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The Clinical Value of Ultrasound Image Texture Analysis in the Diagnosis of Uterine Adhesions

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Abstract

Purpose: This review examines the diagnostic value of transvaginal 3D ultrasound image texture analysis for the diagnosis of uterine adhesions. **Materials and Methods:** The total clinical data of 53 patients with uterine adhesions diagnosed by hysteroscopy and the imaging data of transvaginal three-dimensional ultrasound from the Second Affiliated Hospital of Chongqing Medical University from June 2022 to August 2023 were retrospectively analysed. Based on hysteroscopic surgical records, patients were divided into two independent groups: normal endometrium and uterine adhesion sites. The samples were divided into a training set and a test set, and the transvaginal 3D ultrasound was used to outline the region of interest (ROI) and extract texture features for normal endometrium and uterine adhesions based on hysteroscopic surgical recordings, the training set data were feature screened and modelled using lasso regression and cross-validation, and the diagnostic efficacy of the model was assessed by applying the subjects' operating characteristic (ROC) curves. **Results:** For each group, 290 texture feature parameters were extracted and three higher values were screened out, and the area under the curve of the constructed ultrasonographic scoring model was 0.658 and 0.720 in the training and test sets, respectively. Conclusion Relative clinical value of transvaginal three-dimensional ultrasound image texture analysis for the diagnosis of uterine adhesions.

Keywords

Transvaginal 3D Ultrasound, Intrauterine Adhesion, Texture Analysis

1. Introduction

Intrauterine adhesion (IUA) is a common gynaecological disease that affects fertility. IUA is mostly caused by damage to the basal layer of the endometrium due to a variety of reasons, which results in dysfunction of the auto-repair function of the endometrium and the formation of fibrotic scars, leading to complete or partial destruction of the cavity of the uterine cavity, which leads to symptoms such as menstrual cycle abnormalities, reduced menstrual flow, amenorrhoea, pelvic pain, infertility, or recurrent miscarriage [1]. The current gold standard for diagnosis of IUA is hysteroscopy, but hysteroscopy is invasive and may cause new uterine adhesions if not performed appropriately [2] [3]. Nowadays, transvaginal three-dimensional ultrasonography has become an important modality for the initial diagnosis and follow-up of intrauterine diseases due to its convenience, non-invasiveness and lack of special contraindications [3]. Although transvaginal three-dimensional ultrasound can show the coronal plane of the uterus in its entirety and intuitively, transvaginal three-dimensional ultrasound still has certain misdiagnosis and omissions, and some of them are unable to observe all the images of the uterine cavity in a clear and complete manner, which leads to image distortion [4].

Mazda software is applied to 2D and 3D ultrasound images for texture analysis. It provides a complete path for quantitative analysis of ultrasound image texture analysis, which includes functions such as image separation tools, extraction of texture features, classification algorithms for various types of data, and more. The software is currently being used by researchers in a variety of different areas of imaging and has proven to be an effective and reliable tool for quantitative image analysis [5] [6] [7]. The aim of this study is to apply Mazda software for texture analysis of transvaginal 3D ultrasound images and to preliminarily investigate its clinical value for the diagnosis of IUA.

2. Documentation and Methodology

2.1. Research Population

Retrospective analysis of hysteroscopic surgical records and imaging data of transvaginal three-dimensional ultrasound of 53 patients with a diagnosis of IUA admitted to the Second Affiliated Hospital of Chongqing Medical University from June 2022 to August 2023. According to the diagnostic results of hysteroscopy, the group was divided into the normal endometrium group and the uterine adhesion group.

Inclusion criteria: 1) Refer to the IUA clinical diagnosis and treatment criteria (secondary amenorrhoea and infertility, with recurrent miscarriages, disrupted endometrial echogenicity or uterine blood in the uterine cavity detected by the transvaginal 3D ultrasound, and confirmed by hysteroscopy) to confirm the diagnosis of the condition; 2) Women aged 21 - 45 years old; 3) Those with reduced menstrual flow or amenorrhoea; and 4) Those with a history of abortion or uterine operation.

Exclusion Criteria: 1) Women outside the age range of 21 - 45; 2) Hypothalamic, pituitary, or ovarian amenorrhoea; 3) Ultrasound images of poor quality. The study was approved by the Medical Ethics Committee of our hospital.

