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Original Article

Application of intravoxel incoherent motion diffusion-weighted imaging in differential diagnosis and molecular subtype analysis of breast cancer

Yichuan Ma, Dandan Shan, Jun Wei, Aiqi Chen

Department of Radiology, The First Affiliated Hospital of Bengbu Medical College, Bengbu, Anhui Province, China

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Abstract: Objective: To explore the application of incoherent motion diffusion-weighted imaging (IVIM-DWI) in the differential diagnosis and molecular subtype analysis of breast cancer. Methods: The clinical data of 225 patients with breast masses were selected, including breast cancers (n = 135) and benign breast tumors (n = 90). According to pathological results, breast cancers were divided into four subtypes: Luminal A (n = 24), Luminal B (n = 57), HER-2-overexpression (n = 27) and triple-negative breast cancers (n = 27). The patients were detected by IVIM-DWI, and then the average diffusion coefficient (ADC), perfusion fraction (f) value, true dispersion coefficient (D) value and false dispersion coefficient (D*) value were compared and analyzed. The above index were used to identify breast cancer and its molecular subtypes by using the receiver operating characteristic (ROC) curve. Results: The ADC, D and D*-value in breast cancer group were significantly lower than those in benign tumor group, while the f-value in breast cancer group was higher than that in benign tumor group (P<0.001); The ADC, D, D*, f-value and the combination of four have high diagnostic value in breast cancer; The D-value in PR-positive group was higher than that in the PR-negative group, while it was lower in PR-positive group (P<0.05), and the ADC, D and D*-value in the ER-positive group were significantly lower than those in the ER-negative group (P<0.001); The f-value in HER-2 positive group was higher than that in human epidermal growth factor receptor-2 (HER-2) negative group (P<0.001); The ADC and D-value of Ki-67 high-expression was lower than those of Ki-67 low-expression, while the D-value of Ki-67 high-expression was higher than that of Ki-67 low expression group (P<0.05); The ADC, D, D*, f-value and the combination of four have high diagnostic value in triple negative breast cancer. Conclusion: IVIM-DWI technology has a significant value in differential diagnosis of benign and malignant breast tumors, and the relevant parameters of IVIM-DWI technology have definite value in the differential diagnosis of breast cancer molecular typing.

Keywords: Incoherent motion diffusion-weighted imaging, breast cancer, molecular subtype, differential diagnosis, receiver operating characteristic curve

Introduction

Breast cancer is one of the most common malignant tumors that threaten women's health, accounting for 11.4% of all the new tumors and 6.6% of deaths [1, 2]. Breast cancer is also the most common malignant tumor that causes death in women [3]. Studies have found that the incidence of breast cancer in women continues to rise every year and has a trend to affect women at younger age [4, 5]. Early detection, diagnosis and treatment of breast cancer are of great significance to improve the prognosis of patients [6, 7]. At present, the gold standard for the diagnosis and classification of breast cancer is breast tissue biopsy is still, but this is an invasive operation. How to improve the diagnostic accuracy through non-invasive imaging methods has become a hot spot in clinical research [8]. Magnetic resonance imaging (MRI) has high specificity and sensitivity for the diagnosis of breast cancer, and it can still be used to diagnose multiple lesions and lesions that cannot be detected by mammography targets [9]. Studies have shown that sentinel lymph node biopsy before breast cancer surgery often have false-negative lymph node, and lymph node metastasis was only found during surgery. MRI has a good diagnostic value for metastatic

lymph nodes and is beneficial to the differentiation of benign and malignant breast tumors [10]. Diffusion-weighted imaging (DWI) technology is a new MRI imaging technology that can image the diffusion of tissue water molecules and accurately reflect the tissue microstructure, and it has been used in the diagnosis of glioma grade, breast cancer, stroke and so on [11]. It has been confirmed that DWI has a good value in the differential diagnosis of benign and malignant breast tumors [12]. Clinical studies have found that the accuracy of DWI technique has decreased due to the influence of water molecular diffusion and microcirculation perfusion in tumor tissues [13]. Based on the discrimination between diffusion effect and perfusion effect, the incoherent motion diffusion-weighted imaging (IVIM-DWI) technique is proposed [14]. The high value of IVIM-DWI technique in the diagnosis of benign and malignant breast tumors has been recognized and applied clinically, but there is still controversy in the immunohistochemical classification of breast cancer by IVIM-DWI technique. Some studies have shown that the average diffusion coefficient (ADC) of patients with estrogen receptor (ER)-positive breast cancer detected by IVIM-DWI technology decreased, but another study found that there was no difference in ADC between ER and progesterone receptor (PR)-positive breast cancer and ER and PR-negative breast cancer, respectively [15, 16]. This study aims to provide more evidence for clinical practice based on the study of the diagnostic value of IVIM-DWI in molecular typing of breast cancer.

