

## Evaluation of Diffusion Weighted MRI Findings and ADC Values within the Solid Component According To Histological Types of Ovarian Masses

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### ABSTRACT

**Introduction:** Diffusion-weighted imaging (DWI) is a useful technique in the assessment of adnexal masses; however, its role has been controversial in literature. Thus, the present study was undertaken to determine the relationship between the apparent diffusion coefficient (ADC) values of pathologically confirmed benign and malignant ovarian masses.

**Material and Methods:** The present hospital based observational descriptive study was conducted over 50 patients diagnosed with ovarian masses on Ultrasound or on clinical examination and were evaluated with pelvic MRI. Differences in mean tumor ADC values between benign and malignant groups was evaluated using Student's t - test. p - value < 0.05 was considered statistically significant. Receiver operating characteristic (ROC) curve analysis was performed in order to assess the diagnostic performance of the mean ADC values in terms of characterization of benign and malignant ovarian tumors. Positive and Negative likelihood ratio for malignancy was also determined.

**Results:** Although some overlap in ADC values was observed between the benign and malignant groups, the mean ADC value of the 11 malignant ovarian tumors was significantly lower than that of the 33 benign ovarian tumors (P < 0.001). Our results suggest that an ADC value  $\geq 1.23 \times 10^{-3}$  mm<sup>2</sup>/s

may be the optimal cutoff for differentiating between benign and malignant tumors. Furthermore, a sensitivity of 82.4%, a specificity of 95.2%, a PPV 81.4%, an NPV of 82.1%, and an AUC of 0.94, was observed with this ADC cutoff value.

**Conclusion:** The results suggest a potential role for DW imaging with quantitative analysis of ADC values in improving the diagnostic performance of ovarian MRI and yielding functional measures of the tumor microenvironment.

**Keywords:** Apparent diffusion coefficient (ADC); Diffusion-weighted imaging; Ovarian masses; MRI.

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### INTRODUCTION

Diffusion-weighted imaging (DWI) is a useful technique in the assessment of adnexal masses; however, its role has been controversial in literature as some authors consider it as not useful and "provide no additional information" in discriminating benign from malignant ovarian masses, however some studies demonstrated that the combination of diffusion-weighted and T2-weighted images is helpful in predicting benignity and malignancy: masses with low signal intensity on both sequences were more likely benign, while lesions with high signal intensity on DWI and intermediate signal on T2-weighted images were more likely malignant.<sup>1</sup>

DWI derives its image contrast from differences in the motion of water molecules between tissues, which depends on tissue cellularity and presence of intact cell membranes. Tissues with high cellular density and intact cell membranes have restricted diffusion seen as high signal intensity on DWI.<sup>2</sup>

Qualitatively restricted diffusion is seen as hyperintensity in T2W images with corresponding fall in ADC. Quantitatively ADC maps are generated from different b values. ADC value is then measured by placing ROI manually over the largest possible area for solid and cystic lesions. With recent advances in ultrafast MR

imaging techniques, diffusion-weighted (DW) imaging is available to assess discriminant micro-vascular and cellular characteristics in abdominal and pelvic organs. DW imaging has recently been shown to be effective in the differentiation of benign from malignant adnexal masses.<sup>3</sup> Differences in signal intensity and the apparent diffusion coefficient (ADC) of benign and malignant complex adnexal masses have been reported.<sup>4,5,6</sup> Thus, the present study was undertaken to determine the relationship between the apparent diffusion coefficient (ADC) values of pathologically confirmed benign and malignant ovarian masses.

### MATERIAL AND METHODS

The present hospital based observational descriptive study was conducted over patients reporting the Department of Obstetrics and Gynecology and Department of Surgery in Medical College & Hospitals, Jaipur. A total of 50 patients diagnosed with ovarian masses on Ultrasound or on clinical examination were evaluated with conventional MRI, diffusion-weighted MRI and contrast enhanced MRI. Surgical/Histopathological results served as the gold standard. Informed written consent from patients was taken. Patients with non-availability of the histopathological examination

report and with MR incompatible devices or implants were excluded from the study.