2.2. Equipment and Methods

Inspection Methods Instruments A GE Voluson E10, E8 diagnostic ultrasound machine (GE, USA) was used, with a three-dimensional volumetric probe model RIC 5-9-D, and a probe frequency of 5 to 9 MHz. The patient was instructed to empty the bladder, with a disposable medical examination sheet under the buttocks, and was assisted to adjust to the bladder truncation position. A transvaginal 2D scan was performed to initially investigate the site and morphology of the uterine adhesions, and then switched to a 3D imaging scan to determine the site and morphology of the uterine adhesions and to obtain the clearest 3D images (the lesions were larger in cross-section and the defects were the most obvious).

2.3. Images Extraction Ultrasound Images of Patients with Diagnosed

All ultrasound images of patients diagnosed with IUA were first exported from the ultrasound system workstation, and then the clearest images of IUA were selected and imported into the MaZda software. IUA was first exported from the ultrasound system workstation. The clearest section of the transvaginal 3D ultrasound image was then imported into the MaZda software, and the region of interest (ROI) was sketched by a sonographer with more than 5 years of experience based on the records of the hysteroscopic procedure, see **Figure 1**. Texture features were extracted in six categories: histogram, gradient, tour matrix, covariance matrix, autoregressive model and wavelet variation. Six categories were extracted: histogram, gradient, tour matrix, covariance matrix, autoregressive model and wavelet change. In order to reduce the effect of image contrast and brightness on texture extraction, the image greyness was homogenised ($\mu \pm 3\delta$, μ is the mean of the image greyness and δ is the standard deviation of the image greyness values). Each ROI can extract 290 texture features, see **Figure 2**.

2.4. Ultrasonographic Feature Screening and Model Construction

The overall number of cases was randomly divided into 71 cases in the training

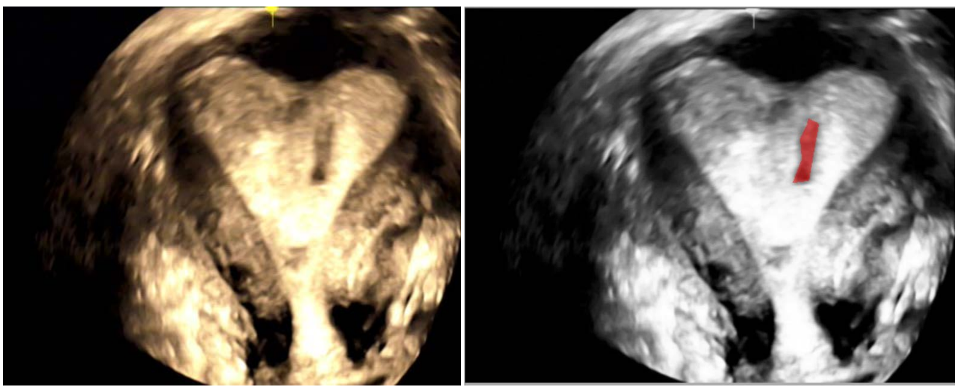

Figure 1. Example of ROI outlining. The left image shows a transvaginal 3D ultrasound image; the right image shows the ROI outlined under the transvaginal ultrasound image.

