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Original Article

The role of dynamic contrast enhanced MR imaging in the assessment of inconclusive ovarian masses

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ABSTRACT

Objectives: To evaluate the diagnostic accuracy of dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) in characterization of inconclusive ovarian tumors, with histologic findings as the reference standard.

Patients & methods: DCE-MRI was done in 30 patients with 32 complex ovarian masses, prior to surgical excision. We analyzed the following kinetic parameters: enhancement amplitude (EA) in the form of MRE %, time to peak in the form of T max and maximal slope (MS) and correlated them with histopathology.

Results: DCE-MRI showed higher overall accuracy (96%) and specificity (100%) than conventional MRI. Malignant masses showed higher MRE% than benign (p = .004) or borderline masses (p = .036). A shorter T max was found in malignant compared to benign (p = .0002) and borderline (p = .049) masses. MS was best at discrimination between benign, borderline and malignant tumors. Finally, Type III curve showed 100% specificity for invasive malignant tumors.

Conclusion: DCE-MRI sequence is a helpful adjunct to conventional MRI for discrimination of inconclusive ovarian masses into benign, borderline and invasive malignant tumors.

1. Introduction

Ovarian tumors are a group of neoplastic lesions showing a wide and varied spectrum of features according to the specific tumor entity. They can be categorized as benign, low-malignant potential/borderline and malignant subtypes [1–3]. The World Health Organization (WHO) provided classification of the ovarian masses based on their histogenetic principles, hence categorizing them with regard to their derivation from coelomic surface epithelial cells (75% of all ovarian neoplasms), germ cells (15–20%), and mesenchyme (the stroma and the sex cord; 5–10%). Metastatic lesions usually arising from breast, colon, endometrium, gastric and cervical cancers, constitute 5% of ovarian neoplasms [4].

Ovarian masses become a diagnostic challenge, when proper categorization into benign or malignant masses can't be reached by imaging [5].

Accurate characterization is greatly valuable for appropriate patient's management, especially young women for whom conservation of fertility is mandatory and can be achieved via conservative surgical approaches [6].

Ultrasonography (US) shows limitations in characterization and staging despite being the first-line imaging modality for suspected adnexal masses, [7]. Magnetic resonance (MR) imaging has shown great accuracy in the detection and discrimination of adnexal masses. In particular, contrast- enhanced MR can depict the lesion's intrinsic architecture with great detail [8].

Dynamic enhanced imaging (DCE-MRI) has added to the diagnostic accuracy of these masses, due to its capacity to characterize tumor microcirculation and angiogenesis in malignant tumors [9,10]. It depends on contrast medium leakage from capillaries into the extravascular extracellular space, therefore enabling quantitative analysis with information on the blood flow as well as vascular permeability [11].

It allows proper characterization of internal architecture, delineation of necrotic areas, solid components, papillary projections, septations, and peritoneal implants [12]. It is likely to play a major role in the evaluation of ovarian malignancy, by acting as a predictive and prognostic tool [13].

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The aim of our study was to evaluate the diagnostic accuracy of DCE-MRI in characterization of inconclusive ovarian masses, with histologic findings as the reference standard.

2. Patients and methods

2.1. Study population

This prospective study was approved by our hospital's ethical committee. Patients were selected from the Obstetrics and Gynecology department in the period from December 2014 to November 2015. They were referred to the radiology department based on preliminary US examination used for cases selection.

Thirty patients (mean age: 40 age ± 11.97 SD; age range: 22–61 years old) with 32 ovarian masses (2 patients had bilateral masses) were included. Patients presented clinically with abdominal distension, abdominal pain, loss of weight, 2ry amenorrhea and infertility.

The examined masses fulfilled the following inclusion criteria:

- Solid and complex ovarian masses with solid/cystic components.
- Cystic ovarian masses with vegetations and/or thick septations.

We excluded purely cystic ovarian masses with no solid components, as verified by ultrasound and pre-contrast MR imaging.

2.2. Methods

2.2.1. Preliminary US imaging

All patients underwent preliminary transabdominal and transvaginal pelvic US with power doppler (LOGIQ 7 PRO, General Electric GE medical system) using 3–4 MHz and 7–8 MHz probes respectively.

