Original Research Article

Accuracy of Magnetic Resonance Imaging (MRI) in Detecting Breast Tumors

ABSTRACT

Aims: The aim of this study was to evaluate the accuracy of magnetic resonance imaging (MRI) in characterizing breast abnormalities and tumors, in comparing to other diagnostic modalities and histopathological findings.

Study Design: This prospective study included 254 patients (14 males and 240 females; ages range between 15-78 years) underwent breast MRI examination.

Place and Duration of Study: This study was conducted in different MRI medical centers in Khartoum, Sudan between June 2014 and July 2016.

Methodology: Patients were examined using two sequences of MRI; routine and dynamic contrast enhanced MRI (DCE-MRI). Signal intensities were evaluated from different MRI sequences in different tumors; the histopathology result was used as a reference for each case.

Results: The sensitivity and specificity of MRI were (82.6%) and (73.2%) respectively. In addition, the breast cancer was more enhanced with fat suppression images. DCE-MRI has been shown to be more sensitive than routine sequences in detecting ductal carcinoma in situ (DCIS). Image subtraction technique showed that breast cancer has heterogeneous features (89.9%), and ring enhancement was clearly seen on (8.7%). DCE-MRI has been used to evaluate focal breast lesions. Adding information derived from the kinetic curve type of architectural features of a lesion, improves the specificity of breast MRI. On the other hand, it revealed that most cases of cancer represented on type 111 curves or rapid wash out. However, quantitative measurements of kinetic curve type resulted in significantly higher diagnostic performance and increasing specificity of MRI.

Conclusion: The accuracy of MRI in this study was more than other imaging modalities in characterizing breast abnormalities and tumors. Therefore, it offers a new method to detect breast cancer in its early stage, and help improve the survival rate.

Keywords: Accuracy, breast tumors, histopathology, imaging, MRI, protocols.

1. INTRODUCTION

Breast cancers are the most common type of cancer among women in the industrialized world. A woman's average lifetime risk for developing breast cancer in the United States is 1 in 8 [1]. In Sudan breast cancer is about (29%-34.5%) of all women's cancers [2]. Breast cancer cannot be prevented at the present time; however, early detection of breast cancer provides the best chance of survival and early treatment options [2]. Because early breast cancer is asymptomatic, the only way to detect it is through screening [3].

Different methods have been used in the diagnosis of breast cancer, including self-examination and clinical examination, mammography, ultrasound, magnetic resonance imaging (MRI) modality, follow up methods and biopsy [2]. Regular breast self-exam (BSE), can be an important way to find a breast cancer early, when it's more likely to be treated successfully. In spite of the fact that breast is superficial organ which is amenable to clinical examination, may not reveal any pathological problems, so that clinical examination would not easily detect sub centimeter lesions if they are deeply situated within the breast and would not easily and confidently differentiate between benign and malignant breast lesion [4]. In certain situation, clinical examination, mammography, and ultrasonography have some limitations, either due to factors in the breast parenchyma such as dense breast in young females, post-operative changes or effect of irradiation or factors in modality itself, such as the inability of mammography to demonstrate deep part of the breast and operator dependency of ultrasound [5].

In diagnosing breast abnormalities and tumors, there is a need for a specific diagnostic modality to reach an accurate diagnosis of these abnormalities, such as mammography, which is an effective means of detecting and diagnosing breast cancer. It decreases breast cancer mortality by 1/3 when used as screening, however, reported high false negative from (4%-34%) [6]. Taking in mind that an abnormal screening mammogram requires a diagnostic test to confirm whether cancer is present, many women who do not have cancer will undergo these unnecessary diagnostic tests [3]. In these difficult situations, a biopsy may be restored to as a diagnostic method. In the last few years, magnetic resonance (MR) imaging has been introduced as a promising method for diagnosis of breast neoplasms particularly when dynamic contrast gadolinium (Gd) enhancement studies are used [7,8]. Several studies have explored a multi-parametric approach to breast imaging that combines analysis of traditional contrast enhancement patterns and lesion architecture with novel methods such as diffusion, perfusion, and spectroscopy to increase the specificity of breast MRI studies [9]. The value of dynamic contrast enhanced MRI (DCE-MRI) is dependent on its ability to demonstrate intrinsic differences between varieties of issues that affect contrast media behavior. Evidence is mounting that DCE-MRI measurements correlate with immune histochemical surrogates of tumor angiogenesis [9].