All patients suspected of adnexal mass clinically or on ultrasonography were evaluated with pelvic MRI. All subjects underwent MRI with a 3T MR unit. The imaging protocol involved axial non-contrast T1-weighted, axial T2-weighted imaging using the following parameters: slice thickness, 4-5 mm; gap, 0-1 mm; field of view (FOV), 32 to 42 cm; matrix, 256 × 256.

Sagittal T2-weighted fast spin echo imaging with chemical shift-selective fat saturation pulse were also performed, as well as post-contrast enhanced axial and sagittal T1-weighted imaging using parameters as described above.

Diffusion weighted MRI were acquired in the axial plane prior to administration of contrast medium using a single-shot echoplanar imaging sequence (TR/TE effective range, 8,000-10,000/70-100; slice thickness/ intersection gap, 5/1.5 mm; FOV, 32 to 42 cm; matrix, 128 × 128; excitation). A b-value of 0 and of 1,000 s/mm<sup>2</sup> were applied in three orthogonal (Z, Y, and X) directions. Conventional MRI and DWI imaging data then were analyzed.

The solid and cystic component were identified according to a previously established classification by Timmerman et al.<sup>7</sup>

ADC values of the solid component were calculated and statistical tests applied to determine the usefulness of ADC values in distinguishing benign from malignant ovarian masses. Signal intensity of the cystic and solid components was classified on the DWI with a b value of 1,000 s/mm<sup>2</sup> as presence (classified as “high” signal intensity) or absence of high signal intensity

(classified as “low” signal intensity) compared with serous fluid (urine or cerebrospinal fluid (CSF)). The solid components of the lesions were identified on T2-weighted and post-contrast T1-weighted images, and was matched on ADC maps. The ADC values of the solid components of each tumor were measured on DW images. In order to minimize variability, the largest possible regions of interest (ROIs), varying from 15 to 150 mm<sup>2</sup>, was manually placed in the solid parts of the tumor. If the lesion exhibits irregular or heterogeneous solid components, numerous vegetations or thickened irregular septa, between two and five ROIs was drawn within the targeted components and the mean ADC value was used in the analysis.

Statistical Analysis was done using IBM SPSS Statistics 21. Surgical pathological findings were used as the reference standard for assessment of ovarian tumors. Non-parametric MRI variables were analyzed using Chi square test or Fischer’s exact test, whichever was applicable.

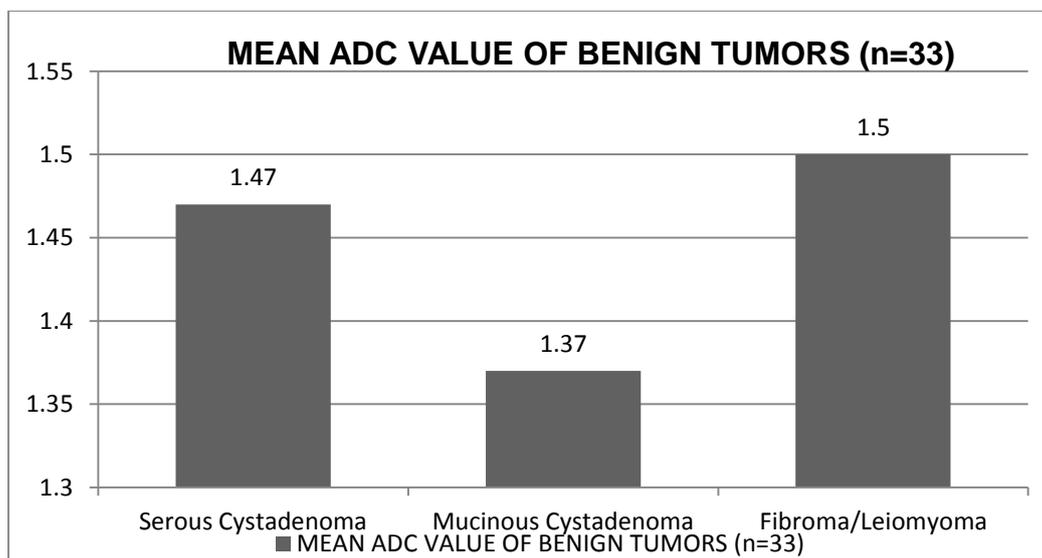
Differences in mean tumor ADC values between benign and malignant groups was evaluated using Student’s t - test. A p - value < 0.05 was considered statistically significant. All tests were two-sided. A P value of less than 0.05 was considered for statistical significance.

