IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 24, Issue 11 Ser. 3 (November. 2025), PP 71-81
www.iosrjournals.org

Accuracy Of the Adnex Mr Scoring System in The Evaluation of Adnexal Lesions on Mri in Correlation with Histopathological Findings: A Prospective Study

Dr. Brunda S[1], Dr. Praneethi K[2], Dr. Umesh K[3]
[1] *JR-3, Department of Radiodiagnosis, Ramaiah Medical College and Hospitals, Bengaluru, India*
[2] *Associate Professor, Department of Radiodiagnosis, Ramaiah Medical College and Hospitals, Bengaluru, India*
[3] *Professor, Department of Radiodiagnosis, Ramaiah Medical College and Hospitals, Bengaluru, India*

ABSTRACT
Background: *Adnexal masses represent a common clinical challenge requiring accurate preoperative characterization to guide appropriate management. Magnetic resonance imaging (MRI) has emerged as a valuable tool for evaluating sonographically indeterminate adnexal lesions. The ADNEX MR scoring system provides a standardized approach for risk stratification of these lesions.*
Objective: *To evaluate the diagnostic accuracy of the ADNEX MR scoring system in differentiating benign from malignant adnexal lesions using histopathology as the reference standard in a tertiary care setting.*
Methods: *This prospective observational study included 60 patients with sonographically indeterminate adnexal masses who underwent pelvic MRI followed by histopathological examination over 18 months. MRI examinations were performed using both 1.5 Tesla and 3 Tesla MRI scanners with a standardized protocol including T1-weighted, T2-weighted, diffusion-weighted imaging, and dynamic contrast-enhanced sequences. Lesions were scored using the ADNEX MR scoring system from 1 to 5 based on morphological features and perfusion characteristics. Diagnostic performance metrics including sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were calculated.*
Results: *Of 60 adnexal lesions, 21 were malignant and 39 were benign on histopathology. The ADNEX MR scoring system demonstrated high diagnostic accuracy with 95.24% sensitivity, 94.87% specificity, and 95% overall accuracy in distinguishing malignant from benign lesions using a cutoff score of 4 or greater. The positive predictive value was 90.91% and negative predictive value was 97.37%. All ADNEX MR score 5 lesions were malignant, while scores 1 and 2 showed excellent correlation with benign pathology.*
Conclusion: *The ADNEX MR scoring system is a highly accurate, reproducible, and clinically valuable tool for preoperative characterization of adnexal masses. Its implementation can facilitate appropriate surgical planning and patient counseling in clinical practice.*
Keywords: *Adnexal mass, ADNEX MR scoring system, magnetic resonance imaging, ovarian cancer, diffusion-weighted imaging, dynamic contrast enhancement*

I. INTRODUCTION

Adnexal masses are among the most frequently encountered findings in gynecologic imaging, occurring in approximately one in ten women during their lifetime and representing the leading indication for gynecologic surgery.[1] The diagnostic challenge lies in accurately distinguishing benign lesions that can be managed conservatively from malignant tumors requiring oncologic intervention. Ovarian cancer accounts for approximately 1% of all new cancer cases among women, with an estimated 20,890 new diagnoses and 12,730 deaths expected in the United States in 2025.[2] Globally, ovarian cancer represents the seventh most commonly diagnosed cancer among women, with approximately 239,000 new cases and 152,000 deaths annually.[3]

The mortality burden of ovarian cancer remains substantial despite advances in treatment modalities. A woman's lifetime risk of developing ovarian cancer is one in 75, with a one in 100 chance of dying from the disease. The overall five-year relative survival rate stands at only 29% when diagnosed at advanced stages, contrasting sharply with 92% survival for localized disease.[3] Only 20.3% of ovarian cancers are diagnosed at the local stage, with the five-year relative survival for localized disease reaching 91.7%.[2] This stark difference in survival rates based on stage at diagnosis underscores the critical importance of early detection and accurate preoperative characterization of adnexal masses.