This study aimed to evaluate the accuracy of MRI in characterizing breast abnormalities and tumors, and to compare the findings with the other diagnostic modalities and histopathological findings.

2. MATERIAL AND METHODS

2.1 Patient samples

The study was conducted in 254 patients, 250 were female (98.4%) and 4 male (1.6%). The mean age of all patients was 47 years, age range between 15-78 years. All patients were examined by DCE-MRI. Clinical examination and full history were taken as well as written informed consent was obtained. Sudanese patients who were 15 years old or older, with proven breast cancer were eligible for recruitment. Exclusion criteria were absolute contraindications to MRI, pregnancy or breast feeding, severe renal failure, known hypersensitivity to gadolinium chelates, inclusion in other clinical trials during the month before enrollment, and clinical status that would limit data reliability.

2.2 Breast mammography, ultrasound and biopsy procedure

Mammography was performed with at least two views per breast (medio-lateral oblique and cranio-caudal views) using a low radiation dose digital mammography system (Mammomat, Siemens, Germany). Additional views or spot compression views were obtained where appropriate.

Breast ultrasound was performed using 7.5-13 MHz probes (high resolution General electric (GE) medical system, logic 5 expert, Sony Corporation, Japan); the entire breast was systematically examined by the physician who interpreted the study.

Breast fine needle aspiration biopsy under the guidance of ultrasound, was performed while the patient lying on back on the examination bed in the ultrasound room. The patient's upper body undressed, with one arm above the head on the pillow in a comfortable position. One physician applied ultrasound gel on the breast and the ultrasound transducer (7.5-13 MHz) slowly moved across the breast to show and identify the lesion. The needle passed through the skin and into the lesion guided by the ultrasound images. Both local anesthetic and antiseptic liquids were used as the needle is inserted. Less than 1cm forward and backward, gentle movements with the needle to collect cells or, if the lesion is a cystic in nature, fluid may be collected. Two or three separate samples are usually taken in this way to ensure a good sample has been obtained.

2.3 Breast MRI protocols

The breast MRI examination was performed using 1.5 Tesla (General Electric, Milwaukee, WIS, USA) MRI scanner using phased-array breast surface coil, with patients lying in prone position. The MRI protocol included an echo-planar DW sequence; for imaging with this sequence the phased-array breast coil was converted to operate in a linear mode to accommodate the high acquisition speeds (~ 80 kHz).

MRI has emerged as an alternative, powerful tool for breast cancer screening as it does not require exposure to ionizing radiation; it is thus safe to use routinely and more suitable than mammography for assessing young women. The MRI protocol consisted of the following sequences: 1) Coronal T_1-weighted spin echo sequence was carried out for localization purpose and followed by plain sequences using T_1-weighted fast spin echo sequence (TR=125msec, TE=5.3msec), in addition to T_2-weighted fast spin echo sequence (TR=3740msec, TE=90msec) in axial orientation. A bolus of gadolinium (Gd-DTPA) (Magnevist, Schering AG Berlin. Germany) was injected manually and intravenously at a dose of (0.1 mmol/kg) followed by a saline flush to ensure that contrast enhanced images could be obtained immediately after contrast agent injection, 2) Dynamic contrast T_1-weighted images, then performed using gradient echo T_1-weighted image with fat suppression at the following time point at 1 min, 2 min, 4 min, and 7 min, 3) Post processing subtraction for the MRI image was obtained between the post contrast imaging showing maximum enhancement and pre-contrast images (in the same axial plane), using the software subtraction function, and 4) Quantitative analysis was done by placing the region of interest (ROI) at the most enhanced part with the lesion result in automatically created time/signal curve. The type of curve (type 1, type 11, type 111), determine the type of tumors. Qualitative analysis of mammography, ultrasound, and breast MRI was done by three radiologists who were blinded to the clinical, operational and histopathological examination.