Receiver operating characteristic (ROC) curve analysis was performed in order to assess the diagnostic performance of the mean ADC values in terms of characterization of benign and malignant ovarian tumors. Positive and Negative likelihood ratio for malignancy was also determined.

**Table 1: DW MRI Findings and ADC Values within the Solid Component According To Histological Types of Benign Ovarian Masses (N=21)**

Histological Type	No of lesions with Solid component (n=21)	Low signal on DWI	Mean ADC Values ± SD
Serous Cystadenoma	8/21(38%)	6/21(28%)	1.47 ± 0.16
Mucinous Cystadenoma	5/21(24%)	3/21(14%)	1.37 ± 0.16
Sex cord stromal tumors(ovarian fibroma /leiomyoma)	8/21(38%)	6/21(28%)	1.50 ± 0.14
Hemorrhagic cyst	0	0	NA*
Tubo ovarian abscess	0	0	NA*
Hydrosalpinx	0	0	NA*

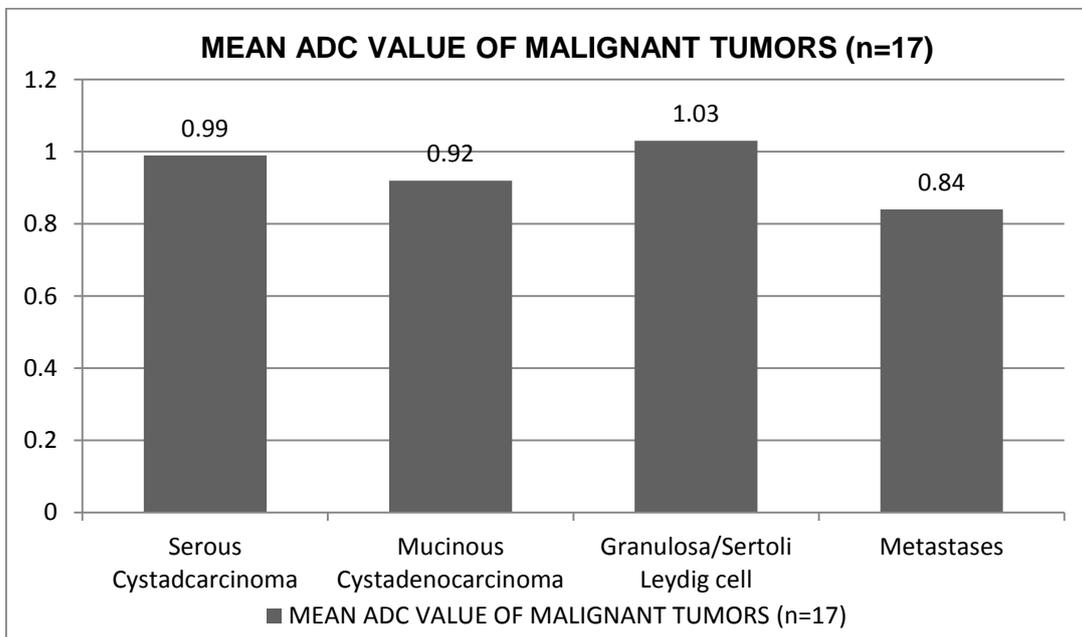
\*No solid component /maximum area of solid component less than 15 mm<sup>2</sup>



**Graph 1: Mean ADC Values Benign Tumors**

**Table 2: DW MRI Findings and ADC Values within the Solid Component According To Histological Types of Malignant Ovarian Masses (n=17)**

Histological Type	No of lesions with solid component	High Signal on DWI	Mean ADC Values
Serous Cystadenocarcinoma	9/17(53%)	8/17(47%)	0.99 ± 0.18
Mucinous Cystadenocarcinoma	4/17(24%)	4/17(24%)	0.92 ± 0.19
Sex cord stromal tumors(granulosa/Sertoli- leydig cell tumor)	2/17(12%)	1/17(6%)	1.03 ± 0.14
Metastasis	2/17(12%)	1/17(6%)	0.84 ± 0.13