Ovarian cancer encompasses a heterogeneous group of malignancies that vary substantially in etiology, molecular biology, histopathology, and clinical behavior. Ninety percent of ovarian cancers are epithelial in origin, with serous carcinoma being the most common subtype.[4] The current understanding recognizes two distinct pathways in ovarian carcinogenesis: Type I tumors, which are typically low-grade, slow-growing, and develop

from borderline tumors, and Type II tumors, which are predominantly high-grade serous carcinomas that arise from the fallopian tube epithelium and exhibit aggressive biological behavior. This molecular and pathological heterogeneity necessitates imaging protocols capable of capturing the diverse morphological and functional characteristics of these lesions.

Ultrasound, particularly transvaginal sonography, serves as the first-line imaging modality for evaluating pelvic masses due to its widespread availability, lack of ionizing radiation, and excellent spatial resolution for visualizing ovarian morphology. While the diagnostic accuracy of ultrasound in distinguishing malignant from benign complex adnexal masses varies between 63% and 92%, approximately 20% of adnexal lesions remain incompletely characterized after ultrasound evaluation.[1] Various ultrasound-based scoring systems and algorithms have been developed to improve diagnostic accuracy, including the International Ovarian Tumor Analysis (IOTA) simple rules and the IOTA Assessment of Different NEoplasias in the adneXa (ADNEX) model. However, limitations persist in cases of complex morphology, obesity, or when overlying bowel gas obscures adequate visualization.

Magnetic resonance imaging has demonstrated superior performance compared to ultrasound in characterizing adnexal masses, with reported accuracy of 88.9% versus 63.9% for transvaginal ultrasound, and significantly better specificity at 83.7% compared to 39.5%.[5] Systematic reviews have established MRI as particularly valuable in the evaluation of ultrasound-indeterminate adnexal lesions, with high specificity in characterizing benign lesions.[6] The superior soft tissue contrast resolution of MRI enables detailed characterization of tissue composition, including the detection of fat, hemorrhage, proteinaceous fluid, and solid tissue components. Furthermore, functional MRI sequences including diffusion-weighted imaging and dynamic contrast-enhanced imaging provide additional information about tissue cellularity and vascularity, enhancing diagnostic confidence.

The integration of morphological and functional MRI features has led to the development of standardized reporting systems aimed at improving diagnostic consistency and communication between radiologists and clinicians. In 2013, the ADNEX MR scoring system was introduced as a structured approach to MRI evaluation of adnexal masses, utilizing a standardized lexicon and a five-point risk stratification scale.[7] The scoring system incorporates multiple imaging parameters including lesion morphology, presence and characteristics of solid tissue, signal intensity patterns on T1-weighted and T2-weighted sequences, and perfusion dynamics on contrast-enhanced imaging.

The ADNEX MR scoring system classifies adnexal lesions into five categories: Score 1 indicates no adnexal mass; Score 2 represents benign masses including simple cysts with no solid tissue or fat-containing lesions such as mature teratomas; Score 3 denotes probably benign masses such as multilocular cysts with simple fluid or solid tissue demonstrating Type 1 perfusion curves characterized by gradual enhancement; Score 4 signifies indeterminate lesions with Type 2 perfusion characteristics showing plateau pattern; and Score 5 indicates probably malignant masses characterized by Type 3 perfusion curves with rapid wash-in and wash-out or definite peritoneal involvement. This systematic approach aims to facilitate consistent interpretation, appropriate risk stratification, and clear communication of findings to referring clinicians.

Several validation studies have demonstrated the clinical utility of the ADNEX MR scoring system across different populations and healthcare settings. The original retrospective study by Thomassin-Naggara and colleagues reported sensitivity of 93.5% and specificity of 96.6% for diagnosing malignancy using a score threshold of 4 or greater.[7] Subsequent prospective multicenter validation studies have confirmed these findings with comparable diagnostic performance. A large prospective study involving 572 sonographically indeterminate adnexal masses demonstrated that the ADNEX MR scoring system achieved sensitivity of 91% and specificity of 95% in distinguishing benign from malignant lesions.[8]

A systematic review and meta-analysis evaluating the diagnostic accuracy of the MR-ADNEX scoring system across five studies reported pooled sensitivity of 91%, specificity of 95%, area under the curve of 98%, and diagnostic odds ratio of 189, demonstrating higher specificity compared to ultrasound-based IOTA-ADNEX scoring systems.[9] These findings support the role of MRI as a problem-solving tool when ultrasound findings remain equivocal. Furthermore, studies have explored modifications to the original ADNEX MR scoring system by incorporating additional parameters such as apparent diffusion coefficient values from diffusion-weighted imaging, demonstrating potential for further improving specificity and reducing false-positive diagnoses.[10]

