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Original article

Value of Diffusion Weighted Imaging in Ovarian Lesion Diagnosis

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Abstract:

Background: Surgical exploration and histologic evaluation are often required to determine the nature of the ovarian tumors being benign or malignant. Therefore, it may be impossible to determine beforehand whether minimally invasive or extensive surgery is required. Better preoperative planning might be accomplished with the use of a trustworthy approach that could distinguish malignant and benign masses. MRI is beneficial for identifying ovarian masses and their origins due to its sensitivity and improved characters by the application of diffusion-weighted imaging. This research aimed to assess the characterization of ovarian lesions using MRI with DWI. **Methods:** Forty patients diagnosed to have ovarian masses were evaluated in this cross-sectional analytical study after being referred to the University Hospital at the radiology department. All patients were exposed to pelvic MRI with DWI, and 7 underwent DWIBS. Surgery was performed with pathologic correlation on 39 individuals. Only one patient was given a 3-month course of routine US monitoring. **Results:** MRI's sensitivity was 99.9 percent, whereas DWI's was one hundred percent. When comparing DWI with traditional MRI, the former has a greater specificity (78.1%) while the latter has a better accuracy (86.0%). On average, malignant lesions had an ADC of ($0.93x\ 10^{-3} \pm 0.43$ SD mm^2/s), whereas benign ones had $1.3 \times 10^{-3} \pm 0.6$ SD mm^2/s with a p value = 0.005. Because of the teratoma's mixed cellularity, mature teratomas exhibited restricted diffusion with ADC values of $0.5x10^{-3} mm^2/s$ (false positive). **Conclusion:** The specificity of conventional MRI was enhanced when combined with DWI, boosting radiologist confidence in picture interpretation and, in turn, improving patients' outcomes and prognoses.

1. Introduction:

The most common reason for gynecological surgery is ovarian masses. The main aim of diagnostic modalities is to avoid unnecessary cancer surgeries, preservation young women's fertility (by enabling laparoscopy), and as required, enable women to be sent to a tertiary care facility where a gynecologic oncologist can provide the highest quality primary surgical treatment [1].

Surgical exploration and histologic evaluation are often required to discriminate the clinically diagnosed tumors of the ovaries whether benign or malignant. Therefore, it may be impossible to determine beforehand whether minimally invasive or extensive surgery is required. Having a reliable approach to determine if the mass is benign or malignant would allow for better management avoiding laparotomies on individuals having benign conditions [2].

Due to recent advancements in technology, diffusion MR imaging may now be used for abdominal and pelvic purposes either with the initial diagnosis or with assessment of treatment [3].

For precise internal architectural characterization of ovarian tumors, including the identification of papillary projections, necrosis, solid components, peritoneal implants, and septations, MRI is advised [4].

Having a pelvic MRI performed may be beneficial in complex instances and may aid with a more accurate diagnosis. When ultrasound cannot provide a definitive diagnosis or when there are concerning or inconclusive findings on ultrasound, MRI is often used to evaluate cystic or solid ovarian tumors. The mass's location and whether it is cystic, solid, or complicated may be determined by MRI as its accuracy in distinguishing benign from malignant tumors is rather good. MRI is considered as a powerful diagnostic modality of teratomas, endometriomas, simple and hemorrhagic cysts, fibromas, exophytic or extrauterine fibroids, and hydrosalpinxes [(5)] .

Diffusion-weighted imaging may be utilized to discriminate between benign and malignant tumors in addition to treatment-related alterations and cancers that have a chance of survival by providing quantitative information about tissue cellularity [(6)] .

Cancers have shown reduced values of apparent diffusion coefficient (ADC) in gynecologic applications of DWI. ADC values are seen to increase in carcinomas that react to radiation therapy, making it a useful biomarker for treatment response, recurrence assessment, and multi-focal evaluation [(7)] .

Ovarian cancer peritoneal implants are a Privilege for diffusion weighted MR imaging because the small seeds coating the intestinal loops at the serosal surface and Solid viscera or invaginated within peritoneal reflections or masked at the adjacent structures. In addition, suppression of the signal by the intestinal contents, ascites or fat around the malignant deposits is alleviated on diffusion-weighted imaging [(8)] .

When anatomic MR pictures are analyzed alongside diffusion weighted images, possible drawbacks of the approach may be avoided. Radiologists will have more tools at their disposal for making diagnoses of gynecologic cancers if they are trained in the computation and modification of diffusion coefficients using imaging software [(9)] .