Materials and methods

General data

The clinical data of 225 patients (the average age was 52.1±8.5 years old, 33-71 years old) with breast tumors treated in the Department of Breast surgery of The First Affiliated Hospital of Bengbu Medical College from January 2017 to January 2020 were collected for retrospective analysis. Among them, the patients with breast malignant tumors (n = 135, the average age was 52.4±8.3 years old) and benign breast tumors (n = 90, the average age was 51.9±9.1 years old) were confirmed by the final pathological study. This study was approved by the Ethics Committee of The First Affiliated Hospital of Bengbu Medical College and all the patients had signed the informed consent form.

Inclusion and exclusion criteria

Inclusion criteria: (1) Patients that meet the diagnostic criteria of breast cancer or benign tumor [17]; (2) Patients with age between 18 and 75 years old; (3) All the included patients were pathologically confirmed to be benign or malignant tumors by radical mastectomy or breast puncture; (4) All patients received IVIM-DWI examination before diagnosis, and they were radiotherapy and chemotherapy treatment-naive for the first diagnosis.

Exclusion criteria: (1) Patients with incomplete clinical data; (2) Patients with severe heart, liver, kidney and other diseases; (3) Patients with mental illness or cerebrovascular disease that inability to cooperate; (4) patients with other cancers or not primary breast cancer; (5) The newly diagnosed patients who were undergoing radiotherapy and chemotherapy or who have received radiotherapy and chemotherapy.

The pathological classification of breast cancer refers to the Chinese Anti-Cancer Association

According to the expression of ER, PR, human epidermal growth factor receptor-2 (HER-2) and cell proliferation antigen marker Ki-67 (Ki-67) in breast cancer tissue that referring to guideline and standard for the diagnosis and treatment of breast cancer by Chinese Anti-Cancer Association, the breast cancer pathology can be divided into four types [17, 18]. (1) Luminal A type: positive for ER and PR, negative for HER-2 and low expression of Ki-67; (2) Luminal B type can be divided into two subtypes: 1) ER and/or PR positive, HER-2 positive but Ki-67 is not required; 2) ER and/or PR positive, HER-2 negative but Ki-67 high expression; (3) HER-2 overexpression type: ER and PR are negative, HER-2 positive but Ki-67 is not required; (4) Triple negative breast cancer: ER, PR and HER-2 are negative but Ki-67 is not required.

Methods

The patients were scanning conventionally by MRI scanner (model: Siemens Skyra 3.0T) and then by DWI (TR = 2486 ms, TE = 71.9 ms, FOV = 320 * 320 mm, layer thickness = 1.0 mm, expansion coefficient b value = 0 and 1000 s/mm^2). A single-phase scanning of 112 levels were scanned for 60 s, and the contrast agent was injected with gadopentetate meglumine

Table 1. Comparison of general data and baseline data in patients between two groups

Items	Breast cancer group (n = 135)	Benign tumor group (n = 90)	χ^2/t	P
Age (years)	51.9±9.1	52.4±8.3	0.418	0.676
Tumor size (mm)	27.81±5.59	27.46±5.39	1.024	0.307
Distance from skin (mm)	7.59±1.82	7.46±1.59	0.552	0.582
Distance from nipple (mm)	4.66±0.67	4.63±0.64	0.335	0.738
breast thickness (mm)	19.58±2.66	19.25±2.61	0.918	0.359
BMI (kg/m^2)	23.32±2.47	23.51±2.29	0.582	0.561
Menopause	69	42	0.033	0.856
History of abortion	52	31	0.764	0.382
Smoking	34	20	0.260	0.610

Note: BMI: body mass index.

