e-ISSN: 0975-9506, p-ISSN: 2961-6093

Available online on www.ijpqa.com

International Journal of Pharmaceutical Quality Assurance 2026; 17(6); 06-14

Original Research Article

Diffusion Weighted Imaging as a Diagnostic Tool in the Evaluation of Ovarian Masses

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Received: 25-03-2026 / Revised: 23-04-2026 / Accepted: 26-05-2026

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Conflict of interest: Nil

Abstract:

Background: Ovarian masses represent a spectrum of pathologies ranging from benign to malignant lesions. Accurate preoperative differentiation between benign and malignant ovarian masses is crucial for appropriate surgical planning and patient management. Diffusion Weighted Imaging (DWI) is an advanced functional MRI technique that reflects tissue cellularity by measuring the random Brownian motion of water molecules, offering quantitative data through Apparent Diffusion Coefficient (ADC) values.

Objectives: To evaluate the diagnostic accuracy of DWI and ADC values in differentiating benign from malignant ovarian masses, and to determine an optimal ADC cutoff value.

Materials and Methods: A retrospective observational study was conducted at the Department of Radiodiagnosis, ACSR Government General Hospital & Government Medical College, Nellore, from January 2023 to June 2025. A total of 30 patients with ovarian masses who underwent plain (non-contrast) MRI pelvis on a 1.5 Tesla Siemens Magnetom Sempra MRI machine were included. DWI was performed and ADC values were calculated. Histopathological findings served as the gold standard.

Results: Of 30 patients, 24 (80%) had benign lesions and 6 (20%) had malignant lesions. DWI restriction was noted in 6 patients, of whom 5 (83.3%) were malignant and 1 (16.7%) was a false positive (endometrioma). One malignant case (low-grade mucinous cystadenocarcinoma) showed no restriction (false negative). The mean ADC value for malignant masses was $0.87 \pm 0.18 \times 10^{-3}$ mm²/s versus $1.52 \pm 0.43 \times 10^{-3}$ mm²/s for benign masses ($p < 0.001$). Sensitivity and specificity of DWI were 83.3% and 95.8%, respectively.

Conclusion: DWI combined with ADC value measurement is a valuable, non-invasive, non-contrast adjunct to conventional MRI in characterizing ovarian masses. Combined evaluation significantly improves diagnostic accuracy for ovarian malignancies.

Keywords: Diffusion Weighted Imaging (DWI), Apparent Diffusion Coefficient (ADC), ovarian masses, MRI, Ovarian cancer, benign ovarian tumors.

DOI: 10.25258/ijpqa.17.6.2

Introduction

Ovarian cancer is one of the most lethal gynaecological malignancies, ranking as the fifth leading cause of cancer-related death among women worldwide. It causes approximately 125,000 deaths annually and presents with poor prognosis due to the absence of reliable early-stage symptoms and effective screening tools [1]. The majority of patients are diagnosed at advanced stages (FIGO Stage III or IV), where 5-year survival rates fall to as low as 20–30% [2]. Early-stage diagnosis carries a significantly better prognosis, with 5-year survival exceeding 90% [3]. Adnexal masses represent a diagnostic challenge in clinical practice. The objectives of imaging in ovarian mass evaluation are to reduce unnecessary surgeries for benign conditions, preserve fertility in younger women, and ensure appropriate referral for potential malignancies to tertiary centres with gynecologic oncology expertise [4]. Ultrasonography (US) remains the first-line imaging modality; however, it has limitations in characterizing complex or indeterminate masses. Computed Tomography (CT) offers whole-body staging but lacks soft tissue contrast resolution in the pelvis. Magnetic Resonance Imaging (MRI) has emerged as the most accurate imaging technique

for characterizing ovarian masses due to its superior soft tissue contrast, multiplanar capability, and lack of ionizing radiation [5, 6]. Diffusion Weighted Imaging (DWI) is a functional MRI sequence based on the measurement of random Brownian motion of water molecules within tissues. In malignant tumors, hypercellularity and disorganized cellular architecture restrict the movement of water molecules, resulting in high signal intensity on DWI and correspondingly low Apparent Diffusion Coefficient (ADC) values [7].

Conversely, benign lesions and normal tissues generally show lower signal on DWI with higher ADC values [8]. DWI has been established as a useful biomarker for differentiating benign from malignant lesions in multiple organ systems. Its application in ovarian mass characterization has gained increasing attention, with several studies demonstrating its utility in improving specificity of conventional MRI [9, 10].