When applied to body applications, DW-MRI has seen a substantial increase in picture quality, especially in the abdominal and pelvic regions, the new imaging techniques, in particular innovative ways of data collecting and parallel imaging [(10)] .

Volumetric whole-body diffusion-weighted pictures are now possible because of the newly established idea of DWIBS. When applied to oncological imaging of the complete body, this novel idea offers potential advantages over traditional DWI. With its “contrast-to-noise” ratio, DWIBS may be particularly helpful in detecting relatively tiny lesions (CNR). DWIBS has the ability to identify ovarian cancer that has spread to the peritoneum. DWIBS may also be used for evaluation of radiotherapy and/or chemotherapy [11] .

This research aimed to assess the added value of DW-MRI to MRI in the detection of ovarian masses.

2. Methods:

Forty patients with ovarian masses were analyzed in this prospective research, all of whom had been referred to radiology from the Gynecology department after an US examination. All patients were subjected to pelvic enhanced MR with DWI, and 7 patients underwent DWIBS. Pathologic correlation was performed during surgery on 39 individuals. One patient was subjected to frequent US monitoring for three months. The research was conducted at the National Cancer Institute and Radiology Department of Beni-Suef University Hospital from January 2016 to May 2017.

Patients' ages covered the range from 12 years old to 75 years old. Twenty patients reported chronic abdominal discomfort; six reported abdominal enlargements; the other cases presented with a variety of additional symptoms, such as infertility, frequent micturition, dysuria, and weight loss. Adnexal masses had also been seen incidentally during transabdominal pelvic US. All patients had a thorough history and physical examination, with specific attention paid to their age, menstrual history, previous pregnancies, gynecological difficulties or procedures, Pelvi-abdominal US/TVUS, and MRI.

Diagnostic magnetic resonance imaging

For the MRI scan, we used a 1.5-Tesla magnet provided by (Achieva, Philips medical system). Scanning was done while the patients lying on their backs using a pelvic phased-array Torso coil.

In order to decrease intestinal peristalsis for MR imaging, prior to the procedure IV antispasmodic medication (10 mg of spasmofree) was administered.

MR imaging protocol

Non-contrast axial procedure was done with, T1-weighted (TR/TE, 487/10 ms), T2-weighted (TR/TE, 8436/115 ms) with Slice thickness, 6 mm. FOV, 32–42 cm. Gap, 1 mm. Matrix, 256 x 256. Sagittal T2-weighted and Coronal T2-weighted was done with, Slice thickness, 8–10 mm. FOV, 40–50 cm. Gap, 1 mm. Matrix, 256 x 256.

Before the contrast medium was injected, a single shot echoplanar imaging sequence was used to obtain an axial DW-MRI. With b values (0, 500, 1000 & 1500).

TR/TE, 1763/63. Slice thickness, 6 mm. FOV, 36 cm. Gap, 1 mm. Matrix, 128 x 128.

The contrast was injected manually using gadolinium (0.1 mmol/kg) with maximum, 20 mL and then rinsing with 20 mL of normal saline. At 0, 30, 60, 90 and 120 S. sequential images were obtained. At last, T1-weighted gradient-echo pictures were obtained in the axial, sagittal, and coronal planes in addition to DWIBS.

Analysis of MR imaging:

Analysis of different MRI images to identify the nature of the tumor whether solid, cystic or mixed, size, involvement of both ovaries or one only, shape of the lesion, wall thickness, presence of septations and vegetation. In addition, analysis should include ascites, lymph node involvement either the pelvic or the paraaortic, pelvic organ infiltration, deposits on the peritoneum or omentum.

Predictive MRI Findings for Noncancerous Masses:

- In T1WI, high signal indicates either fat or blood. (Such as dermoid, teratoma or endometrioma, for instance). Images with fat subtraction showed low signal with fat and high signal with blood.
- Fibrous tumors often appeared as solid masses with low signal intensity at T2WI.

Adnexal masses that met the criteria for malignancy on MRI were classified as mentioned in Rajkotia and his colleague work [(5)].

DWI Interpretation

Qualitative analysis

As regards the intensity of the signal, malignant masses usually appeared on diffusion images with high signal intensity (restricted diffusion) and on matched ADC maps with low signal intensity, and vice versa for benign masses.