2.4 MRI image interpretation and criteria for evaluating the presence of breast lesions

Conventional T_1 and T_2 weighted images were first examined to detect the presence or absence of benign lesions (e.g. cysts and fat containing lesions) then T_1 dynamic and subtraction images were examined to detect the presence or absence of lesion enhancement.

In case of lesion enhancement the corresponding non subtracted pre-contrast and post contrast images in each time point was viewed together and lesions interpretation took place, whether it is a focus, mass or non-mass like enhancement.

In case of mass enhancement evaluation was carried out as follows: 1) Its shape (regular or irregular), 2) Its border (well defined, ill defined, speculated), 3) Pattern of enhancement (homogenous, heterogeneous or ring enhancement), 4) The dynamic behavior of the mass with evaluation of the percentage of enhancement as well as the shape of time/signal intensity curve (type I, type II or type III) was studied, 5) In case of non-mass like enhancement, its distribution and enhancement pattern were evaluated, and 6) MRI findings were correlated with histopathological result.

2.5 Statistical analysis

Data were initially summarized in a form of comparison tables and graphs. All statistical calculations were done using computer program of the standard Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) version 20 for windows.

3. RESULTS

The results of this study were obtained from 254 patients; 14 (5.5%) males and 240 (94.5%) female, aged between 15-78 years old as presented in Figure 1 below. Table 1 demonstrates MRI findings and histopathological results cross tabulation.

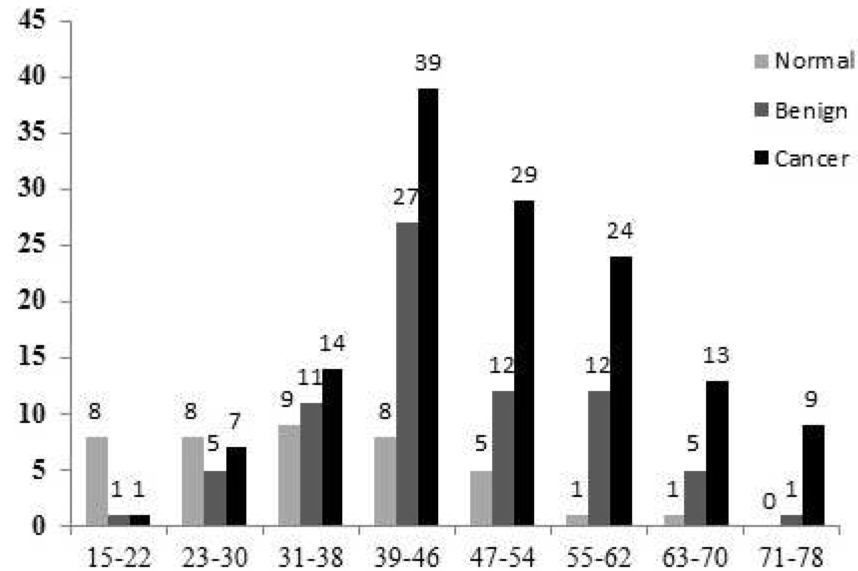

Fig. 1. The distribution of females' age, according to tumors count.

Table 1. MRI findings and histopathology result cross-tabulation

Histopathology	MRI examination finding			Total
	Normal	Benign tumors	Irregular/Suspected Cancers	
Normal	30	11	0	41
Benign	1	62	19	82
Malignant	0	17	114	131
Total	31	90	133	254

The sensitivity of DCE-MRI in detecting breast lesions was (82.7%) and the accuracy was (81.1%), when compared to other diagnostic modalities as mammography or ultrasonography as shown in Table 2.

Table 2. The sensitivity, specificity and accuracy of MRI compared with other imaging modalities

Modality	Specificity (%)	Sensitivity (%)		Accuracy (%)
		Benign	Malignant	
DCE-MRI	(73.2%)	(82.7%)	(82.6%)	(81.1%)
Ultrasound	(75.6%)	(68.0%)	(30.4%)	(48.8%)
Mammography	(73.2%)	(60.0%)	(37.7%)	(50.0%)

In Table 3, T_1 with contrast presented high signal in malignant breast lesions (97.8%). This signal increased after contrast administration. In addition, there was an increase in the signal, when the images that subtracted the tumors were isolated from normal tissues. Such findings were presented in Table 4, and Figure 2. Also, it was found that T_2 has high signal in some benign tumors such as cyst, and duct ectasia (95.1%).