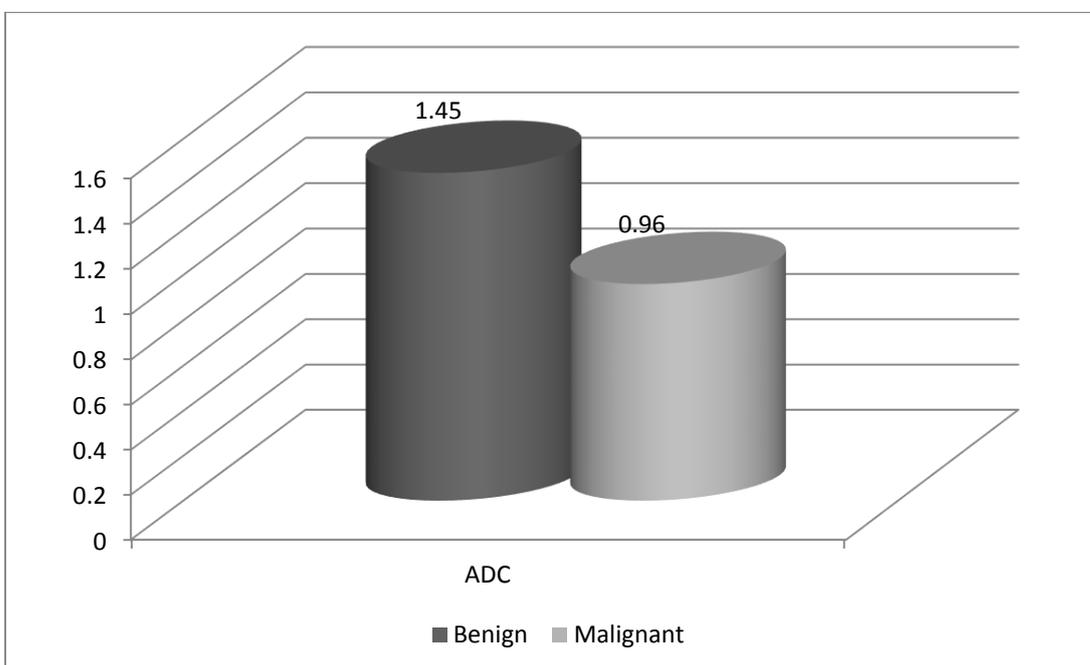


**Graph 2: Mean ADC Values Malignant Tumors**

**Table 3: Mean ADC Value of Benign vs. Malignant Tumors**

	Benign	Malignant	P value*
ADC value (mean)	1.45 ± 0.15×10 <sup>-3</sup> mm <sup>2</sup> /s	0.96 ± 0.16×10 <sup>-3</sup> mm <sup>2</sup> /s	0.001

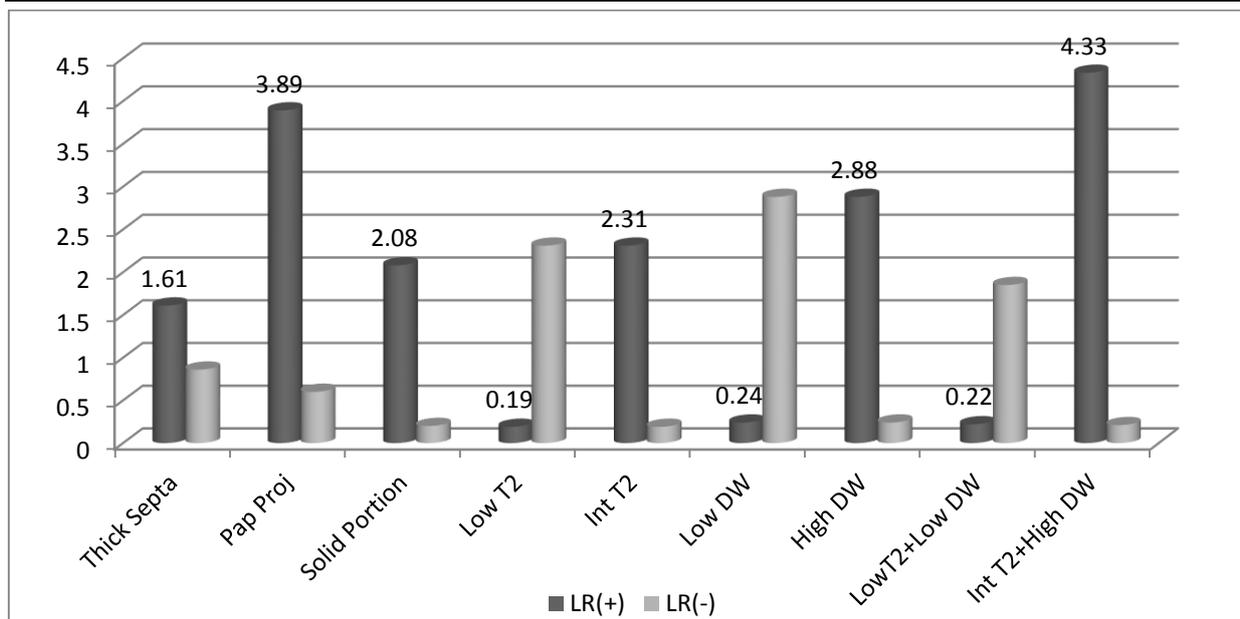
\*P value from independent sample t-test