(Gd-DTPA, Bayer Schering Pharma, Germany) at 3 mL/s with a total injection of 0.2 mmol/kg. After image processing, the image was read by two professional readers, and the ADC was measured and calculated. The b-value of IVIM-DWI data was selected from 12 values between 0 and 1500 to fit the calculation of the f-value, the D-value and the false D*-value, and the average value was taken for three times.

Outcome measures

The ADC, D, D* and f-values of benign and malignant tumors were compared between the two groups, and the receiver operating characteristic (ROC) diagnostic curve was used for differential diagnosis.

The differences of ADC, D, D* and f-values under different expressions of ER, PR, HER-2 and Ki-67 were compared.

The differences of ADC, D, D* and f-value in patients with four types of breast cancer were compared, and ROC curve was used to verify the diagnostic value of ADC in triple negative breast cancer.

Statistical indicators

The data were analyzed by SPSS 17.0 statistical software. Continuous variables were expressed by mean ± standard deviation ($\bar{x}$ ± sd). Independent sample t test, which was represented by t, was used for the data fitting normal distribution and homoscedasticity. t test is used for comparison between groups and paired sample t test should be used for comparison of different positions within groups. In the comparison of multiple groups, one-way ANOVA was used to detect whether there were differences, and if there is a difference, the bonferroni method was used for pairwise comparison between post hoc groups; The numeration data were analyzed by Pearson chi-square test (χ^2). The diagnostic value was evaluated by ROC diagnostic curve, which was drawn by Medcalc software. The predictive value of ROC diagnostic was diagnosed by logistic regression formula for joint diagnosis. P<0.05 was indicated that the difference was statistically significant.

Results

Comparison of general data and baseline data in patients between two groups

There was no significant difference in age, tumor size, distance from skin, distance from nipple, breast thickness, body mass index, menopause, history of abortion and smoking in patients between the two groups (P>0.05), as shown in **Table 1**.

Comparison of relevant parameters between the two groups of patients

The ADC, D, and D*-value in breast cancer group were significantly lower than those in benign tumor group, while the f-value in breast cancer group was higher than that in benign tumor group (all P<0.001). See **Table 2**.

ROC curve of breast benign and malignant tumors diagnosed by IVIM-DWI related parameters

The area under ROC curve, sensitivity, specificity and cutoff value of ADC-value in diagnosis of

Table 2. Comparison of relevant parameters between the two groups of patients

Parameters	Breast cancer group (n = 135)	Benign tumor group (n = 90)	χ^2/t	P
ADC (*10^{-3} mm^2/S)	0.88±0.35	1.72±0.42	16.261	<0.001
D (*10^{-3} mm^2/S)	0.78±0.33	1.54±0.35	16.901	<0.001
D* (*10^{-3} mm^2/S)	40.95±10.62	54.27±11.32	8.990	<0.001
f (%)	33.16±8.62	17.76±5.79	16.029	<0.001

Table 3. The diagnostic value of MRI related parameters for breast cancer

MRI parameters	AUC	95% CI		Cutoff value	P	Sensitivity	Specificity
		Lower limit	Upper limit				
ADC (*10^{-3} mm^2/S)	0.932@	0.893	0.972	1.245	<0.001	0.933	0.889
D (*10^{-3} mm^2/S)	0.936@	0.896	0.972	1.130	<0.001	0.935	0.891
D* (*10^{-3} mm^2/S)	0.845	0.789	0.984	47.972	<0.001	0.856	0.837
f (%)	0.927@	0.897	0.964	25.073	<0.001	0.933	0.856
Combination of the four parameters	0.999*,#,@,&	0.995	1.000	-	<0.001	1.000	0.993

Note: compared with ADC-value, *P<0.05; compared with D-value, #P<0.05; compared with D*-value, @P<0.05; compared with f-value, &P<0.05. ADC: average diffusion coefficient; MRI: magnetic resonance imaging.