Quantitative analysis

We manually picked the ROI (region of interest) on the solid and the cystic component of the tumors, and the workstation automatically computed the ADC values, all as part of the quantitative analysis of DWI. The mean ADC value for benign lesions was (1.69 x 10^{-3} ± 0.6 SD mm^2/s), while the mean ADC value for malignant lesions was (0.93x 10^{-3} ± 0.43 SD mm^2/s), with a cutoff value of $1.15x10^{-3}$. This data comes from research conducted by Li and colleagues in 2011 [(12)].

Statistical analysis:

Descriptive data were reported as mean ± SD. Categorical variables were reported as counts and proportions. Univariate analysis included Fisher exact or Chi-square tests to compare categorical variables and T-test for scale data. Two-tailed tests were performed on all comparisons, and results with a p value less than 0.05 were deemed significant. The IBM SPSS version 25 statistical program was used for the analyses.

Ethical considerations:

All data was anonymous and confidential. No one was obliged to participate in this study and all patients have the right to withdraw from the study at any time. All permissions were taken from the included departments in the study.

3. Results:

The total number of participants in this research was 40. People as young as 12 and as old as 75 made up our patient population. Pateints with benign tumor had an average age 41.83 ± 12.8 years (range was between 21 and 60 years), while the ages of patients having malignant tumors 47.69 ± 12.53 years (range was between 12 to 75 years). A total of 39 cases were confirmed by pathology. Pathological subtypes of cancers were identified as twenty-two benign lesions (56.4%), one borderline lesion (2.6%) and sixteen malignant lesions (41%).

The benign lesions addressed as: six fibro-thecomas, two papillary serous cyst adenofibromas, three serous cystadenomas, two mucinous cystadenoma, one endometrioma, one tubo-ovarian abscess, four mature cystic-teratomas, one struma ovarii, one hemorrhagic infarction in a simple cyst and one ovarian fibroma with infection and infarction transformation. The borderline lesion was sertoli-leydig tumor (sex cord stromal tumor). Malignant lesions contained: five mucinous cystadenocarcinomas, five papillary serous cystadenocarcinoma, one dysgerminoma, one case with clear cell carcinoma, two cases with juvenile granulosa cell tumor and two immature teratoma.

A missing instance that required neither surgical excision nor pathological proof (hemorrhagic cyst). Solid, convoluted cystic, and combined cystic and solid lesions were also often seen. Ten individuals had malignant tumors that met diagnostic criteria, and MRI was able to identify them. More than 6 centimeters in length, 3 millimeters or more in thickness or septae, and 1 centimeter or more of solid vegetation. The pathology results on five instances that seemed suspicious on MRI due to their size, thickness of the septae, or presence of a solid nodule ruled out malignancy: papillary serous cystadenofibroma, simple cyst haemorragic infarction, fibrothecoma, struma ovarii, and mature cystic teratoma,

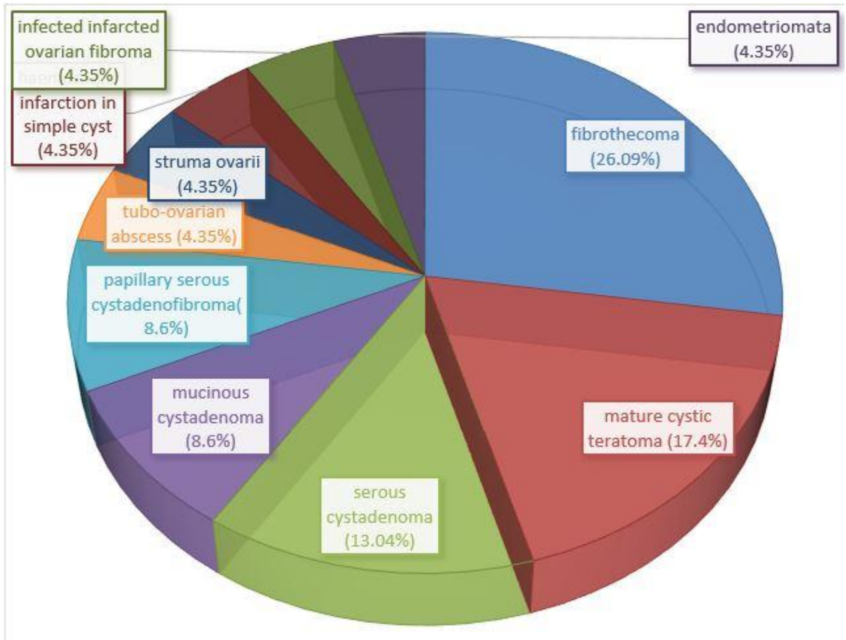


Figure (1) Different types of benign lesions.

