investigate the feasibility of using 3-D transvaginal tomographic ultrasound imaging (TUI) to stage patients with cervical carcinoma. Eighty women with cervical cancer who underwent transvaginal TUI examinations were enrolled. In all patients, cancer was confirmed pre-operatively by pathologic examination. Staging on the basis of clinical features, ultrasonography and magnetic resonance imaging was performed according to the International Federation of Gynecology and Obstetrics (FIGO) staging system. Clinical, TUI and magnetic resonance imaging staging was compared with that based on histology. Depth of invasion into the stroma was measured by TUI in 52 cases and compared with pathologic results. An interclass correlation coefficient was used to analyze reproducibility. In total, all 80 patients underwent surgical treatment. The accuracy of pre-operative staging, compared with histologic findings, was 92.50% for TUI, 82.50% for magnetic resonance imaging and 78.75% for clinical examination. The mean depth of lesions as measured with TUI was 12.5 ± 6.2 mm (range: 3.5–40.0 mm), and that measured on histology was 10.5 ± 8.0 mm (range: 3.0–40.0 mm). The interclass correlation coefficient of the two methods was 0.933 (95% confidence interval: 0.887–0.961). Pre-operative TUI is promising as a method for pre-operative staging of cervical carcinomas. TUI can also reliably assess lesion depth. (E-mail: litaosun1971@sina.com) © 2015 Published by Elsevier Inc. on behalf of World Federation for Ultrasound in Medicine & Biology.

Key Words: Tomographic ultrasonic imaging, Ultrasound, Cervical carcinoma, Staging.

INTRODUCTION

Cervical cancer is the third most common malignancy among females, with 85% of new cases occurring in developing countries and ~150,000 new cases per year in China (Koh et al. 2013). Assessment of the infiltration limits and involvement of cervical stroma and adjacent organs is essential for individualized treatment (Pecorelli et al. 2009). The International Federation of Gynecology and Obstetrics (FIGO) recommends a clinical staging system for cervical carcinomas based on findings from physical examination, colposcopy, biopsy of lesions, chest radiography, cystoscopy, sigmoidoscopy

excretory urography and barium enema (Creasman et al. 1998; Koh et al. 2013; Sheu et al. 2001). Compared with surgical/histologic staging, clinical staging for primary cervical cancer has an error rate ranging from 26% to 66% (Sheu et al. 2001). Therefore, a more accurate evaluation method is necessary for successful treatment.

Although the revised staging system did not previously include imaging modalities, FIGO now encourages their use in the staging of cervical cancers (Haie-Meder et al. 2010). FIGO recommended the use of three imaging modalities to improve pre-operative evaluation, including computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound. Compared with CT, which has inherently low contrast with soft tissue, MRI has been viewed as the ideal modality for pre-operative staging of cervical carcinomas (Delgado et al. 1990; Lagasse et al. 1980; Parkin et al. 2001). Several studies have reported that T2-weighted MRI is the best imaging modality to reveal cervical neoplasms (Bipat et al. 2003;

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Boss et al. 2000; Hricak et al. 1993; Nicolet et al. 2000; Sheu et al. 2001). However, MRI is expensive and cumbersome and cannot be performed in those with certain intrauterine devices. Ultrasound is gaining more attention as a non-invasive alternative because it is less time consuming, easy to perform and less expensive than MRI. Moreover, ultrasound has been found to be similar to MRI in diagnostic accuracy. Some prospective studies have suggested that it might be superior to MRI in identifying parametrial involvement (Byun et al. 2013; Fischerova et al. 2008; Ghi et al. 2007; Testa et al. 2009).