Dynamic contrast-enhanced MRI plays a pivotal role in the ADNEX MR scoring system by providing functional information about tissue vascularity and perfusion patterns. The time-intensity curves derived from dynamic imaging sequences characterize the enhancement kinetics of solid tissue components relative to the myometrium as an internal reference standard. Type 1 curves demonstrate gradual progressive enhancement without a definite peak, typically seen in benign fibrous lesions such as fibromas and thecomas. Type 2 curves show an initial steep increase in signal intensity followed by a plateau phase, which can be observed in both benign and malignant lesions, necessitating integration with morphological features for accurate characterization. Type 3 curves exhibit rapid initial enhancement steeper than myometrium followed by washout, a pattern highly suggestive of malignancy due to increased vascular permeability and arteriovenous shunting in neoplastic tissues.

Diffusion-weighted imaging represents another valuable functional sequence that assesses tissue cellularity based on the random motion of water molecules. Malignant lesions typically demonstrate restricted diffusion manifesting as high signal intensity on high b-value images and low signal on apparent diffusion coefficient maps due to increased cellular density and reduced extracellular space. Benign lesions generally show facilitated diffusion with low signal on high b-value images and high signal on apparent diffusion coefficient maps. The integration of diffusion-weighted imaging findings with conventional morphological sequences and dynamic contrast enhancement enhances diagnostic confidence, particularly in characterizing solid tissue components and distinguishing between cellular benign lesions and malignancies.

Despite the established accuracy of the ADNEX MR scoring system in Western populations, there remains a need for validation studies in diverse geographical regions and healthcare settings to assess its generalizability and clinical applicability. The prevalence of different histological subtypes, patient demographics, and healthcare infrastructure may influence diagnostic performance and implementation strategies. Furthermore, interobserver variability in scoring assignment and the learning curve associated with adopting standardized reporting systems warrant investigation to ensure reproducibility in routine clinical practice.

The appropriate management of adnexal masses depends critically on accurate preoperative risk stratification. Lesions classified as low risk can be managed conservatively with surveillance imaging or minimally invasive surgery performed by general gynecologists. In contrast, masses with high malignancy risk require referral to tertiary oncology centers for comprehensive staging and treatment by specialized gynecologic oncology teams. The ADNEX MR scoring system facilitates this clinical decision-making process by providing objective, reproducible criteria for risk assessment. Implementation of standardized reporting may reduce unnecessary surgical interventions for benign lesions while ensuring appropriate oncologic management for malignant disease.

II. AIMS AND OBJECTIVES

The primary objective of this study was to evaluate the diagnostic accuracy of the ADNEX MR scoring system in differentiating benign from malignant adnexal lesions in patients with sonographically indeterminate masses, using histopathological examination as the reference standard. Secondary objectives included determining the sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy of the ADNEX MR scoring system; analyzing the distribution of adnexal lesions across different ADNEX MR score categories; correlating specific MRI features with histopathological findings; and assessing the clinical utility of the scoring system for guiding appropriate patient management and surgical planning in a tertiary care hospital setting.

III. MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted at the Department of Radiodiagnosis, Ramaiah Medical College and Hospital, Bengaluru, a tertiary care teaching institution, over a period of 18 months from January 2023 to June 2024. The study protocol received approval from the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrollment. The study adhered to the principles of the Declaration of Helsinki and good clinical practice guidelines.

Study Population and Sample Size

The study included 60 female patients with sonographically indeterminate adnexal masses who were referred for pelvic MRI evaluation. Sample size calculation was based on an expected sensitivity of 90% for the ADNEX MR scoring system, with 95% confidence interval and 10% absolute precision, yielding a minimum required sample of 35 patients. The sample was expanded to 60 patients to enhance statistical power and enable subgroup analyses.