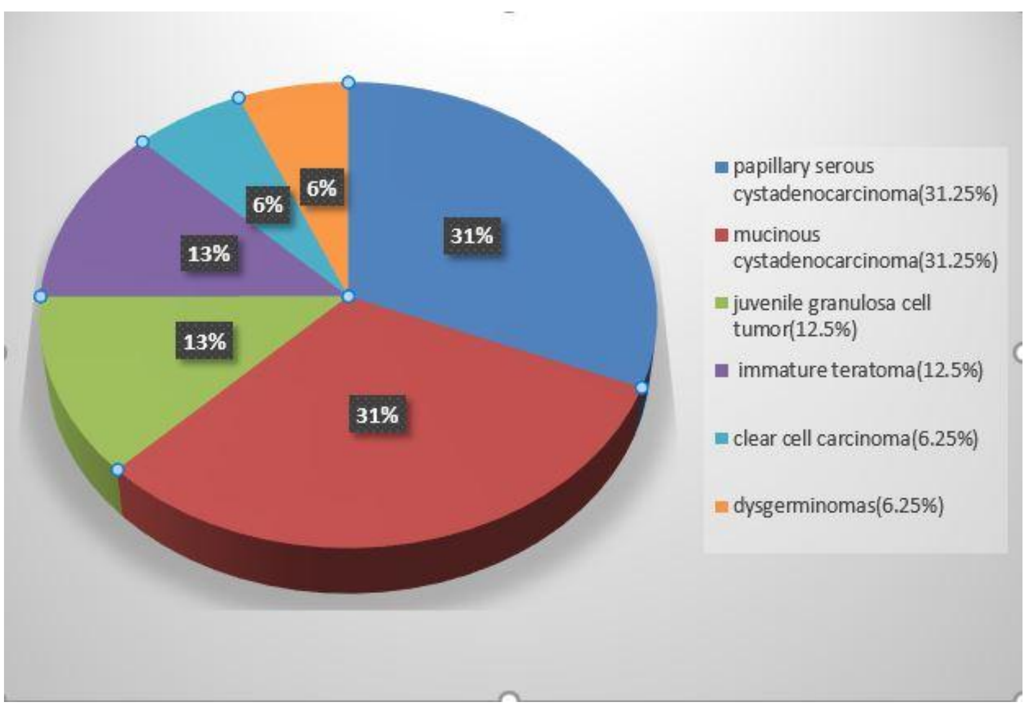


Figure (2) Tumors with varying malignant pathology.

Table (1) Comparison between different lesions regarding the ADC values.

Pathology	ADC values
Tubo-ovarian abscess (n=1)	**($0.9x10^{-3}$ mm^2/s)**
Papillary serous cystadenocarcinoma(n=5)	**(0.5 -$1.1x10^{-3}$ mm^2/s)**
Juvenile granulosa cell tumor (n=2)	**($0.7x10^{-3}$ mm^2/s)**
Borderline sertoli-leydig tumor of low malignant potential (n=1)	**($1x10^{-3}mm^2/s$)**
Mucinous cystadenocarcinoma (n=5)	**($1.1x10^{-3}$ mm^2/s)**
Fibrothecoma (n=6)	**($1x10^{-3}$ mm^2/s)**
Mature cystic teratoma (n=4)	**($0.6x10^{-3}$ mm^2/s)**
Mucinous cystadenoma(n=2)	**(0.8-2.6 x 10^{-3} mm^2/s)**
Papillary serous cystadenofibroma(n=2)	**($1.9x10^{-3}mm^2/s$)**
Serous cystadenoma (n=3)	**($1.9x10^{-3}mm^2/s$)**
Clear cell carcinoma (n=1)	**($1.1x10^{-3}mm^2/s$)**

Figure (3) showed that average ADC levels for cancerous tumors were (0.93x 10^{-3} ± 0.43 SD mm^2/s), whereas the average of the cases of benign lesions were (1.3 x 10^{-3} ± 0.6 SD mm^2/s). The ADC value can significantly distinguish malignant and benign lesions with a cut off $1.15x10^{-3}$ (p-value = 0.005).