Furthermore, DWI eliminates the need for intravenous contrast administration, making it particularly valuable in patients with renal insufficiency, contrast allergies, or during pregnancy [11].

This study was undertaken to evaluate the role of DWI as a diagnostic tool in the evaluation of ovarian masses at a government tertiary care center in Southern India, with histopathological correlation serving as the gold standard.

Aims and Objectives

Primary Objective: To assess the diagnostic accuracy of Diffusion Weighted Imaging (DWI) and Apparent Diffusion Coefficient (ADC) values in differentiating benign from malignant ovarian masses.

Secondary Objectives:

1. To determine an optimal ADC cutoff value for distinguishing benign from malignant ovarian lesions.
2. To correlate DWI and ADC findings with histopathological diagnosis.
3. To evaluate the sensitivity, specificity, PPV, NPV, and accuracy of DWI as a diagnostic tool.

Materials and Methods

Study Design and Setting: This was a retrospective observational study conducted at the Department of Radiodiagnosis, ACSR Government General Hospital and Government Medical College, Nellore, Andhra Pradesh, India, in collaboration with the Department of Pathology. The study was conducted over a period of approximately 30 months, from January 2023 to June 2025.

Study Equipment: All MRI examinations were performed on a 1.5 Tesla Siemens Magnetom Sempra MRI machine using a dedicated pelvic phased-array coil.

Study Population: A total of 30 female patients who were referred from the Department of Obstetrics and Gynaecology for MRI pelvis evaluation of ovarian masses, and for whom postoperative histopathological results were available, were enrolled in this study.

Inclusion Criteria: All female patients referred for MRI pelvis evaluation of ovarian masses who subsequently underwent surgical intervention and had available histopathological reports were included.

Exclusion Criteria: The following patients were excluded: patients with contraindications to MRI (such as pacemakers, ferromagnetic implants, or severe claustrophobia); patients who had received prior treatment (chemotherapy or radiotherapy) before MRI; patients with purely simple cystic lesions on ultrasound with classic benign features; and patients whose histopathological results were unavailable.

Patient Preparation: Patients were instructed to fast for approximately 3 hours prior to examination. All metallic objects including keys, coins, ornaments, and hairpins were removed. Claustrophobic patients were offered the option of being accompanied by a relative or staff member after appropriate screening. Patients were placed in the supine (head-first) position on the MRI table and immobilized using cushions. Cushions were also placed under the legs for patient comfort. An intravenous antispasmodic (Hyoscine butylbromide / Buscopan 20 mg) was administered intramuscularly approximately 20 minutes prior to examination to suppress bowel peristalsis and reduce motion artifacts on DWI.

MRI Protocol: The study was conducted as a plain (non-contrast) MRI pelvis. A three-plane localizer was initially acquired to localize and plan the subsequent sequences. The standard MRI protocol included the following sequences:

- Axial T1-weighted TSE (TR/TE: 550/24 ms; Slice thickness: 5 mm; Gap: 1 mm; FOV: 36 cm; Matrix: 576×576)
- Axial T2-weighted TSE (TR/TE: 7649/115 ms; Slice thickness: 5 mm; Gap: 1 mm; FOV: 36 cm; Matrix: 560×560)
- Sagittal and Coronal T2-weighted sequences (Slice thickness: 5–8 mm; Gap: 1 mm; FOV: 36–80 cm)
- Axial Diffusion Weighted Imaging (DWI) using a single-shot Echo Planar Imaging (EPI) sequence with b-values of 0, 500, and 800 s/mm² (TR/TE: 4000/75 ms; Slice thickness: 5

mm; Gap: 1 mm; FOV: 36 cm; Matrix: 128×128)

Apparent Diffusion Coefficient (ADC) maps were automatically generated from the DWI data at the MRI workstation.

Image Analysis: All MRI images were reviewed by a consultant radiologist with experience in gynaecological radiology. Conventional MRI sequences were analyzed for morphological features including lesion size, laterality, T1 and T2 signal intensity, the presence of solid components, papillary projections, septations, wall thickness, ascites, lymphadenopathy, and involvement of adjacent organs.

For DWI, qualitative analysis was performed by assessing signal intensity on high b-value (b=800) images and the corresponding ADC maps. Diffusion restriction was defined as high signal intensity on DWI with corresponding low signal intensity on ADC map (true restriction), excluding T2 shine-through artifacts. Quantitative analysis involved placing a Region of Interest (ROI) on the solid or most suspicious component of the ovarian lesion and calculating mean ADC values.