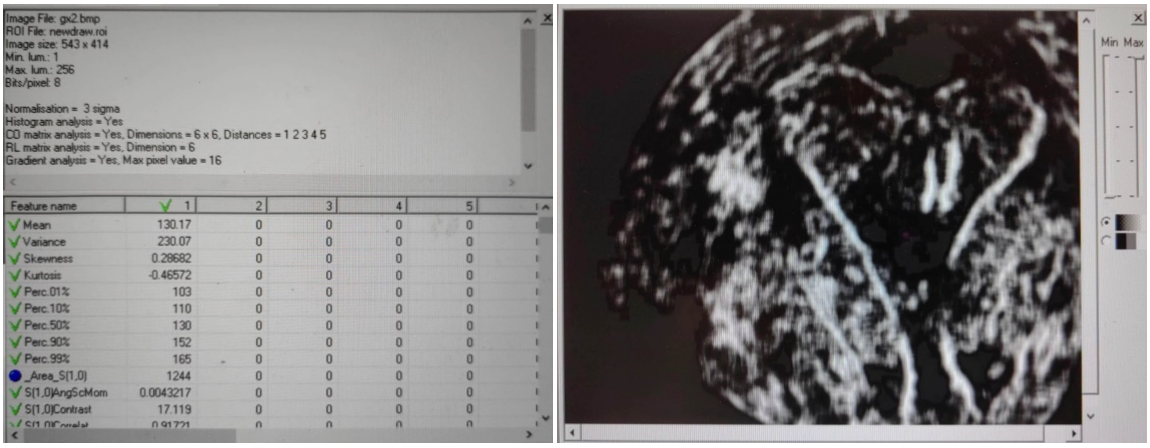

Figure 2. MaZda software to extract texture features and processed images.

set and 32 cases in the test set by 7:3. The most effective combination of features for diagnosing IUA was obtained by screening the extracted 290 features based on the training set using the least absolute shrinkage and selection operator (LASSO) regression and 10-fold cross-tests. The coefficients of the filtered texture features were linearly weighted with the intercept to construct an ultrasonographic model, and the corresponding ultrasonographic score (Radscore) was calculated for each ROI. The diagnostic efficacy of the model was assessed by the area under the curve (AUC) of the subjects' work characteristics (ROC) for the training set, and the test set.

2.5. Statistical Methods

Using R 4.1.0 and SPSS 19.0 software. The overall data were randomly sampled using the "caret" software package and included in the training and test sets in the ratio of 7:3. SPSS 19.0 software was used to test the consistency between the training set and the test set. Count data were expressed as the number of cases, and comparisons between groups were made using the χ^2 test, with continuity correction where necessary; Measures were subjected to t-tests or non-parametric rank-sum tests, and those that conformed to a normal distribution were expressed as $\overline{x} \pm s$; those with a skewed distribution were expressed as M(Q1, Q3). The "glmnet" software package was used to perform LASSO on the quantitative texture features extracted from the ultrasound images in the training set and to filter the texture features by a 10-fold cross-test. The "pROC" software package was used to plot ROC curves and assess the diagnostic performance in terms of AUC.

3. Results

3.1. Diagnostic Rate of Transvaginal 3D Ultrasound

A total of 44 cases of IUA were diagnosed by transvaginal 3D ultrasound and 53 cases of IUA were diagnosed by hysteroscopy, so the diagnostic rate of transvaginal 3D ultrasound was 83% (Table 1).

Table 1. Diagnostic rate of transvaginal 3D ultrasound.

Transvaginal 3D Ultrasound (case)	Hysteroscopy (case)	Diagnostic Rate of Transvaginal 3D Ultrasound
44	53	83%

3.2. Screening and Construction of Texture Features Radscore Model Construction

For each case, 290 textural features were obtained from ROIs of selected normal endometrium and uterine adhesions. Based on the training set, three texture features (Table 2) with non-zero coefficients were screened by LASSO regression using 10-fold cross-validation (Figure 3). The Radscore calculation formula is established based on the linear weighting of the characteristic coefficients with the intercept as follows: Radscore = 0.6283732804 + 0.6283732804 × _MinNorm + 0.6306237974 × S(4, 4) Entropy + 0.5177501899 × S(4, −4) InvDfMom − 0.0123982634 × Horzl_ShrtREmp + 0.0005793791 × GrKurtosis. Use this formula to calculate the ultrasound histology score for each case in the training and test sets.

3.3. Evaluation of Ultrasonographic Scoring Model Efficacy

The ultrasonographic scoring model had an AUC of 0.658 in the training set and 0.720 in the test set (Figure 4).

4. Discussion

4.1. Diagnostic Rate of Transvaginal 3D Ultrasound

Vaginal 3D ultrasound can examine the status of the uterine cavity from multiple angles to identify and localise the location of adhesions. In this study, the application of three-dimensional vaginal ultrasound for the diagnosis of IUA was consistent with the 83% diagnostic rate of hysteroscopy, and three-dimensional vaginal ultrasound has a high diagnostic rate.

4.2. Application of IUA Texture Features in Diagnosis

Vaginal 3D ultrasound can examine the status of the uterine cavity from multiple angles to identify and localise the location of adhesions. In this study, the application of three-dimensional vaginal ultrasound for the diagnosis of IUA was consistent with the 83% diagnostic rate of hysteroscopy, and three-dimensional vaginal ultrasound has a high diagnostic rate.