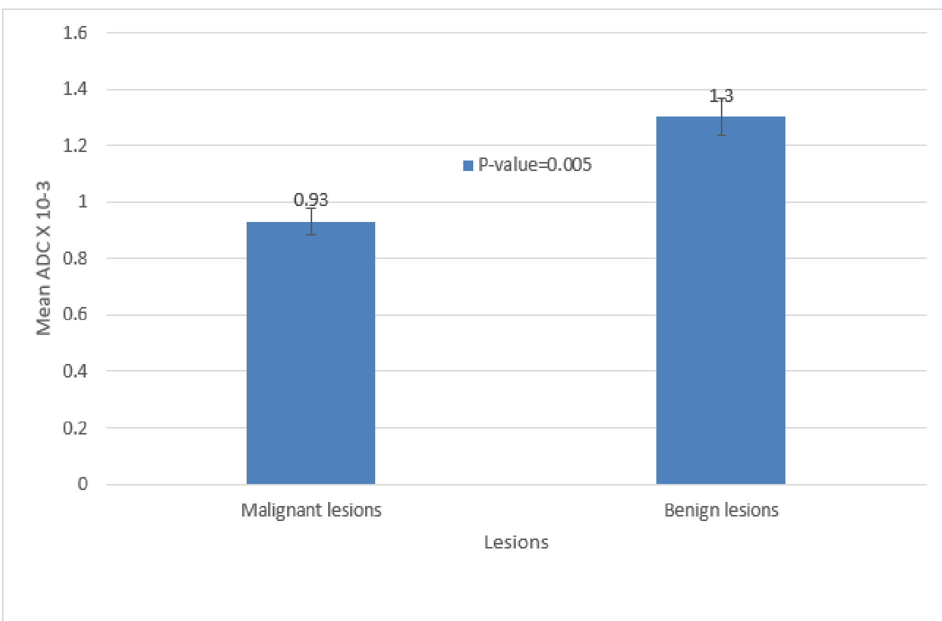
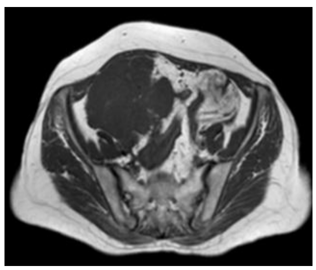
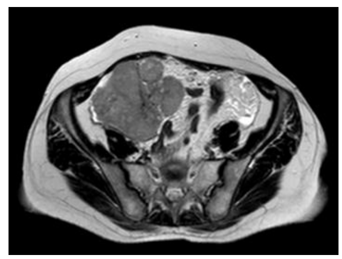


Figure (3) Comparison between benign and malignant lesions regarding their ADC value.

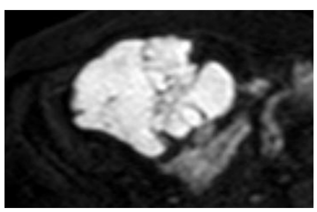
Figure 4: Fifty-three years old female presented with abdominal swelling. Ultrasound detected a mass in the right adnexa. The existence of a largely solid mass with modest regions of cystic collapse in the right adnexa was verified by conventional MRI scans (a&b). T2-weighted images revealed moderate signal intensity in the peritoneum, with maximum TS X AP dimensions of around 5 x 4 cm. **DWI (c & d),** Low signal on ADC maps corresponds with the restricted diffusion seen around the lesion on DWI. An analog-to-digital converter reading of 0.9 x 10^{-3} mm^2/s was obtained. **CE-MRI (e), the** lesion had heterogeneous enhanced contrast. The case pathologically proved as a papillary serous adenocarcinoma.



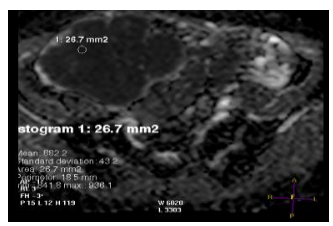
(a)axial T1 WI (TR/TE,487/10ms)



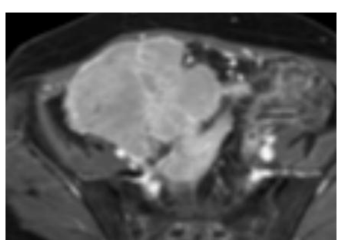
(b) Axial T2 WI(TR/TE,8436/115)



(c) DWI (TR/TE 1763/63)