Statistical Analysis: Data were analyzed using standard statistical methods. Continuous variables were expressed as mean ± standard deviation (SD). The diagnostic performance of DWI was assessed by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy using histopathology as the gold standard. Receiver Operating Characteristic (ROC) curve analysis was performed to determine the optimal ADC cutoff value. A p-value of < 0.05 was considered statistically significant.

Ethical Considerations: The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical clearance was obtained from the Institutional Ethics Committee. Patient confidentiality was maintained throughout the study, and data were analyzed anonymously.

Results

Patient Demographics: A total of 30 female patients were included in this study. Patient age ranged from 18 to 72 years with an overall mean age of 41.6 ± 13.4 years. The mean age of patients with benign lesions was 38.4 ± 11.2 years, while patients with malignant lesions had a mean age of 52.7 ± 9.6 years, indicating that malignant lesions were more prevalent in older, postmenopausal women. Demographic and clinical characteristics are summarized in Table 1.

Table 1: Demographic and Clinical Characteristics of Study Population

Parameter	Benign (n=24)	Malignant (n=6)
Age Range (years)	18–65	35–72
Mean Age (years)	38.4 ± 11.2	52.7 ± 9.6
Premenopausal	18 (75%)	2 (33.3%)
Postmenopausal	6 (25%)	4 (66.7%)
Bilateral lesions	3 (12.5%)	2 (33.3%)
Unilateral lesions	21 (87.5%)	4 (66.7%)

Histopathological Distribution: Of the 30 ovarian masses evaluated, 24 (80%) were histopathologically confirmed as benign and 6 (20%) as malignant. Serous cystadenoma was the most common benign lesion (n=8, 26.7%), followed by simple cysts (n=6, 20%). Among malignant lesions, serous cystadenocarcinoma was most prevalent (n=3, 10%). One case of low-grade mucinous cystadenocarcinoma was identified. The complete histopathological distribution is presented in Table 2.

Table 2: Histopathological Distribution of Ovarian Masses

Diagnosis	Number of Cases	Percentage (%)
Benign (Total)	24	80%
Serous Cystadenoma	8	26.7%
Simple Cyst	6	20%
Mucinous Cystadenoma	3	10%
Endometrioma	3	10%
Ovarian Fibroma	2	6.7%
Mature Cystic Teratoma	1	3.3%
Tubo-ovarian Abscess	1	3.3%
Malignant (Total)	6	20%
Serous Cystadenocarcinoma	3	10%
Mucinous Cystadenocarcinoma (Low grade)	1	3.3%
Endometrioid Adenocarcinoma	1	3.3%
Granulosa Cell Tumor	1	3.3%
TOTAL	30	100%

DWI Findings and Correlation with Histopathology: Diffusion restriction on DWI (defined as high signal intensity at b=800 s/mm² with corresponding low signal on ADC map) was observed in 6 of 30 cases (20%). Of these 6 cases with restriction, 5 were confirmed malignant on histopathology (true positives) and 1 was benign (endometrioma — false positive). Among the 24 cases without DWI restriction, 23 were benign (true negatives) and 1 was malignant (low-grade mucinous cystadenocarcinoma — false negative).

The cross-tabulation of DWI restriction versus histopathological diagnosis is shown in Table 3.

Table 3: Cross-Tabulation of DWI Restriction vs. Histopathological Diagnosis

DWI Restriction	Malignant	Benign	Total
Present	5	1	6
Absent	1	23	24
Total	6	24	30

ADC Values: The mean ADC value for malignant ovarian masses was significantly lower than that for benign masses ($0.87 \pm 0.18 \times 10^{-3}$ mm²/s versus $1.52 \pm 0.43 \times 10^{-3}$ mm²/s; $p < 0.001$). ROC curve analysis identified an optimal ADC cutoff value of $\leq 1.10 \times 10^{-3}$ mm²/s for predicting malignancy. ADC values are detailed in Table 4. The notable false negative case (low-grade mucinous cystadenocarcinoma) had an ADC value of 1.14×10^{-3} mm²/s, which fell just above this threshold, consistent with the lower cellularity characteristic of low-grade mucinous tumors.