Inclusion Criteria

Patients were included if they met the following criteria: female patients aged 18 years or above; presence of an adnexal mass on ultrasound examination that remained indeterminate or incompletely characterized; willingness to undergo contrast-enhanced pelvic MRI; availability of histopathological confirmation through surgical specimen examination or biopsy; and provision of written informed consent for participation in the study.

Exclusion Criteria

Patients were excluded if they had: contraindications to MRI examination including metallic implants, pacemakers, or severe claustrophobia; contraindications to gadolinium-based contrast agents including previous severe allergic reactions or severe renal impairment with estimated glomerular filtration rate less than 30 mL/min/1.73m²; pregnancy or lactation; purely physiological ovarian cysts less than 3 cm in diameter; or refusal to provide informed consent for the study.

MRI Protocol and Technique

All MRI examinations were performed using both 1.5 Tesla and 3 Tesla MRI scanners with phased-array body coils. Patients were instructed to fast for 4-6 hours prior to the examination to reduce bowel peristalsis. Antiperistaltic agents were administered when necessary to minimize motion artifacts. The standardized imaging protocol included the following sequences:

T1-weighted spin-echo sequences were acquired in the axial plane with repetition time of 400-600 ms and echo time of 10-15 ms, with both in-phase and out-of-phase imaging to detect microscopic fat. T1-weighted fat-suppressed sequences were obtained in the axial plane to improve lesion conspicuity and characterize hemorrhagic content. T2-weighted fast spin-echo sequences were performed in three orthogonal planes (axial, sagittal, and coronal) with repetition time of 3000-5000 ms and echo time of 80-100 ms, providing excellent contrast for tissue characterization.

Diffusion-weighted imaging was performed using single-shot echo-planar sequences in the axial plane with b-values of 0, 500, and 1000 s/mm². Apparent diffusion coefficient maps were automatically generated to quantify diffusion characteristics. The presence of restricted diffusion in solid components was noted and factored into the overall assessment.

Dynamic contrast-enhanced imaging was acquired following intravenous administration of 0.1 mmol/kg body weight of gadolinium-based contrast agent (gadoterate meglumine) at a rate of 2-3 mL/second using a power injector, followed by a 20 mL saline flush. Dynamic T1-weighted gradient-echo sequences were obtained in the axial plane with high temporal resolution, acquiring images every 15-20 seconds for a total duration of 5-6 minutes. Time-intensity curves were generated by placing regions of interest on solid tissue components and the myometrium for comparison.

Post-contrast T1-weighted fat-suppressed images were obtained in three planes to assess enhancement patterns, detect peritoneal implants, and evaluate lymph node involvement.

Image Analysis and ADNEX MR Scoring

All MRI examinations were independently evaluated by two radiologists with 8 and 12 years of experience in gynecologic imaging, who were blinded to the clinical information, tumor markers, and histopathological results. Any discrepancies in scoring were resolved through consensus discussion. The adnexal lesions were systematically analyzed for the following parameters:

Lesion morphology was assessed including size measured in three orthogonal dimensions, laterality, number of locules in cystic lesions, wall characteristics including thickness and regularity, presence and characteristics of septations, and presence of solid tissue components. Signal characteristics were evaluated on T1-weighted imaging for the presence of hemorrhage or proteinaceous content, T2-weighted imaging for fluid signal characteristics and solid tissue signal intensity, and fat-suppressed sequences for fat-containing lesions such as mature teratomas.

Solid tissue components when present were analyzed for signal intensity on T2-weighted images, with particular attention to very low signal suggesting fibrous tissue. Diffusion characteristics were assessed on diffusion-weighted imaging and apparent diffusion coefficient maps. Dynamic contrast enhancement patterns were classified into three types based on time-intensity curve morphology: Type 1 curves showed gradual progressive enhancement without a peak, Type 2 curves demonstrated initial steep enhancement followed by plateau, and Type 3 curves exhibited rapid initial enhancement steeper than myometrium followed by washout.

Based on the comprehensive MRI assessment, each lesion was assigned an ADNEX MR score from 1 to 5 according to the standardized criteria: Score 1 indicated no adnexal mass; Score 2 represented benign masses including cysts without wall enhancement or solid tissue, unilocular cysts with smooth enhancing walls and no solid tissue, or fat-containing lesions without solid tissue; Score 3 denoted probably benign masses including unilocular cysts with irregular enhancing walls, multilocular cysts with simple or hemorrhagic fluid, or solid tissue with very low T2 signal or Type 1 perfusion curves; Score 4 indicated indeterminate masses with solid tissue demonstrating Type 2 perfusion curves; Score 5 signified probably malignant masses with solid tissue showing Type 3 perfusion curves or definite peritoneal or omental involvement.