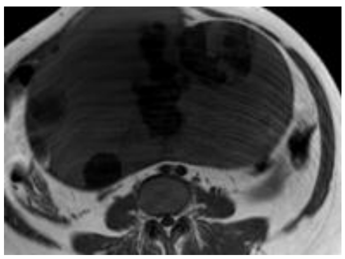


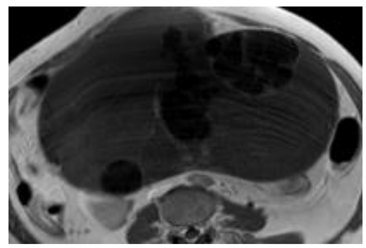
(d) ADC



(e)T1post contrast

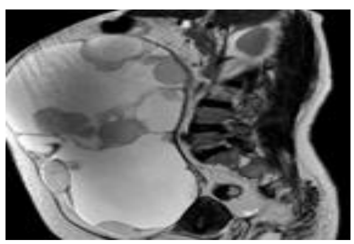
Figure 5. multilocular adnexal lesion was seen on conventional MRI (a & c). It's made up of several locules with different signal intensity ; some are small and faint on T1WI while others are large and bright on T2-WI and measures about 15 mm length and 10 mm width at their maximum TS X AP. **DWI (d & e)** The presence of a low signal on DWI with low signal on the matching ADC maps is diagnostic of a benign adnexal mass lesion. The ADC of the lesion was 2.6 x 10^{-3} mm^2/s. **CE-MRI (b):** Internal septations inside the lesion were shown to be enhanced by contrast. **Radiological diagnosis:** Mucinous cystadenoma is the most likely diagnosis for this benign cystic ovarian tumor with varying signal intensities and no solid component. **Pathological diagnosis:** concluded that it was a benign mucinous cystadenoma.



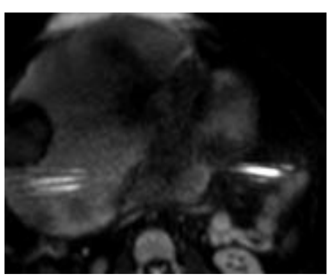


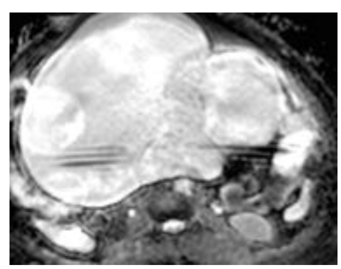
(a)axial T1 WI (TR/TE , 487/10 ms)

(b)T1post contrast



(c) sagittal T2WI (TR/TE , 8436/115)





(d) DWI (TR/TE, 1763/63)

(e) ADC

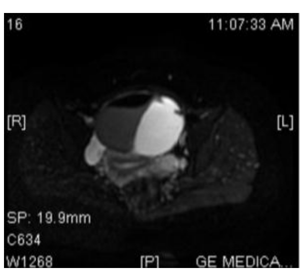
Figure 6: 34-year-old female patient complaining of abdominal discomfort . A well-defined RT adnexal mass with mixed signal and fat fluid level was seen on conventional MRI (a-c). The high T1 and T2 WI in the anterior region, together with the corresponding reduction of signal in the fat suppression image, is indicative of the presence of fat in the region. Cystic features are consistent with the low T1 and high T2 values seen in the posterior region. The TSxAP sizes are 7 cm and 5 cm, respectively. Signal loss at a single location is seen in all pulse sequences, which is consistent with calcification. **DWI (d & e):**

Both DWI and ADC indicated a high signal in the cystic area. There was a 0.5 x 10^{-3} mm^2/s increase in the lesion's ADC. **Radiological diagnosis:** Lesion of the right adnexa, most likely an ovarian teratoma. **Pathological diagnosis:** revealed mature (benign) cystic teratoma.

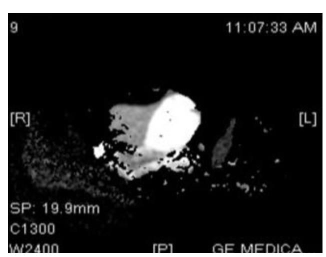
(a) axial T1WI (TR/TE , 487/10 ms)

(b) axial T2WI(TR/TE , 8436/115)

(c) T1 with contrast fat suppression

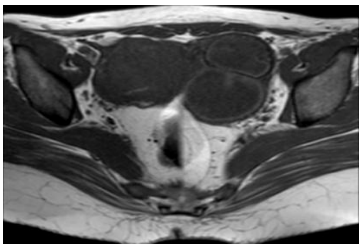


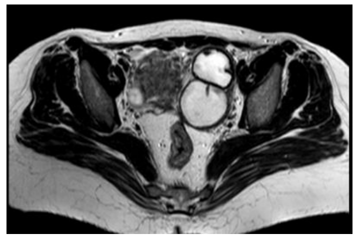
(d) DWI (TR/TE, 1763/63)