Table 4: ADC Values in Benign vs. Malignant Ovarian Masses

Parameter	Benign Masses	Malignant Masses
Mean ADC value ($\times 10^{-3}$ mm²/s)	1.52 ± 0.43	0.87 ± 0.18
ADC Range ($\times 10^{-3}$ mm²/s)	0.92 – 2.74	0.62 – 1.14
Cutoff ADC value ($\times 10^{-3}$ mm²/s)	—	≤ 1.10
p-value		< 0.001

Diagnostic Performance of DWI: The diagnostic performance of qualitative DWI, quantitative ADC analysis, and combined conventional MRI with DWI is summarized in Table 5. Qualitative DWI demonstrated a sensitivity of 83.3% and specificity of 95.8% for detecting malignancy. The combined use of conventional MRI and DWI achieved a sensitivity of 100% with a negative predictive value of 100%, ensuring no malignant lesion was missed, albeit with a modest reduction in specificity.

Table 5: Diagnostic Performance of DWI in Evaluation of Ovarian Masses

Parameter	DWI (Qualitative)	ADC (Quantitative)	Combined MRI + DWI
Sensitivity	83.3%	83.3%	100%
Specificity	95.8%	91.7%	87.5%
PPV	83.3%	71.4%	75.0%
NPV	95.8%	95.7%	100%
Accuracy	93.3%	90.0%	90.0%

Summary of DWI Cases: A case-by-case summary of DWI findings and their correlation with histopathology is presented in Table 6.

Table 6: Summary of DWI Findings with Histopathological Correlation

Case	Diagnosis (Histopathology)	DWI Signal	ADC ($\times 10^{-3}$ mm²/s)	MRI Impression	Outcome
1	Serous Cystadenocarcinoma	Restricted	0.71	Malignant	TP
2	Serous Cystadenocarcinoma	Restricted	0.68	Malignant	TP
3	Serous Cystadenocarcinoma	Restricted	0.79	Malignant	TP
4	Endometrioid Adenocarcinoma	Restricted	0.82	Malignant	TP
5	Granulosa Cell Tumor	Restricted	0.91	Malignant	TP
6	Low Grade Mucinous Cystadenocarcinoma	Not Restricted	1.14	Benign	FN
7	Endometrioma	Restricted	0.88	Malignant	FP
8–30	Various Benign Lesions	Not Restricted	1.52 ± 0.43	Benign	TN

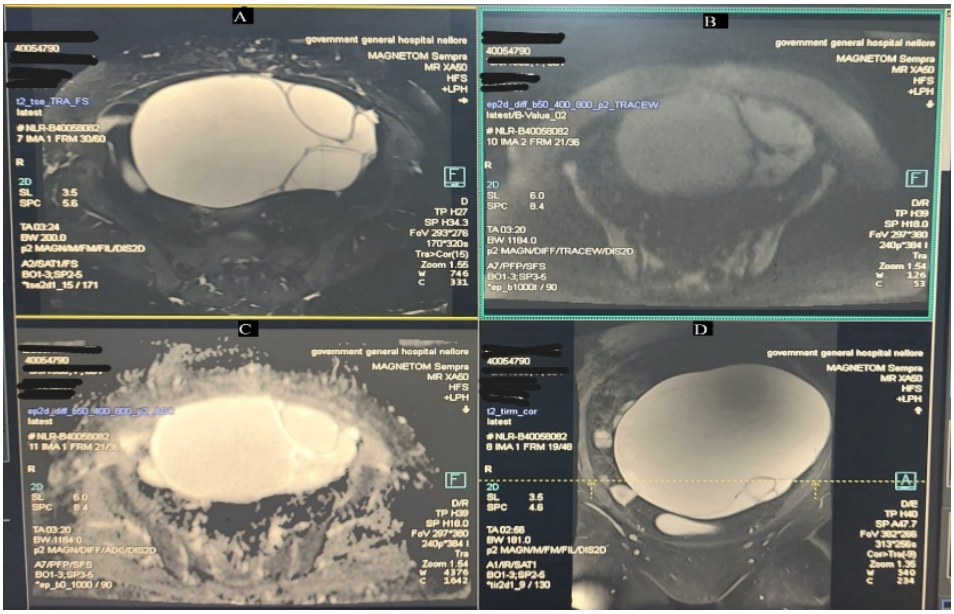

Figure 1: A. Axial T2 weighted image of MRI pelvis showing well defined hyperintense lesion with thin hypointense internal septations. B. DWI image at b1000 showing no Restricted diffusion in the lesion. C.ADC image showing facilitated diffusion in the lesion. D. Coronal T2 weighted image showing eccentric internal septations