Histopathological Examination

All patients underwent surgical intervention or biopsy within four weeks of MRI examination. Surgical procedures included laparoscopic or open oophorectomy, salpingo-oophorectomy, or complete staging procedures depending on clinical indication and intraoperative findings. Histopathological examination was performed by experienced gynecologic pathologists who were blinded to the MRI findings. Specimens were processed according to standard protocols with hematoxylin and eosin staining. Immunohistochemistry was performed when necessary for definitive classification. Lesions were categorized as benign, borderline, or malignant according to the World Health Organization classification of ovarian tumors.

Statistical Analysis

Statistical analysis was performed using SPSS software version 25.0. Descriptive statistics were calculated for demographic and clinical variables. Continuous variables were expressed as mean ± standard deviation or median with interquartile range depending on distribution. Categorical variables were presented as frequencies and percentages. The diagnostic performance of the ADNEX MR scoring system was evaluated using histopathology as the reference standard. A cutoff score of 4 or greater was used to classify lesions as malignant, while scores less than 4 were considered benign, consistent with previous validation studies.

Sensitivity was calculated as the proportion of malignant lesions correctly identified by MRI. Specificity was calculated as the proportion of benign lesions correctly identified by MRI. Positive predictive value represented the probability that a lesion scored as malignant on MRI was truly malignant on histopathology. Negative predictive value represented the probability that a lesion scored as benign on MRI was truly benign on histopathology. Overall accuracy was calculated as the proportion of all lesions correctly classified by MRI. Ninety-five percent confidence intervals were calculated for all performance metrics. A p-value less than 0.05 was considered statistically significant. Receiver operating characteristic curve analysis was performed to assess the discriminatory ability of the ADNEX MR scoring system.

IV. RESULTS

Demographic and Clinical Characteristics

The study cohort comprised 60 female patients with a mean age of 44.5 ± 13.2 years (range 22-68 years). The majority of patients (58.3%) were in the premenopausal age group, while 41.7% were postmenopausal. The most common presenting symptoms included abdominal pain (63.3%), abdominal distension (48.3%), abnormal uterine bleeding (35.0%), and palpable abdominal mass (28.3%). Twelve patients (20%) were asymptomatic, with masses detected incidentally during routine health examinations or imaging for unrelated indications. The mean duration of symptoms prior to presentation was 4.8 ± 3.6 months.

Serum CA-125 levels were measured in all patients, with mean values of 185.4 ± 312.6 U/mL. Among patients with subsequently confirmed malignant lesions, the mean CA-125 level was significantly elevated at 428.3 ± 398.2 U/mL compared to 68.4 ± 89.6 U/mL in patients with benign lesions ($p<0.001$). However, considerable overlap existed between benign and malignant groups, with some benign conditions such as endometriosis demonstrating markedly elevated CA-125 levels.

Distribution of ADNEX MR Scores and Histopathological Correlation

Table 1: Distribution of Adnexal Lesions According to ADNEX MR Score and Histopathological Diagnosis

ADNEX MR Score	Benign (n=39)	Malignant (n=21)	Total	Malignancy Rate (%)
Score 1	0	0	0	N/A
Score 2	18	0	18	0
Score 3	19	1	20	5.0
Score 4	2	6	8	75.0
Score 5	0	14	14	100.0
Total	**39**	**21**	**60**	**35.0**

The distribution of lesions across ADNEX MR score categories demonstrated clear stratification of malignancy risk. All 18 lesions assigned Score 2 were confirmed as benign on histopathology, yielding 100% specificity for this category. Among the 20 lesions classified as Score 3, nineteen were benign and one was malignant, representing a malignancy rate of 5%. The single malignant lesion in this category was a borderline mucinous tumor that exhibited predominantly benign morphological features with only focal areas of epithelial proliferation identified on histopathology.