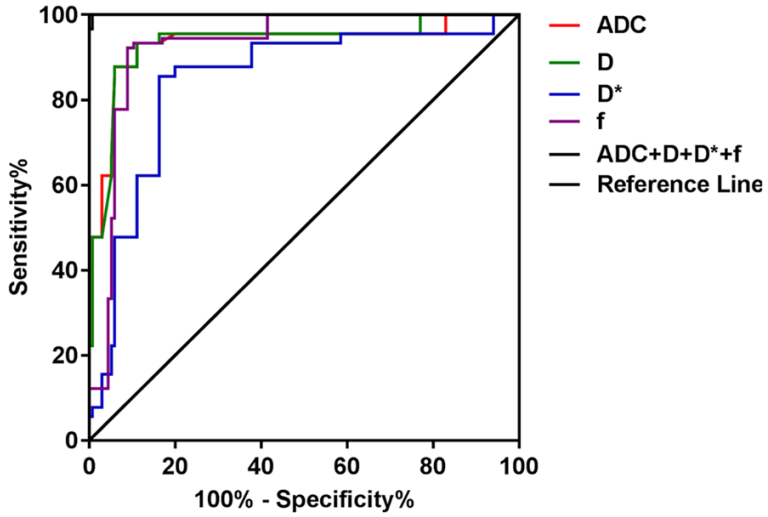

Figure 1. ROC curve of IVIM-DWI related parameters in the diagnosis of benign and malignant breast tumors. IVIM-DWI: diffusion-weighted imaging; ADC: average diffusion coefficient; ROC: receiver operating characteristic.

breast cancer were 0.932, 0.933, 0.889 and 1.245 respectively; The area under ROC curve, sensitivity, specificity and cutoff value of D-value in diagnosis of breast cancer were 0.936, 0.935, 0.891 and 1.130 respectively; The area under ROC curve, sensitivity, specificity and cutoff value of D*-value in diagnosis of breast cancer were 0.845, 0.856, 0.837, and 47.972 respectively; The area under the ROC curve, the sensitivity, the specificity and the cutoff value of f-value in diagnosis of breast cancer were 0.927, 0.933, 0.856 and 25.073 respectively. Logistic regression was performed for the combined diagnosis of the four indicators to obtain the best diagnosis model equation: Logit (P) = 18.607+ ((-8.023) * ADC_{-value} + (-5.361) * D_{-value} + (-0.162) * D^*_{-value} + (0.235) * f_{-value}), and the risk probability value of breast cancer was established (risk probability value refers to the probability of predicting the occurrence of disease based on risk factors P = $+e^{-((-8.023) * ADC\text{-value} + (-5.361) * D\text{-value} + (-0.162) * D^*\text{-value} + (0.235) * f\text{-value})}$). The area under ROC curve, sensitivity and specificity for the combined diagnosis of four values in the diagnosis of breast cancer were 0.999, 1.000 and 0.993 respectively. See **Table 3** and **Figure 1**.

Comparison of general data of patients with different types of breast cancer

There was no significant difference in the general data of patients with different types of breast cancer (all P>0.05), as shown in **Table 4**.

Comparison of the expression of parameters related to different molecular typing

The D-value in PR positive group was higher than that in PR negative group, but D*-value in PR positive group was lower than that in PR negative group (P<0.001). ADC, D and D*-value

Table 4. Comparison of general data of patients with different types of breast cancer

Items	Luminal A (n = 24)	Luminal B (n = 57)	HER-2 overexpression (n = 27)	Triple negative breast cancer (n = 27)	χ^2/F	P
Age (years)	51.8±8.9	50.9±8.4	52.3±9.6	51.6±9.2	0.169	0.917
Tumor size (mm)	26.95±5.69	27.49±5.58	28.14±5.85	28.24±5.67	0.287	0.835
Distance from the skin (mm)	7.61±1.86	7.42±1.65	7.62±1.86	7.59±1.58	0.128	0.934
Distance from nipple (mm)	4.67±0.63	4.62±0.65	4.65±0.69	4.72±0.63	0.136	0.939
Breast thickness (mm)	19.36±2.84	19.28±2.59	19.68±2.74	19.69±2.84	0.154	0.897
BMI (kg/m^2)	23.29±2.47	23.53±2.31	23.56±2.28	23.21±2.54	0.196	0.869
Menopause	12	28	13	12	0.090	0.993
History of abortion	10	21	11	10	0.383	0.944
Smoking	7	14	8	6	0.330	0.954
Pathological type					5.564	0.943
Infiltrating ductal carcinoma	17	45	19	18		
Infiltrating lobular carcinoma	4	4	4	4		
Colloid carcinoma	2	3	3	3		
Medullary carcinoma	1	4	1	1		
Others	0	1	0	1		
Tissue grading					0.823	0.988
Grade I	10	29	12	13		
Grade II	8	15	9	8		
Grade III	6	13	6	6		