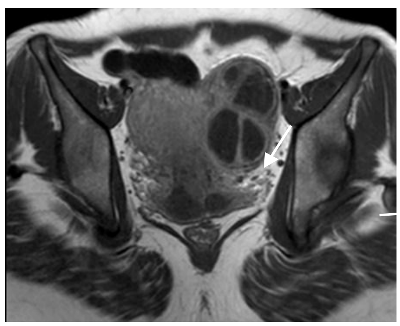
(e) ADC

Figure 7: 35 years old female presented with fever and lower abdomen discomfort. US revealed a left bilocular cystic adnexal tumor. The left adnexa had a cystic mass lesion with intermediate signal at T1 thick septa (a & b). Its maximum TS and AP dimensions are 6x2 cm. **DWI (d & e):** low signal on the ADC maps. The lesion's ADC value was 0.8 x 10^{-3} mm^2/s. **CE-MRI (c):** Contrast enhanced lesion with thick septations. **Pathological diagnosis:** left tubo-ovarian abscess was confirmed.

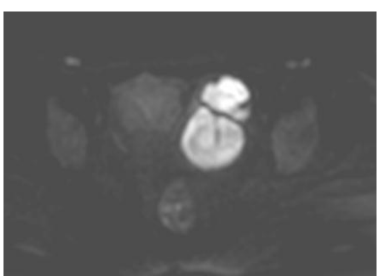


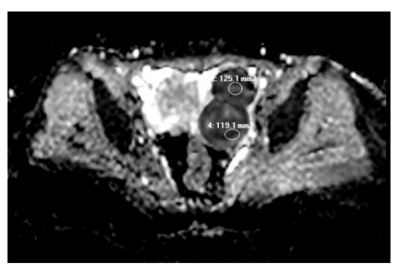


a)axial T1WI (TR/TE , 487/10 ms)   (b) axial T2WI(TR/TE , 8436/115 ms)



(c) coronal T1 post contrast.





(d) DWI (TR/TE , 1763/63)   (e) ADC

4. Discussion:

Imaging is used to determine whether a tumor in the adnexa is cancerous. Accurate diagnosis will direct patients to right management, decreasing unnecessary cancer surgery and protecting young women's fertility. The treatment plan might change to laparoscopy, and referral to a specialist gynecologic oncologist when necessary [13] .

MRI has been useful for a long time in detecting malignant tumors prior to surgery, especially when US results are less than ideal or inconclusive. Papillary projections, presence of septae, nodularity, presence of solid parts, and signal intensity on T1- and T2-weighted MRI are all morphologic features that may be shown, however none of them effectively differentiate benign from malignant tumors [14] .

It has been established that DWI is one of the potential novel functional imaging approaches in detection of adnexal tumors in addition to differentiation between benign and malignant lesions [15] .

DWI found that MRI had a sensitivity of 99.9 percent in this trial, whereas its own sensitivity was 100 percent. Adding DWI to an MRI scan has been shown to improve both its specificity (78.3%) and the overall accuracy (86.9%), as compared to those of traditional MRI sequences (58%). Statistics showed that average ADC levels for cancerous tumors were ($0.93x\ 10^{-3} \pm 0.43$ SD mm^2/s), whereas the average of the cases of benign lesions were ($1.3\ x\ 10^{-3} \pm 0.6$ SD mm^2/s). The ADC value can significantly distinguish malignant and benign lesions with a cut off $1.15x10^{-3}$ (p-value = 0.005). Due to the teratoma's mixed cellularity, mature teratomas exhibited limited diffusion with ADC values of $0.5x10^{-3}mm^2/s$. (false positive). Both hemorrhagic cysts and endometriomas had significant signal on diffusion imaging, with matching ADC maps and ADC values of 1.3 to $1.4x10^{-3}$, which may be described as T2 Shine through.

In 2008, Fujii and coworkers examined 123 ovarian tumors, 42 of which were cancerous and 81 of which were benign. On DWI, he observed that malignant tumors, mature cystic teratomas, and nearly 50% of endometriomas had high signal intensity, but benign lesions and fibromas did not. Malignant ovarian tumors tended to have abnormally strong signals in their solid regions, mature cystic teratomas showed keratinoid substances and a Rokitansky protuberance, and endometriomas showed intracystic clots. Our findings are consistent with the literature, which reports that keratinoid material is responsible for the strong signal on DWI seen in 100% of malignant lesions and in 2 cases with mature cystic teratomas [9] .