Tomographic ultrasound imaging (TUI) is a relatively new technique that combines several advantages of CT, MRI and traditional ultrasound. It allows multiplanar scanning and continuous imaging of the uterus. Volumetric reconstruction can be performed from different angles, including transverse planes, to reveal structures that are not visible using traditional transvaginal ultrasound. TUI has been satisfactory in first-trimester fetal cardiac examinations and scanning of the pelvis (Fischerova 2011; Turan et al. 2009). The improved resolution of transvaginal sonography and TUI might allow cervical cancer staging. The study described here investigated whether 3-D transvaginal TUI can accurately and reliably stage cervical carcinomas. TUI was used to assess the presence and extent of tumors and their depth of invasion into the stroma. All imaging results were compared with pathologic results, which were considered the gold standard.

METHODS

Patients

This protocol was approved by the ethics committee of Harbin Medical University. From December 2011 to June 2013, 87 patients (42 ± 11 y, range: 19–71 y) at the 2nd Affiliated Hospital of Harbin Medical University with invasive cervical cancer confirmed by biopsy were enrolled in this study. Patients with recurrent cervical cancer were excluded. Patients who previously received chemotherapy and/or radiotherapy were also excluded. Ultrasound and pelvic MRI examinations were performed within 1 wk before surgery. All patients signed informed consent forms before enrollment.

Ultrasonography

Real-time transabdominal ultrasound was performed using a Voluson E8 (GE Healthcare, Wauwatosa, WI, USA) with a 4- to 8-MHz transabdominal probe. Patients were asked to lie in the supine position with their bladders moderately full. Visceral organs and peritoneal surfaces, including the omentum majus and lymph nodes surrounding the abdominal aorta and iliac arteries, were examined. Patients were then asked to empty their blad-

ders and lie in the lithotomy position for the transvaginal examination. Transvaginal ultrasound imaging was performed using the Voluson E8 with a 5- to 9-MHz transvaginal transducer protected by a disposable condom. The transvaginal probe was placed in the posterior fornix to reveal the cervix and the tumor. Position, shape, size, depth of invasion into stroma and echogenicity of the cervical lesions were recorded. Color Doppler flow imaging (CDFI) was used to assess blood supply to the lesion. The highest sensitivity setting was used to detect blood flow signals with low velocities (≤ 2 cm/s). Afterward, the clearest sagittal view was selected, and the system was switched to 3-D mode to perform TUI. The parameters were as follows: sweep angle, 120° ; sweep velocity, maximum quality; sensitivity, highest. Volumetric data sets with the following characteristics were considered satisfactory: (i) the image had to reveal both the tumor and its growth pattern (exophytic/endophytic) clearly; (ii) the distance between the tumor and the internal cervix of the mouth should be observable; and (3) both the bladder and the rectum must be included. Tissues surrounding the cervix should also be able to be viewed clearly on the coronal plane.

After acquisition of volumetric data, off-line TUI analysis was performed using Voluson 4DView software (GE Healthcare). First, the sagittal image was rotated so that the scan line was perpendicular to the cervical canal. A reference point was placed in the center of the tumor. Second, a 3-D box was drawn to encompass the cervix plus 2 cm on each side. Then 3-D reconstruction was performed with a slice interval of 2 mm and 15–29 slices, to ensure that all study slices could be displayed on the screen.

Examinations were performed in succession by a single sonographer who had more than 10 y of experience in ultrasound scanning. The sonographer was blinded to colposcopy, physical examination and MRI findings. Before analysis, the sonographer underwent a 1-month training course on analytical procedures from General Electric.

Evaluation of TUI

All images were assessed by a single sonographer based on volumetric measurements. On volumetric sonography, parametrial involvement was suspected if (i) the limits between the cervix itself or the tumor and the surrounding tissue became unclear or discontinuous; (ii) the hyper-echoic pericervical fascia of the cervix became disrupted; or (ii) the hyper-echoic gap between the cervix and the bladder/rectum disappeared (Epstein et al. 2010). Rectal or bladder invasion was suspected when the limit between the cervical tumor and the rectum or bladder was unclear, or the serosa of the bladder or rectum was interrupted. When hypo-echoic masses extended to the

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