Table 3. T_1-weighted with contrast and histopathology result cross-tabulation

Histopathology	T_1 with contrast			Total
	Hyper-signal	Hypo-signal	Iso-signal	
Normal	3	15	23	41
Benign	17	39	19	75
Cancer	115	16	7	138
Total	135	70	49	254

Table 4. Image subtraction result and histopathology cross-tabulation

Subtraction	Histopathology			Total
	Normal	Benign	Malignant	
Normal	1	3	1	5
Homogeneous	40	42	12	94
Heterogeneous	0	26	113	139
Ring enhances	0	4	12	16
Total	41	75	138	254

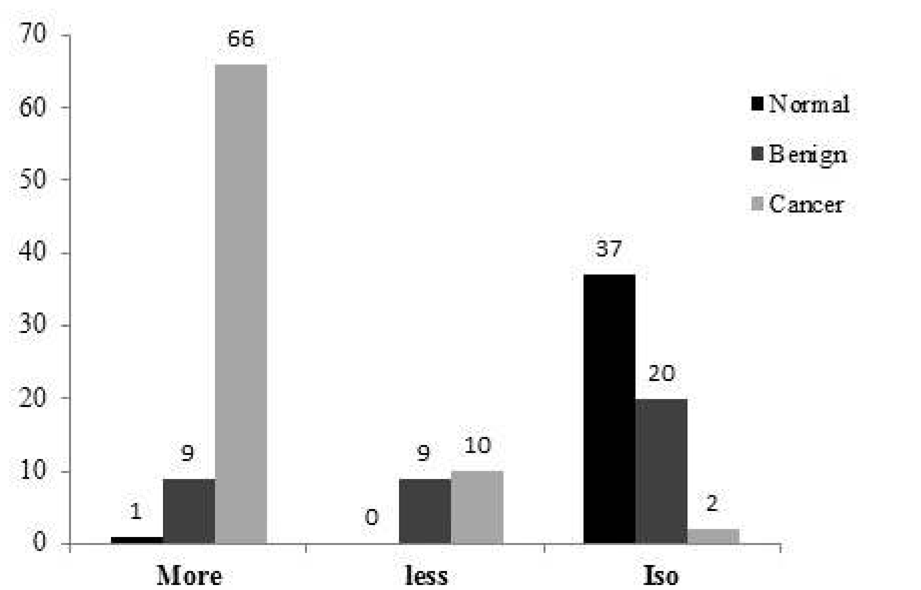

Fig. 2. Signal intensity in fat suppression images.

Quantitative measurement of kinetic curve type resulted in significantly higher diagnostic performance when compared with the qualitative assessment, that rapid wash (86.0%) is highly suggested of cancer, plateau (26.7%) cancer and persistent cancer (1.6%) as depicted in Table 5.

Table 5. Shows curve type in dynamic contrast enhanced MRI (DCE-MRI)

Curve type	Histopathology			Total
	Normal	Benign	Malignant	
Persistent	2	17	1	20
Plateau	1	13	16	30
Rapid	0	7	43	50
Total	3	37	60	100

4. DISCUSSION

This study consisted of 254 patients with the aim to evaluate the accuracy of magnetic resonance imaging (MRI) in characterizing breast abnormalities and tumors, in comparing to other diagnostic modalities and histopathological findings. The result of this study revealed that the incidence of breast cancer increased in all ages, but more so in women in the group (39-47) years (Figure 1). Risk factors for incident include older age and family history. The sensitivity and specificity of MRI were (82.6%) and (73.2%) respectively (Table 2). This result was in line with a previous study conducted in ductal carcinoma, which also reveals the high sensitivity of MRI over mammography in detecting breast tumors [10].