**Graph 3: Mean ADC Value of Benign vs. Malignant Tumors**

Table 4: Likelihood Ratio (LR) For Malignancy

Parameter	Positive LR	Negative LR
Ascites/Peritoneal Deposits	2.12	0.44
Thick Septa	1.61	0.86
Papillary Projections	3.89	0.60
Solid Portion	2.08	0.20
Signal Intensity		
Low T2 signal	0.19	2.31
Intermediate T2 signal	2.31	0.19
Low DW signal	0.24	2.88
High DW signal	2.88	0.24
Low T2 + Low DW signal	0.22	1.85
Intermediate T2+ High DW	4.33	0.21

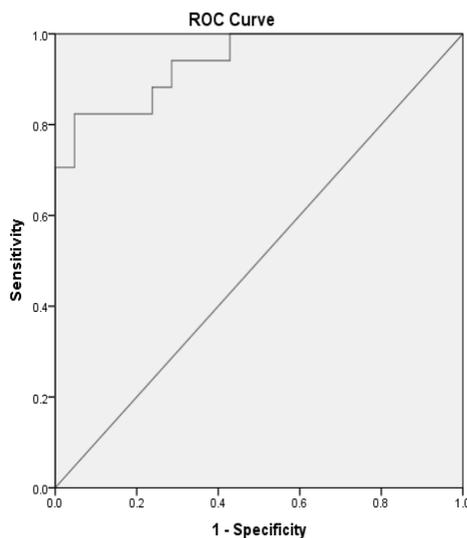


Graph 4: Likelihood Ratio (LR) For Malignancy

Table 5: ROC Curve values

Area Under the Curve	Significance	95% Confidence Interval	
		Lower Bound	Upper Bound
0.938	.000	.866	1.000

Cutoff value =  $1.23 \times 10^{-3}$  mm<sup>2</sup>/sec, Sensitivity = 0.824, 1-Specificity = 0.048



Graph 5: ROC Curve

**RESULTS**

DW MRI findings and ADC Values within the solid component according to histological types of benign ovarian masses is given in table 1 and graph 1 and according to histological types of malignant ovarian masses is given in table 2 and graph 2. Mean ADC value of benign vs. malignant tumors are given in table 3 and graph 3. Table 4 and graph 4 represents likelihood ratio (LR) for malignancy.

In the present study, ADC measurements in the solid component contributed significantly in differentiating benign from malignant adnexal masses. Our findings demonstrate that the presence of high signal intensity in solid components of ovarian lesions on DW and T2-weighted imaging combined with low ADC values can be used to distinguish malignant from benign ovarian lesions. The results also suggest a potential role for DW imaging with quantitative analysis of ADC values in improving the diagnostic performance of ovarian MRI and yielding functional measures of the tumor microenvironment.

In the present study, ADC values are largely proportional to the ratio of extracellular and intracellular components, cell density, intracellular organelles, matrix fibers, and soluble macromolecules. Although some overlap in ADC values was observed between the benign and malignant groups, the mean ADC value of the 11 malignant ovarian tumors was significantly lower than that of the 33 benign ovarian tumors ( $P < 0.001$ ).