Imaging S/O Serous cystadenoma. Post-operative HPE report- Serous cystadenoma

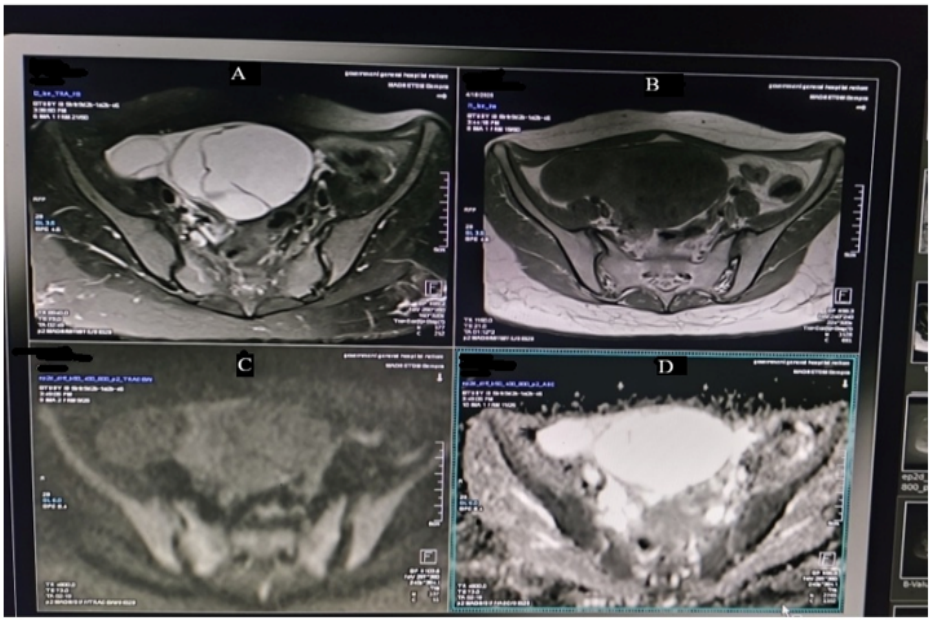

Figure 2: A. Axial T2 weighted image of MRI pelvis showing well defined multiloculated hyperintense lesion in right adnexa with thin internal septations. B. Axial T1 weighted image the lesion is hypointense. C. DWI image at b1000 showing no Restricted diffusion. D. ADC image showing facilitated diffusion

MRI S/O Mucinous cystadenoma of ovary. HPE-Mucinous cystadenoma

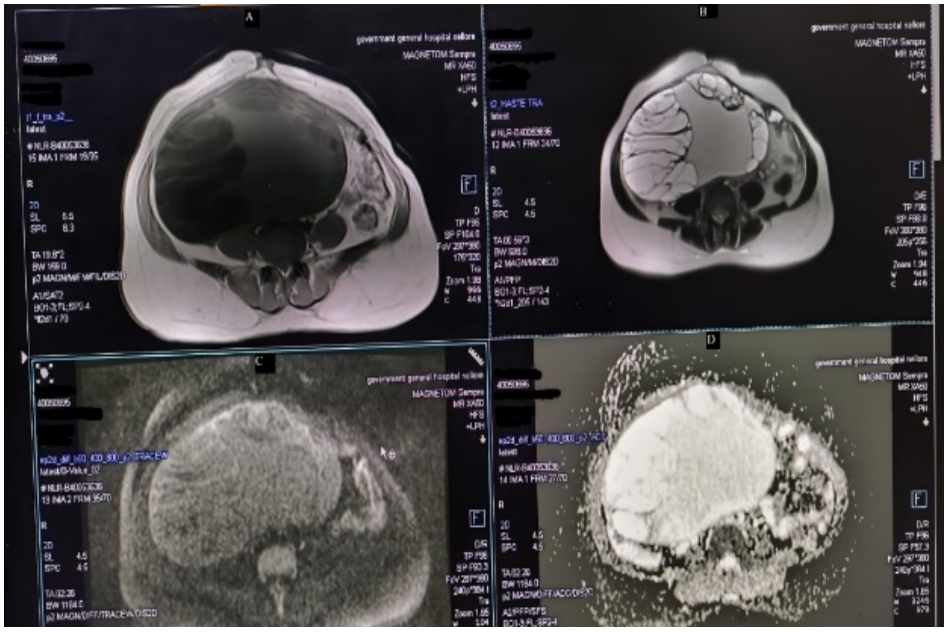

Figure 3: A. Axial T1 weighted image of MRI pelvis predominantly hypointense lesion with intermediate intensity areas within with hypointense thin septations. B. Axial T2 weighted image showing well defined multiloculated predominent hyperintense lesion with central intermediate intensity areas with thin hypointense internal septations. C. DWI image at b1000 showing no true Restricted diffusion. D. ADC image showing facilitated diffusion