Note: HER-2: human epidermal growth factor receptor-2; BMI: body mass index.

in ER positive group were lower than those in ER negative group (all P<0.001); The f-value of HER-2 positive group was higher than that of HER-2 negative group (P<0.001); The ADC and D-value in high-expression of Ki-67 was lower than those in low-expression of Ki-67, while the D*-value in high-expression of Ki-67 was higher than that in low-expression of Ki-67 (P<0.05). See **Table 5**.

Comparison of related parameters in different types of breast cancer

The levels of ADC and D-value in triple negative breast cancer were lower than those of Luminal A, Luminal B and HER-2 overexpression types of breast cancer, while D* and f-value were higher (P<0.05); The ADC-value in HER-2-overexpression and Luminal B types of breast cancer was lower than that of Luminal A type of breast cancer, while D*-value was higher (P<0.001); The D and f-value in HER-2 overexpression type of breast cancer were lower than Luminal A and Luminal B types of breast cancer (all P<0.05); The ADC, D and f-value of Luminal B type of breast cancer were lower than those of Luminal A type, while the D*-value was higher (all P<0.05). See **Table 6**.

The diagnostic value of relevant parameters for triple-negative breast cancer

Because the above four related parameters are different from the other three in the diagnosis of triple negative breast cancer, the area under ROC curve, sensitivity, specificity and cutoff value of ADC in the diagnosis of triple negative breast cancer were 0.804, 0.917, 0.518 and 0.595 respectively; The area under ROC curve, sensitivity, specificity and cutoff value of D-value in diagnosis of triple negative breast cancer were 0.881, 0.704, 0.923 and 0.700 respectively; The area under ROC curve, sensitivity, specificity and cutoff value of D*-value in the diagnosis of triple negative breast cancer were 0.714, 0.722, 0.630 and 44.553 respectively; The area under ROC curve, sensitivity, specificity and cutoff value of f-value in the diagnosis of breast cancer were 0.756, 0.765, 0.907 and 37.741 respectively; Logistic regression was performed for the combined diagnosis of the four factors, and the best diagnostic model equation was obtained: Logit (P) = 2.130 + ((-5.648) * ADC_{-value} + (-12.404) * D_{-value} + 0.013 * D^*_{-value} + 0.218 * f_{-value}). The risk probability value (which refers to the probability of predicting the occurrence of the disease

Table 5. Comparison of the expression of parameters related to different molecular typing

Molecular typing	ADC (*10^{-3} mm^2/S)	D (*10^{-3} mm^2/S)	D* (*10^{-3} mm^2/S)	f (%)
PR				
Positive (n = 81)	0.88±0.34	0.93±0.28	37.64±10.32	33.05±8.08
Negative (n = 54)	0.88±0.37	0.57±0.23	45.86±9.12	33.32±9.45
t	0.131	7.746	4.742	0.174
P	0.896	<0.001	<0.001	0.862
ER				
Positive (n = 74)	0.75±0.37	0.62±0.28	37.83±10.57	33.04±8.14
Negative (n = 61)	0.98±0.29	0.92±0.27	44.69±9.47	33.30±9.24
t	4.008	6.292	3.935	0.170
P	<0.001	<0.001	<0.001	0.865
HER-2				
Positive (n = 37)	0.87±0.26	0.82±0.26	39.31±10.28	37.85±8.97
Negative (n = 98)	0.88±0.38	0.77±0.33	51.54±10.73	31.39±7.82
t	0.202	0.784	1.113	4.108
P	0.840	0.343	0.270	<0.001
Ki-67				
High-expression (n = 96)	0.78±0.31	0.69±0.26	42.32±10.60	32.58±8.29
Low-expression (n = 39)	1.13±0.31	1.01±0.31	37.50±9.99	34.60±9.34
t	5.917	6.022	2.438	1.235
P	<0.001	<0.001	0.016	0.219

Note: ADC: average diffusion coefficient; HER-2: human epidermal growth factor receptor-2; ER: estrogen receptor; PR: progesterone receptor.