IUA textural features in diagnosis Related studies have shown that uterine adhesions can be caused by a variety of reasons in currently fertile women. When endometrial adhesions occur in the uterine cavity, the basal layer of the endometrium is damaged, resulting in endometrial auto-repair dysfunction and the formation of fibrotic scarring, which leads to complete or partial morphological destruction of the uterine cavity [1]. A total of three more meaningful texture features were screened for modelling in this study, where MinNorm is

Table 2. Texture features with 3 non-zero coefficients.

Texture Analysis	Ratio
MinNorm	0.002035668
S(5, 5) Entropy	0.294329046
Vertl_GLevNonU	0.060204993

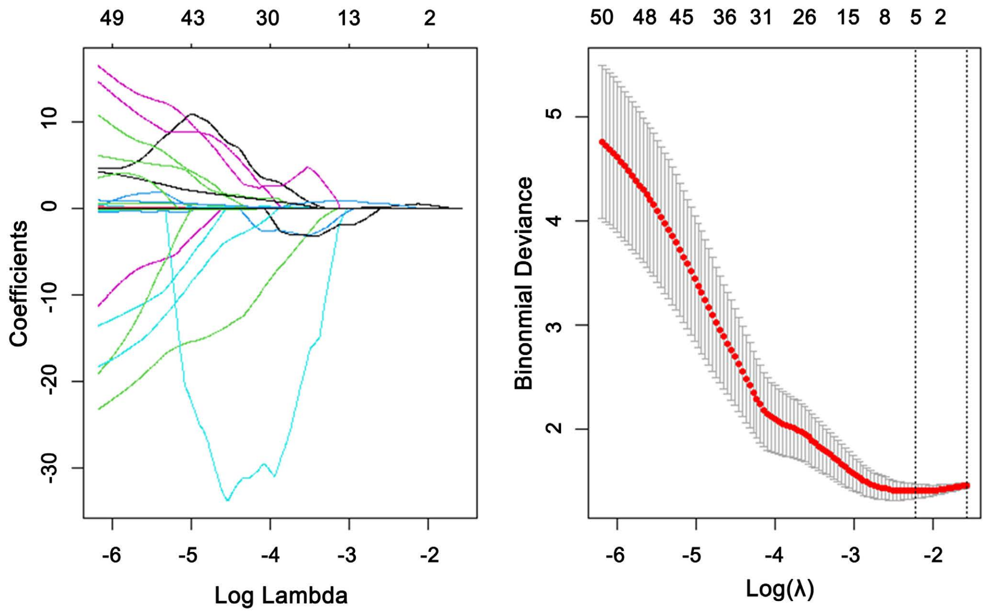

Figure 3. The categorically important features were further extracted by LASSO regression modelling. The left-hand panel shows the process of dimensionality reduction of histological features and model efficacy change based on the value of the minimum deviation λ, with a value of $\lambda = 0.107742$; the right-hand panel shows the convergence of the coefficients of the feature selection process.