MRI S/O Mucinous cystadenoma of ovary HPE- low grade Mucinous cystadenocarcinoma

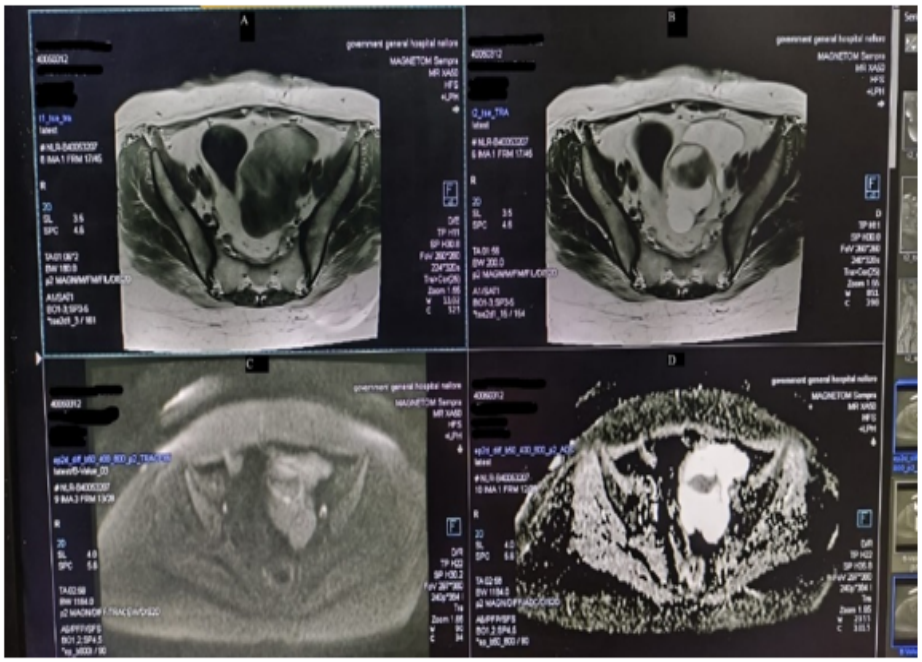

Figure 4: A. Axial T1 weighted imageof MRI pelvis predominantly hyperintense lesion with intermediate intensity areas within with hypointense thin internal septations. B. Axial T2 weighted image showing well defined multiloculated predominent hyperintense lesion with central intermediate to hypo intensity area with T2 shading thin hypointense internal septations. C. DWI image at b1000 showing patchy Restricted diffusion in the central portion of the lesion. D. ADC image showing predominent facilitated diffusion with hypointensity within the central portion

MRI S/O Endometriotic cyst of ovary HPE- Endometriotic cyst

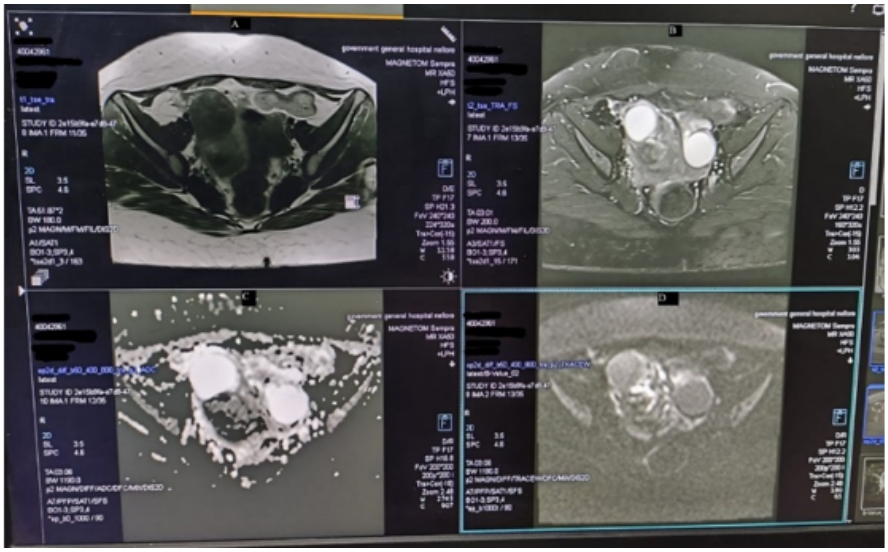

Figure 5: A. Axial T1 weighted image of MRI pelvis showing hypointense lesions in bilateral adnexal regions B. On T2 weighted image lesions are hyperintense. C. ADC image showing facilitated diffusion. D. DWI image with no Restricted diffusion