Fat suppression is commonly used in MR imaging to suppress the signal from adipose tissue or detect adipose tissue. However, this technique is not specific for fat, and the signal intensity of tissue with a long T_1 and tissue with a short T_1 may be ambiguous. Opposed-phase imaging is a fast and readily available technique [11]. The result of this study showed that breast cancer was more enhanced with fat suppression images (Figure 2), because this method suppressed the fat signal more potently and improved contrast and visibility of the breast lesions that embedded in fatty tissue [12].

In T_1 and T_2 relaxation times additively contribute to the contrast; therefore, also considering the inherent fat suppression, contrast is extremely good, and tissue with long T_1 and long T_2 may appear very bright [13].

Regarding signal intensity, the study showed that breast cancer has high signal intensity on T_1 image (Table 3), while it has hypo or iso-signal intensity on T_2 images. On T_2 weighted images, fat has intermediate signal intensity. The signal intensity of remaining tissue depends on their water contents, and increases from the fibrous element which very low signal to glandular and ductal element to cystic lesions which have a very high signal intensity [14].

CE-MRI has been shown to be more sensitive than mammography in detecting DCIS. The study showed that most breast cancer cases have been enhanced, the result was in line with the study of Wiener et al, 2004 [15], it showed that the primary index lesions, the sensitivity of MRI was (100%) in predicting a breast malignancy and the specificity was (73.7%) in predicting benign lesions. MRI detected an additional 37 lesions, of which 23 were cancerous, beyond those suspected on mammography or sonography [15].

The image subtraction technique was performed it showed that the cancer has heterogeneous features (89.9%), and ring enhancement was clearly seen on (8.7%). This result in line with the previous studies as speculated or irregular margin is suspicious for carcinoma where a smooth margin is more suggestive of benign lesion [16].

DCE-MRI has been used to evaluate focal breast lesions (Table 5). Adding information derived from the kinetic curve type of the architectural features of a lesion, improves the specificity of breast MRI [17]. By categorizing the type of the enhancement curve either as an absolute change in percentage enhancement, significantly greater values were seen compared with the qualitative method. In this study only 100 patients were selected for DCE-MRI, it revealed that most cases of cancer represented on type 111 curve or rapid wash out. However, quantitative measurements of kinetic curve type resulted in significantly higher diagnostic performance and increasing specificity of MRI.

It was stated that DCE-MRI imaging has high negative predictive value in excluding breast cancer, so it plays a role in the evaluation of selected clinical and imaging findings of the breast, especially when biopsy is not technically feasible. Case selection is very important in ensuring the efficacy of this use of MR imaging because of potential false-positive and false-negative results [18]. In our study the overall sensitivity of DEC-MRI, ultrasound, and mammography was 82.7%; 82.6%, 68.0%; 30.4% and 60.0%; 37.7% for both benign and malignant breast lesions respectively (Table 2) .Their specificity was 73.2%, 75.6%, and 73.2% respectively (Table 2). DEC-MRI was the most sensitive imaging method for detection of cancer but with limited specificity due to overlap in features of benign and malignant lesions.

The main additional diagnostic value of DEC-MRI relies on detecting foci of multifocal, multicentric or contra-lateral disease unrecognized on conventional assessment (physical examination, mammography and ultrasound); recognition of invasive components in ductal carcinoma in situ (DCIS); assessing the response to neoadjuvant chemotherapy (NAC); detecting an occult primary breast cancer in patients presenting with metastatic cancer in axillary nodes; and detection of cancer in dense breast tissue [19]. DCE-MRI is an emerging imaging method to enable the depiction of physiologic alterations and to assess tumor angiogenesis [20]. This angiogenesis have been often too small to be proved by another imaging method [21]. Among the limitations of breast MRI are its higher cost, longer examination time, and lower availability compared with mammography and ultrasound [22].

5. CONCLUSION

In conclusion, the accuracy of MRI in this study was more than other imaging modalities in characterizing breast abnormalities and tumors. Therefore, it offers a new method to detect breast cancer in its early stage, and help improve the survival rate.

CONSENT

All authors declare that written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

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