Table 6. Comparison of related parameters in different types of breast cancer

Type of breast cancer	ADC (*10^{-3} mm^2/S)	D (*10^{-3} mm^2/S)	D* (*10^{-3} mm^2/S)	f (%)
Luminal A (n = 24)	1.24±0.41	1.12±0.38	28.31±9.74	35.96±7.15
Luminal B (n = 57)	0.87±0.25***	0.83±0.21***	41.75±5.43***	32.06±4.38*
HER-2 overexpression (n = 27)	0.89±0.21***	0.70±0.13$^{***,\#}$	42.18±5.19***	25.94±8.42$^{***,\#\#\#}$
Triple negative breast cancer (n = 27)	0.58±0.30$^{***,\#\#\#,@@@}$	0.47±0.23$^{***,\#\#\#,@@@}$	49.16±13.66$^{***,\#\#\#,@@@}$	40.21±10.48$^{*,\#\#\#,@@@}$
F	22.154	33.401	4.742	0.174
P	<0.001	<0.001	<0.001	0.862

Note: compared with the Luminal A type, *P<0.05, ***P<0.001; compared with Luminal B, $^{\#}$P<0.05, $^{\#\#\#}$P<0001; compared with overexpression type, $^{@@@}$P<0.001. ADC: average diffusion coefficient.

according to the risk factors) of triple negative breast cancer was established: $P = +e^{-((-5.648) * ADC\text{-value} + (-12.404) * D\text{-value} + 0.013 * D^*\text{-value} + 0.218 * f\text{-value})}$. The area under ROC curve, sensitivity and specificity for the combined diagnosis of the four of breast cancer were 0.983, 0.982 and 0.956 respectively. See **Table 7** and **Figures 2**, **3**.

Discussion

The incidence and development of breast cancer are closely related to the interaction of many kinds of cells and molecules. Different pathological types directly affect the prognosis of patients and treatment plan [19]. Therefore, it is of great significance to seek non-invasive diagnosis for early differential diagnosis, especially for patients who are unable to undergo operation or puncture pathological diagnosis. MRI is a non-invasive, well-differentiated and radiation-free means of examination, which can effectively and accurately evaluate the blood perfusion of breast tumor tissue, and it has a unique advantage in the differentiation of benign and malignant breast tumors [20]. Previous studies using DWI in the differential diagnosis of benign and malignant breast cancer had found that the ADC-value of benign

Table 7. MRI related parameters in the diagnosis of triple-negative breast cancer

MRI indicators	AUC	95% CI		Cutoff value	P	Sensitivity	Specificity
		Lower limit	Upper limit				
ADC (*10^{-3} mm^2/S)	0.804	0.726	0.904	0.595	<0.001	0.917	0.518
D (*10^{-3} mm^2/S)	0.881$^{@,\&}$	0.826	0.951	0.700	<0.001	0.704	0.923
D* (*10^{-3} mm^2/S)	0.714	0.579	0.824	44.553	<0.001	0.722	0.630
f (%)	0.756	0.629	0.868	37.741	<0.001	0.765	0.907
Combination of the four indicators	0.983$^{*,\#,@,\&}$	0.959	1.000	-	<0.001	0.982	0.956

Note: compared with ADC, *P<0.05; compared with D, $^{\#}$P<0.05; compared with D*, $^{@}$P<0.05; compared with f, $^{\&}$P<0.05. ADC: average diffusion coefficient; MRI: magnetic resonance imaging.