MRI S/O Simple ovarian cysts HPE- simple ovarian cysts

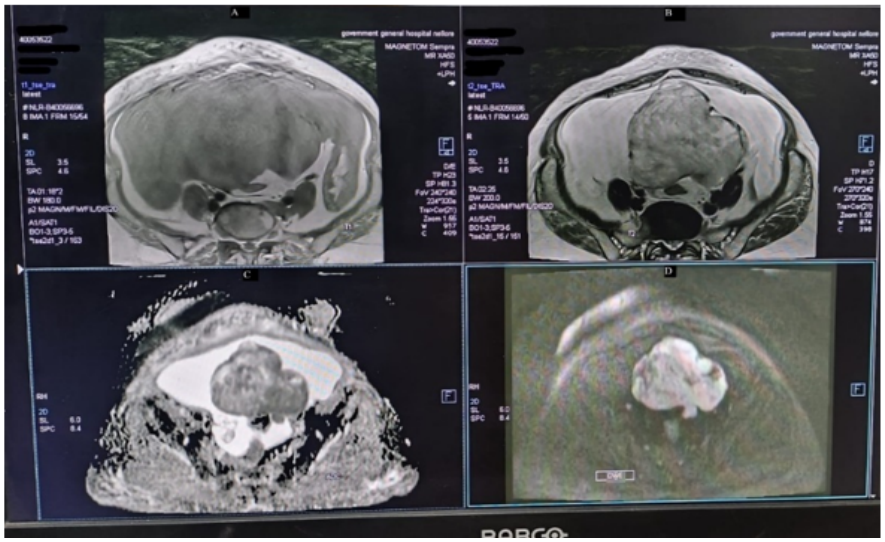

Figure 6: A: Axial T1 weighted imageof MRI pelvis predominantly solid lobulated hypointense lesion with few intermediate signal intensity areas within. B. Axial T2 weighted image showing lobulated heterogenously hyperintense lesion. C. ADC image showing hypointense signal in entire lesion. D. DWI image at b1000 showing true Restricted diffusion

MRI S/O Malignant predominantly solid ovarian lesion HPE- Malignant predominant solid epithelial tumor of ovary with few small areas of necrosis

Discussion

This retrospective observational study evaluated the role of DWI as a diagnostic tool in the evaluation of 30 ovarian masses at a tertiary government hospital in South India, using histopathology as the gold standard.

Our findings demonstrate that DWI is a valuable, non-invasive adjunct to conventional MRI in the characterization of ovarian masses. In our study, 80% of lesions were benign and 20% were malignant. The mean age of patients with malignant lesions (52.7 years) was significantly higher than those with benign disease (38.4 years), with malignancy predominantly affecting postmenopausal women.

This is consistent with the well-established epidemiological pattern of ovarian cancer, which peaks in the sixth and seventh decades of life [1, 12]. The preponderance of benign lesions in our cohort reflects the general prevalence of ovarian pathology in a mixed gynecological practice. DWI restriction was identified in 6 cases (20% of total), of which 5 were malignant — yielding a sensitivity of 83.3% and specificity of 95.8% for qualitative DWI analysis. These results compare favorably with published literature. Yuan et al. in their 2017

meta-analysis of 12 studies (1,142 lesions) reported pooled sensitivity of 86% and specificity of 81% for DWI in ovarian cancer detection [13]. Ali et al. (2020), in a study of 51 patients, reported 100% sensitivity and 71.4% specificity for combined conventional MRI and DWI [14]. Tantawy et al. (2018) reported 92.3% sensitivity and 88.2% specificity using ADC of the cystic component [15].

The mean ADC value for malignant masses in our study ($0.87 \pm 0.18 \times 10^{-3}$ mm²/s) was significantly lower than that for benign masses ($1.52 \pm 0.43 \times 10^{-3}$ mm²/s), with a p-value of < 0.001. This finding aligns with the underlying pathophysiological mechanism: malignant tumors exhibit hypercellularity with dense nuclear-to-cytoplasmic ratios and reduced extracellular space, which mechanically restricts water molecule diffusion, resulting in lower ADC values [7, 8]. Our ADC values for malignant masses are concordant with those reported by Othman et al. (2017) [mean 0.9×10^{-3} mm²/s] and Abdallah et al. (2018) [mean 0.86×10^{-3} mm²/s] [16, 17]. The optimal ADC cutoff of $\leq 1.10 \times 10^{-3}$ mm²/s determined in our study is comparable to cutoff values reported in similar studies, ranging from 0.90 to 1.25×10^{-3} mm²/s [13, 15, 16].