Our results suggest that an ADC value  $\geq 1.23 \times 10^{-3}$  mm<sup>2</sup>/s may be the optimal cutoff for differentiating between benign and malignant tumors (table 5 and graph 5). Furthermore, a sensitivity of 82.4%, a specificity of 95.2%, a PPV 81.4%, an NPV of 82.1%, and an AUC of 0.94, was observed with this ADC cutoff value.

## DISCUSSION

In the present study, ADC measurements in the solid component contributed significantly in differentiating benign from malignant adnexal masses. Our findings demonstrate that the presence of high signal intensity in solid components of ovarian lesions on DW and T2-weighted imaging combined with low ADC values can be used to distinguish malignant from benign ovarian lesions. Our results suggest that an ADC value  $\geq 1.23 \times 10^{-3}$  mm<sup>2</sup>/s may be the optimal cutoff for differentiating between benign and malignant tumors. The results suggest a potential role for DW imaging with quantitative analysis of ADC values in improving the diagnostic performance of ovarian MRI and yielding functional measures of the tumor microenvironment. This result is consistent with previous reports.<sup>3,8-10</sup> In a study by Fujii et al<sup>11</sup> the authors evaluated the contribution of DWI in combination with quantitative ADC analysis to the characterization of 123 ovarian lesions, which included 42 malignant and 81 benign lesions (including 7 fibromas, 18 mature cystic teratomas and 24 endometriomas) and results suggest that DW imaging of ovarian lesions and ADC values of the solid component are not useful for differentiating between benign and malignant ovarian lesions. This apparent discrepancy is probably due to the pathologic architectures of benign tumors. In our series, fibrothecomas and cystadenomas demonstrated low signal intensity in the solid components on DWI and low ADC values, due to the presence of abundant collagen-producing.

However, in our experience, b<sub>1,000</sub> signal intensity within the solid component on DWI remains relevant for discriminating benign from malignant masses, because b<sub>1,000</sub> signal intensity is the result of the combination of T2 signal intensity and ADC value.<sup>8</sup>

Exclusion of endometriomas and cystic teratomas in our series could be considered a potential bias but, as recommended by Moteki et al, all tumours displaying a high T1 signal before the DW sequence should be excluded to limit T1 contamination.<sup>6,12</sup> Previous studies have reported that endometriomas and cystic teratomas exhibit a low ADC value.<sup>3,12</sup> However, these tumours are accurately characterized in more than 90% of cases by conventional MR imaging<sup>3-15</sup> and hence do not represent a diagnostic challenge.

Katayama et al<sup>4</sup> assessed the feasibility of DWI for the differentiation of benign and malignant ovarian lesions. They concluded that the ADC values of cystic and solid components were not useful for differentiating between lesions. However, their data included endometrial cysts, mature cystic teratomas, and fibromas and fibrothecomas, in which hemorrhagic contents, sebaceous materials and fibrous tissue may cause an increase or

a reduction in signal on DWI. If these lesions are excluded ADC value can be used to differentiate benign from malignant ovarian lesions. Zhang et al found that a cutoff ADC value of  $1.20 \times 10^{-3}$  mm<sup>2</sup>/s may be the optimal one for differentiating between benign and malignant tumors.<sup>16</sup>

Our study demonstrates that diffusion-weighted MR imaging (DWI) combined with classical T2-weighted imaging is an accurate tool to assess the nature of complex adnexal masses depicted by ultrasonography (US). When a solid component is depicted, our study demonstrates that low T2 signal and low DW signal on diffusion-weighted images of this component are the best criteria for excluding malignancy.

In the present study, mean ADC value of solid component of benign masses was significantly higher than malignant masses ( $p = 0.001$ ). Thus, ADC measurements in the solid component contributed significantly in differentiating benign from malignant adnexal masses. Our findings demonstrate that the presence of high signal intensity in solid components of ovarian lesions on DW and T2-weighted imaging combined with low ADC values can be used to distinguish malignant from benign ovarian lesions. Our results suggest that an ADC value  $\geq 1.23 \times 10^{-3}$  mm<sup>2</sup>/s may be the optimal cutoff for differentiating between benign and malignant tumors.

## CONCLUSION

The results suggest a potential role for DW imaging with quantitative analysis of ADC values in improving the diagnostic performance of ovarian MRI and yielding functional measures of the tumor microenvironment. To summarize, conventional MRI has high accuracy in differentiating benign from malignant ovarian masses. Addition of Diffusion Weighted Imaging further increases the diagnostic accuracy.