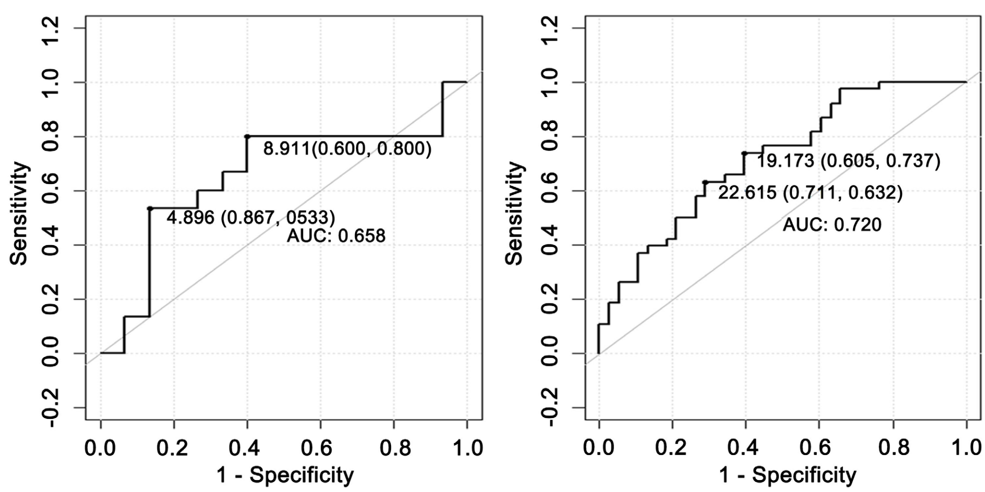

Figure 4. ROC curves for the diagnosis of IUA by the ultrasound histological scoring model; the left panel is the training set and the right panel is the test set.

the minimum number of norms, showing the range of normalised intensities [8]. S(5, 5) Entropy comes from the entropy value, which indicates the uncertainty of the random variable and reflects the complexity of the grey scale distribution of the image, the larger the value, the more complex the image is and the higher the heterogeneity of the IUA it represents [9]. Vertl_GlevNonU is the vertical grey scale non-uniformity, which comes from the grey scale tour matrix and represents the unevenness of the grey scale in the vertical direction, a larger value of GLNU indicates a more uneven grey scale distribution. Dercle *et al.* [10] concluded that Entropy is a promising quantitative imaging biomarker for characterisation of tumour imaging phenotypes, which is associated with tumour gene expression, tumour metabolism, tumour staging, metastasis and patient's prognosis and response to treatment, and in the present study it can be seen that it has a certain degree of correlation for IUA as well, but its correlation with its staging, prognosis and response to treatment still needs to be further investigated. As the main pathological changes of IUA are endometrial stroma loss, fibrosis, scarring, reduction of glands or replacement by other tissues, which ultimately leads to thinning or absence of endometrium [11], its pixel grey scale will be changed, and the image texture will become complex and inhomogeneous due to the change of the tissue composition, so the texture distribution of IUA is more complex and inhomogeneous than that of the normal endometrial tissue.

4.3. Ultrasound Histological Scoring in the Diagnosis of Uterine Adhesions

In this study, we established a model for predicting IUA by texture analysis of transvaginal 3D ultrasound images of IUA, and the results showed that the AUCs in the training and test sets were 0.658 and 0.720, respectively, which showed a certain diagnostic efficacy, indicating that the model has a relative diagnostic value in the prediction of IUA, suggesting that the diagnosis of IUA can be enhanced by the texture features extracted from transvaginal 3D ultrasound. IUA and normal endothelium-related fine texture features. This shows that transvaginal 3D ultrasound has good diagnostic value for IUA diagnosis. However, it should be noted that transvaginal three-dimensional ultrasound can often be difficult to image because of uterine stretching, excessive anterior tilt of the uterus, and so on, resulting in unclear images [12], or because patients with uterine adhesions are not examined during the endometrial secretion phase, which may result in the endometrium being too thin, which affects the quality of the imaging [13] [14]. It may also be susceptible to missed or misdiagnosed cases when vaginal 3D ultrasound is used alone, as the endothelial echoes are more similar to the tissue membrane-like adhesions as well as the adhesion bands. In addition, if the uterus is curved or in retroflexion, it is difficult to accurately determine the position of the uterine fundus and the uterine horns from the coronal position of the uterus during three-dimensional reconstruction, which may lead to missed diagnosis or misdiagnosis [15] [16] [17], and increasing the analysis of the ultrasound texture at the IUA will increase the rate of the diagnosis of the IUA, which can help ultrasonographers to improve the diagnostic rate.

4.4. Limitations of This Study

This study is a single-centre study, the model sample size is small, only internal validation, still need to expand the sample size and and external validation; this study is a retrospective study, with a certain selection bias; this study only establishes the Radscore scoring model, did not incorporate the clinical risk factors, such as the establishment of a comprehensive model and the column line diagram; did not carry out the postoperative imaging prognosis assessment of the patients, to be further researched; guided from the workstation, pixel has a certain deviation. In conclusion, the ultrasonographic scoring model constructed in this study based on the textural features of transvaginal three-dimensional ultrasound has a certain diagnostic efficacy for IUA, which can provide relative imaging information for the diagnosis of IUA and improve the diagnostic rate of IUA.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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