The single false positive case in our study was an endometrioma, which demonstrated restricted diffusion with a low ADC value (0.88×10^{-3} mm²/s). Endometriomas are well-known DWI pitfalls; the hemorrhagic, proteinaceous content of the cyst causes true diffusion restriction, mimicking malignancy on DWI. This phenomenon has been documented extensively in the literature [18, 19]. Similarly, other benign lesions such as mature cystic teratomas (due to keratinoid substances), tubo-ovarian abscesses (purulent contents), and ovarian fibromas (dense fibrous stroma) may exhibit restricted diffusion and should be distinguished using conventional MRI features including T1 fat saturation, T2 signal characteristics, and clinical context [9, 14, 18].

The single false negative case in our study was a low-grade mucinous cystadenocarcinoma (ADC value 1.14×10^{-3} mm²/s). This is a recognized limitation of DWI in ovarian malignancy characterization. Low-grade mucinous tumors typically demonstrate lower cellular density compared to high-grade serous carcinomas, resulting in less restricted diffusion and higher ADC values that may overlap with benign lesions [20]. This is supported by Patel et al. (2021), who noted that well-differentiated tumors and lesions with significant necrosis or mucin may exhibit higher ADC values due to their composition [21]. These limitations underscore the importance of correlating DWI findings with conventional MRI morphology and clinical data rather than relying on DWI alone.

The combined evaluation of conventional MRI and DWI in our study achieved 100% sensitivity and 100% NPV, ensuring no malignant case was missed. While the specificity of combined imaging (87.5%) was lower than DWI alone, the high sensitivity and NPV are clinically more critical, as missing a malignancy carries greater consequences than a false positive leading to further evaluation. This approach is consistent with recommendations from multiple studies emphasizing that DWI should complement rather than replace conventional MRI, with integrated interpretation of both qualitative and quantitative parameters [9, 14, 15, 16].

The use of plain (non-contrast) MRI with DWI in our study is an important practical consideration, particularly relevant in resource-limited settings like public sector tertiary hospitals in India.

This approach is also valuable for patients with contraindications to contrast media, including those with renal dysfunction, prior contrast reactions, or pregnant patients, as reported by Ali et al. (2020) and Abd-Elmageed et al. (2021) [14, 22]. The Siemens Magnetom Sempra 1.5T MRI platform used in this study represents the standard available at government facilities and is appropriate for DWI evaluation of pelvic masses.

Limitations of this study include the relatively small sample size (n=30), which limits statistical power and the generalizability of ADC cutoff values. The retrospective design introduces potential selection bias. DWI was performed without intravenous contrast, which may limit characterization in some cases. The single-center nature of the study and variability in tumor histotypes (including low numbers of specific subtypes) should be considered when interpreting results. Future prospective multicenter studies with larger cohorts, standardized DWI protocols, and broader histological representation are needed to validate these findings.

Conclusion

Diffusion Weighted Imaging (DWI) is an effective, non-invasive, and contrast-free functional MRI technique that significantly enhances the diagnostic capability of conventional MRI in the evaluation of ovarian masses.

In this study, DWI demonstrated a sensitivity of 83.3% and specificity of 95.8% for detecting malignancy, with malignant masses exhibiting significantly lower ADC values (mean $0.87 \pm 0.18 \times 10^{-3}$ mm²/s) compared to benign lesions (mean $1.52 \pm 0.43 \times 10^{-3}$ mm²/s). An ADC cutoff value of $\leq 1.10 \times 10^{-3}$ mm²/s was identified as optimal for predicting malignancy.

The combined interpretation of conventional MRI morphological features and DWI with ADC quantification achieved 100% sensitivity and 100% NPV, ensuring no malignant case was missed.

Awareness of potential DWI pitfalls — particularly benign lesions such as endometriomas, mature teratomas, and tubo-ovarian abscesses — is essential to avoid false positive diagnoses.

DWI is particularly valuable in resource-limited government hospital settings and in patients for whom contrast media is contraindicated. It should be incorporated as a routine adjunct to conventional MRI protocols for ovarian mass evaluation. Larger prospective multicenter studies are recommended to further standardize DWI protocols and ADC thresholds for clinical application.

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