2.2.2. MR imaging

Pelvic MRI was done using two 1.5 Tesla machines (Intera and Achieva, Philips medical system) with dedicated phased array pelvic coils (Sense xl torso coil 16 channels).

Patients were instructed to fast for 3 h and void urine 2 h prior to the examination. Pre-contrast sequences included axial T1 and T2 weighted sequences (TR/TE, 500/10 msec. and TR/TE, 3300/100 msec. respectively; slice thickness, 6 mm; gap, 1 mm; field of view (FOV), 32–42 cm; Matrix, 256 × 256). The chosen FOV included the entire mass and the surrounding pelvic structures and not only the solid component of the desired ovarian masses. Sagittal and coronal T2-weighted were obtained (slice thickness, 8–10 mm; gap, 1 mm; FOV, 40–50 cm; matrix, 256 × 256). Axial T1 weighted spectral pre-saturation inversion recovery images were obtained (TR/TE = 532/8 ms, slice thickness = 4 mm with 0.5- to 1.0-mm gap, matrix = 256 × 192 pixels, flip angle = 90° and field of view (FOV) = 340–370 mm).

Contrast-enhanced MRI was then done, including:

- Dynamic Post contrast T1 fat sat THRIVE (High Resolution Isotropic Volume Examination) images obtained immediately after manually injected gadolinium at a dose of 0.1 mmol/kg of body weight (maximum, 20 mL), images obtained every 36–40 sec. according to the selected FOV and the whole dynamic study lasted for an average of 5 min 30 sec.
- Axial and coronal oblique T1-weighted gradient-echo delayed post contrast images.

2.2.3. MR imaging analysis

The following criteria were recorded:

- Uni or bilateral ovarian involvement.
- Morphological appearance and pre-contrast signal intensity of the ovarian mass.
- Enhancement of the solid component.
- Presence of ascites.
- High signal on T1 images was interpreted as fat or blood (dermoid/teratoma and endometrioma). Fat suppressed sequences helped in further discrimination.
- Criteria for malignancy were noted as follows according to Hricak [14]:
  - Wall thickness > 3 mm.
  - Solid vegetations > 1 cm.
  - Thick septa > 3 mm.
  - Areas of necrosis and breaking down.

DCE-MRI semi-quantitative analysis: was done using Philips Advantage windows workstation 4.4 with functional tool Breast Analysis software (IntelliVue XDS software, Philips Healthcare, The Netherlands). We placed regions of interest (ROIs) manually within the greatest enhancing solid areas of the ovarian masses on subtracted enhanced series. ROI size ranged from 15 up to 150 mm^2. If the masses showed large or numerous discrete solid components; we placed multiple ROIs to reduce signal-to-noise (SNR) ratio. In that instance, we only considered the maximum enhancement parameters. We recorded the following dynamic parameters:

- "**Enhancement amplitude**" automatically calculated as Maximum relative enhancement percentage (MRE%).
- **"Time of initial peak of uptake -T max**" including early (two phases post uptake – ≤120 sec.) and delayed (three phases prior to end of examination – ≥200 sec.) peaks of contrast uptake.
- And "**Maximal slope (MS)**" in the form of Slope enhancement ratio (SER) curves (time/relative signal intensity curves) automatically generated at the workstation. MS is calculated at the point of abrupt decline in the Tmax elicited by the SER curves. "*Early washout*" is the decrease in the post-contrast SI by 10% following the initial peak of contrast uptake. There were 3 patterns of plotted SER curves: (I) continuous rise, (II) plateau and (III) early washout. These patterns suggest the behavior of contrast uptake by the examined masses in the form of graphed curves [15].

2.2.4. Reference standard

The pathology of ovarian tumors inferred by combined MRI and DCE analysis was then correlated with histopathology.

2.3. Statistical analysis

All statistical calculations were done using SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) version 15 for Microsoft Windows. Data were statistically described in terms of mean ± standard deviation (± SD) and range, or frequencies (number of cases) and percentages when appropriate. Comparison of numerical variables between the study groups was done using Student *t* test for independent samples. Chi square ($\chi 2$) test was performed for comparison of categorical data. Fisher exact test was used instead when the expected frequency was <5. Accuracy was represented using the terms sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy. *p* values < .05 were considered statistically significant.

3. Results

We included thirty patients (mean age: 40 age ± 11.97 SD; age range: 22–61 years old). The mean age of patients with benign