## REFERENCES

1. Foti PV, Attinà G, Spadola S, et al. MR imaging of ovarian masses: classification and differential diagnosis. *Insights into Imaging* 2016;7(1):21-41.
2. Bansal R, Shah V, Aggarwal B. Qualitative and quantitative diffusion-weighted imaging of the breast at 3T - A useful adjunct to contrast-enhanced MRI in characterization of breast lesions. *The Indian Journal of Radiology & Imaging* 2015;25(4):397-403.
3. Thomassin-Naggara I, Darai E, Cuenod CA, Fournier L, Toussaint I, Marsault C, Fournier L, Tossaint I, Marsault P, Bazot M. Contribution of diffusion weighted MR imaging for predicting benignity of complex adnexal masses. *EurRadiol* 2009, 19:1544 – 1552.
4. Katayama M, Masui T, Kobayashi S, Ito T, Sakahara H, Nozaki A, Kabasawa H. Diffusion-weighted echo planar imaging of ovarian tumors: is it useful to measure apparent diffusion coefficients? *J Comput Assist Tomogr* 2002;26:250 – 256.
5. Li WH, Chu CT, Cui YF, Zhang P, Zhu MJ. Diffusion-weighted MRI: a useful technique to discriminate benign versus malignant ovarian surface epithelial tumors with solid and cystic components. *Abdom Imaging* 2012, 37:897 – 903.
6. Moteki T, Ishizaka H. Evaluation of cystic ovarian lesions using apparent diffusion coefficient from turbo FLASH MR images. *Br J Radiol* 1998, 71:612 – 620.
7. Timmerman D, Valentin L, Bourne TH, Collins WP, Verrelst H, Vergote I. Terms, definitions and measurements to describe the sonographic features of adnexal tumors: a consensus opinion from the International Ovarian Tumor Analysis (IOTA) Group. *Ultrasound Obstet Gynecol* 2000, 16:500 – 505.

8. Timmerman D, Schwärzler P, Collins WP, et al. Subjective assessment of adnexal masses with the use of ultrasonography: an analysis of inter observer variability and experience. *Ultrasound Obstet Gynecol* 1999; 13 (1): 11 – 16.
9. Hricak H, Chen M, Coakley FV, et al. Complex adnexal masses: detection and characterization with MR imaging—multivariate analysis. *Radiology* 2000; 214 (1): 39–46.
10. Rieber A, Nüssle K, Stöhr I, et al. Preoperative diagnosis of ovarian tumors with MR imaging: comparison with transvaginal sonography, positron emission tomography, and Histologic Findings. *AJR Am J Roentgenol* 2001; 177 ( 1 ): 123 – 129.
11. Fujii S, Kakite S, Nishihara K, Kanasaki Y, Harada T, Kigawa J, Kaminou T, Ogawa T. Diagnostic accuracy of diffusion-weighted imaging in differentiating benign from malignant ovarian lesions. *J Magn Reson Imaging*. 2008;28(5):1149-56.
12. Bazot M, Darai E, Nassar-Slaba J, Lafont C, Thomassin-Naggara I. Value of magnetic resonance imaging for the diagnosis of ovarian tumors: a review. *J Comput Assist Tomogr* 2008, 32:712 – 723.
13. Comerci JT, Jr, Licciardi F, Bergh PA, Gregori C, Breen JL. Mature cystic teratoma: a clinicopathologic evaluation of 517 cases and review of the literature. *Obstet Gynecol*. 1994;84:22–8.
14. Bazot M, Nassar-Slaba J, Thomassin-Naggara I, Cortez A, Uzan S, Darai E. MR imaging compared with intraoperative frozen-section examination for diagnosis of adnexal tumors; correlation with final histology. *Eur Radiol* 2006, 16:2687 – 2699.
15. Curtin JP. Management of the adnexal mass. *Gynecol Oncol* 1994;55: S42 – S46.
16. Zhang P, Cui Y, Li W, Ren G, Chu C, Wu X. Diagnostic accuracy of diffusion weighted imaging with conventional MR imaging for differentiating complex solid and cystic ovarian tumors at 1.5T. *World Journal of Surgical Oncology* 2012;10:237.

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