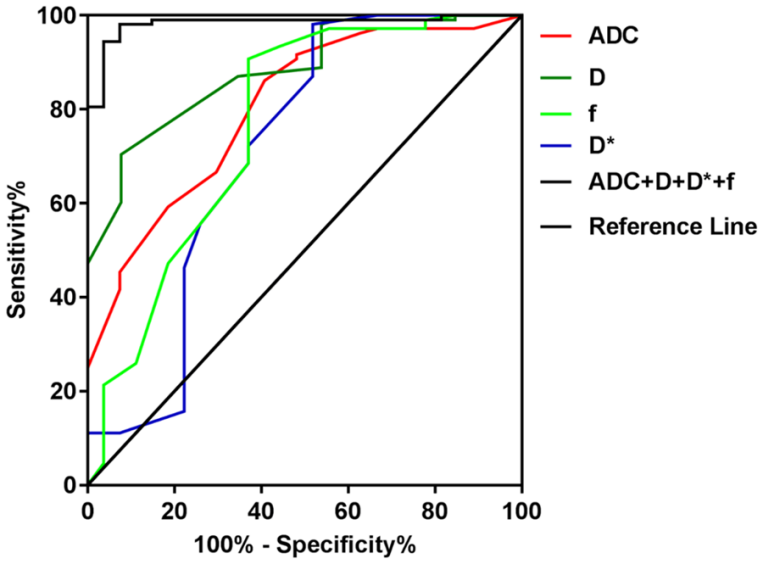

Figure 2. ROC curve of IVIM-DWI related parameters in the diagnosis of triple negative breast cancer. IVIM-DWI: diffusion-weighted imaging; ADC: average diffusion coefficient; ROC: receiver operating characteristic.

tumors was significantly higher than that of malignant tumors, which was consistent with our study [21]. In this study, IVIM-DWI technique was further used to differentiate benign tumor from malignant breast cancer. It was found that D and D*-value in breast cancer group were significantly lower than those in benign tumor group, while f-value in breast cancer group was significantly higher than that in benign tumor group. D-value is to distinguish ADC pure water molecules from blood perfusion to obtain true diffusion coefficient (D), and it can better respond to the diffusion of water molecules in the body [11]. The decrease of D*-value in malignant tumors may be related to the decrease of blood flow caused by abnormal proliferation of malignant tumor cells invading blood vessels, f-value reflects the blood flow velocity and the number of capillaries, while malignant tumor cells are often accompanied by abnormal vascular proliferation leading to the increase of f-value. In this study, ROC diagnostic curve was further used to diagnose benign and malignant breast tumors, the above detection index have good diagnostic value for benign and malignant breast tumors, and the combined use of the above four indexes has a higher diagnostic value, which is consistent with previous research results [21].

The patients with positive expression of ER were considered to be more effective in endocrine therapy. Study had found that the higher tumor density of ER-positive patients leads to a decrease in the diffusion of water molecules, and the values of ADC, D and D*-value decreased, which was consistent with the results of this study [22]. However, another study found that there was no difference in ADC between ER and PR-positive breast cancer and ER and PR-negative breast cancer, respectively. So the correlation between the expression of ER and PR and the ADC-value has not been determined [16]. HER-2 overexpression is closely related to tumor aggressiveness, and it can promote the growth of vascular endothelial factor, blood vessel and lymphatic vessel in tumor tissues [23]. In this study, it is also shown that the f-value of HER-2 positive group is higher than that of negative group, which may be related to angiogenesis. The high expression of Ki-67 can accelerate the proliferation of tumor cells and lead to the rapid pro-