For the purpose of characterizing 77 complicated adnexal masses, Thomassin-Naggara et al. assessed the role of DWI combined with morphological features (30 benign and 47 malignant). They postulate that the absence of confined diffusion signal in the solid component of the mixed adnexal masses and a low signal intensity on T2-weighted images are indicative of benignity. They hypothesized that the high collagen content of the extracellular matrix in benign fibrous tumors including fibromas, Brenner tumors, and cystadenofibromas explains the low mean ADC values seen in these tumors. Only two mature cystic teratomas (one diagnosed as hemorrhagic infarction in a simple cyst and the other as struma ovarii) were the only benign tumors in our research to exhibit strong signal on DWI [1] .

In 2010, the study of Takeuchi and colleagues performed on forty nine ovarian masses (thirty nine malignant/borderline malignant, and ten benign lesions) demonstrated that 39 malignant lesions had solid portions with heterogeneous or homogenous high intensity as detected by DWI, while only 3 of the 10 benign lesions (3 thecomas) showed high intensity, and the average ADC value in the 39 malignant lesions was 1.03×10^{-3} mm^2/s and was significantly lower than that of the ten benign lesions [16] .

In 2012, Zhang and coworkers examined 199 individuals with 202 ovarian masses to see whether they could tell benign from malignant tumors before surgery by comparing their ADC values for the malignant ovarian surface epithelial tumors and solid component of benign. After excluding endometriomas, mature cystic teratomas, and pure cystic adenomas, the research concluded that DWI had good sensitivity and specificity for discrimination between malignant tumors and benign epithelial tumors having solid components. Benign and malignant lesions have vastly different mean ADC values for solid component. Benign tumors had a value of 1.69×10^{-3} while malignant tumors had an average ADC of 1.03×10^{-3} 0.22 SD mm^2/s. The lower values of ADC in malignant lesions were found to be significant statistically. According to their findings, a cutoff value of ADC 1.25×10^{-3} mm^2/s may be useful for distinguishing the malignant from the benign ovarian lesions. Based on our findings, a threshold value of 1.15×10^{-3} mm^2/s may be useful for distinguishing malignant from benign ovarian tumors, with the mean ADC value for malignant lesions being (0.93x 10^{-3} ±0.43 SD mm^2/s) and that for benign lesions being (1.3 x 10^{-3} ±0.6 SD mm^2/s) [14] .

While fen et al. conducted their own investigation using a threshold value of ADC (1.063x 10^{-3} mm^2/s), we found that our study's cutoff value of 1.1510^{-3} was more appropriate for detecting ovarian cancer [17] .

In 2015, Ahmad and colleagues conducted research using DWI on twenty women with ovarian cancer. Adnexal tumors were analyzed for their shape, size nature (solid-cystic), enhancement, and signal intensit. They demonstrated that the conventional MRI and DWI sensitivity was 96.5% and specificity was 89.1%. and results in our study showed sensitivity was 100% and specificity was 78.3% [18] .

In 2011, Li and coworkers evaluated the efficacy of DWI in ovarian masses characterization in patients who performed MRI. There was a total of twenty-sex benign lesions, eight malignant lesions, and 1 tumor that was on the cusp of becoming malignant included in the research. Only in DW images did malignant lesions exhibit a clear high signal intensity [12] .

While the majority of malignant epithelial ovarian tumors (MEOTs) showed low signal intensity on DWI, most of borderline epithelial ovarian tumors (BEOTs) showed high signal intensity on DWI, according to a study conducted by Zhoa and colleagues in 2014 comparing BEOTs with MEOTs, the solid component of BEOTs had a substantially higher average ADC value than MEOTs (1.562±0.346 x 10^{-3} mm^2/s Vs 0.841±0.209 x 10^{-3} mm^2/s) respectively. DWI indicated the tumor to have persistently high and moderate signal intensity on the ADC map with a relatively high ADC value (1.2 x 10^{-3} mm^2/s), although our analysis only comprised a single tumor with low malignant potential (a sertoli-leydig tumor) [19] .

Seven patients underwent DWIBS, which has a high "contrast-to-noise" ratio and may therefore be used to identify relatively minor lesions (CNR).

5. Conclusion:

Combination between DWI and conventional MRI, increased in the accuracy of MRI. Also, being no ionizing imaging modality added more advantage to that imaging modality. As an extra bonus, this procedure doesn't add much time or money to an MRI scan, making it valuable option for many types of research. Diffusion images can be done without contrast in cases with renal impairment.

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