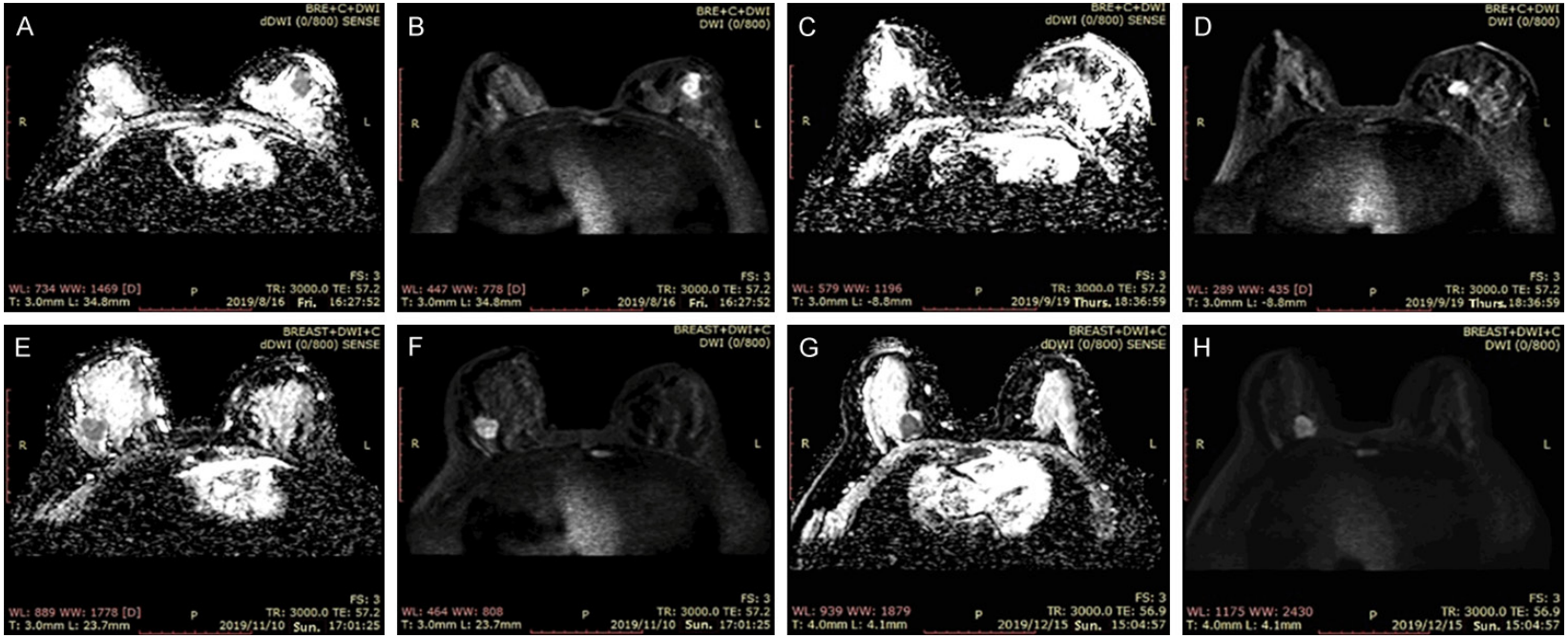

Figure 3. Comparison of IVIM-DWI imaging for different molecular subtypes. A and B: Luminal A, ADC and IVIM-DWI image; C and D: Luminal B, ADC and IVIM-DWI image; E and F: HER-2 overexpression, ADC and IVIM-DWI image; G and H: ADC and IVIM-DWI image of triple negative breast cancer. IVIM-DWI: diffusion-weighted imaging; ADC: average diffusion coefficient; HER-2: human epidermal growth factor receptor-2.

liferation of tumor cells. Previous studies have shown that there is a negative correlation between the expression of Ki-67 and D value [24]. Indeed, we have shown that ADC and D-value decreased in tumor tissues with high expression of Ki-67.

Further studies on the related parameters of different types of breast cancer found that compared with the other three groups of breast cancers, the ADC and D-value of triple-negative breast cancer decreased, while D* and f-value of triple-negative breast cancer increased. The triple-negative breast cancer, which refers to the above three receptors are negative, has a poor response on endocrine and targeted therapy, and also has a poor response on chemotherapy. However, the incidence of TNBC recurrence and metastasis is significantly higher than other types [25-27]. Due to the poor effect of conventional and chemotherapy treatment and easy recurrence and metastasis, the prognosis of triple negative breast cancer is worse than that of other types, and studies have found that triple negative breast cancer proliferates rapidly and is prone to invasion and metastasis [28]. The decreas of ADC and D-value in triple negative breast cancer indicates that their proliferation is robust and angiogenesis is significantly increased, while the increase of D*-value in the tissue around the tumor indicates that it is highly invasive. Therefore, this study suggests that the related parameters of IVIM-DWI have a great value in the diagnosis of triple negative breast cancer. Further study found that the use of ADC, D, D* and f-value in the combined diagnosis of triple negative breast cancer is of high value, which needs to be further investigated and confirmed in clinical practice.

In conclusion, IVIM-DWI technology has a good value in differentiation of benign and malignant breast tumors, and the related parameters of IVIM-DWI technology have a certain value in differentiation the molecular type of breast cancer. Further study found that IVIM-DWI technology has a good value in the differential diagnosis of triple negative breast cancer and other types of breast cancer.

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Disclosure of conflict of interest

None.

Address correspondence to: Yichuan Ma, Department of Radiology, The First Affiliated Hospital of Bengbu Medical College, No. 287 Changhuai Road, Bengbu 233004, Anhui Province, China. Tel: +86-0552-3086216; Fax: +86-0552-3086216; E-mail: mayichuanh8d3@163.com

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