Of the 8 lesions assigned Score 4, six were malignant and two were benign, corresponding to a malignancy rate of 75%. The two false-positive cases in this category included one case of ovarian torsion with hemorrhagic infarction that demonstrated Type 2 enhancement pattern mimicking malignancy, and one case of tubo-ovarian abscess with solid inflammatory tissue showing plateau enhancement. All 14 lesions categorized as Score 5 were confirmed as malignant on histopathology, achieving 100% positive predictive value for this highest-risk category.

Histopathological Spectrum of Adnexal Lesions

Table 2: Histopathological Distribution of Benign and Malignant Adnexal Lesions

Histopathological Diagnosis	Number (n)	Percentage (%)
BENIGN LESIONS (n=39)		
Epithelial tumors		
- Serous cystadenoma	9	15.0
- Mucinous cystadenoma	7	11.7
Endometriotic cyst	8	13.3
Mature cystic teratoma	6	10.0
Fibroma/Thecoma	4	6.7
Hemorrhagic corpus luteum cyst	3	5.0
Tubo-ovarian abscess	1	1.7
Ovarian torsion with hemorrhage	1	1.7
MALIGNANT LESIONS (n=21)		
High-grade serous carcinoma	8	13.3
Mucinous adenocarcinoma	3	5.0
Endometrioid adenocarcinoma	2	3.3
Clear cell carcinoma	2	3.3
Borderline mucinous tumor	2	3.3
Granulosa cell tumor	2	3.3
Metastatic adenocarcinoma	1	1.7
Immature teratoma	1	1.7
TOTAL	**60**	**100.0**

Among benign lesions, epithelial tumors predominated with serous cystadenomas (n=9, 15%) and mucinous cystadenomas (n=7, 11.7%) being most frequent. Endometriotic cysts represented 13.3% of all cases and were typically characterized by T1 hyperintense signal with T2 shading, corresponding to the presence of hemorrhagic debris and hemosiderin deposition. Mature cystic teratomas accounted for 10% of cases and were readily diagnosed based on the presence of macroscopic fat identified on T1-weighted imaging with signal dropout on fat-suppressed sequences. Fibrous lesions including fibromas and thecomas demonstrated characteristic very low signal intensity on T2-weighted sequences with minimal or no enhancement, corresponding to dense collagenous stroma.

Among malignant lesions, high-grade serous carcinoma was the most common histological subtype (n=8, 38.1% of malignancies), consistent with the known epidemiology of ovarian cancer. These lesions typically presented as complex masses with predominantly solid components, papillary projections, and Type 3 enhancement patterns. Mucinous adenocarcinomas (n=3) manifested as large multilocular cystic masses with varying signal intensity fluid and solid mural nodules. Two cases of borderline mucinous tumors were encountered, one of which was misclassified as Score 3 due to minimal solid tissue and absence of aggressive features. Granulosa cell tumors, representing sex cord-stromal malignancies, presented as predominantly solid masses with heterogeneous signal intensity reflecting areas of hemorrhage and cystic degeneration.

Diagnostic Performance of ADNEX MR Scoring System

Table 3: Diagnostic Performance Metrics of ADNEX MR Scoring System Using Cutoff Score ≥4 for Malignancy

Performance Metric	Value	95% Confidence Interval
Sensitivity	95.24%	76.2% - 99.9%
Specificity	94.87%	82.7% - 99.4%
Positive Predictive Value (PPV)	90.91%	70.8% - 98.9%

Performance Metric	Value	95% Confidence Interval
Negative Predictive Value (NPV)	97.37%	86.2% - 99.9%
Overall Accuracy	95.00%	86.1% - 99.0%
Area Under ROC Curve (AUC)	0.976	0.934 - 1.000

Using a threshold score of 4 or greater to indicate malignancy, the ADNEX MR scoring system demonstrated excellent diagnostic performance with 95.24% sensitivity and 94.87% specificity. Of the 21 histopathologically confirmed malignant lesions, 20 were correctly identified by the scoring system (true positives), while one borderline mucinous tumor was misclassified as Score 3 (false negative). Among the 39 benign lesions, 37 were correctly categorized as low-risk scores 2 or 3 (true negatives), while two lesions were incorrectly assigned Score 4 (false positives).

The positive predictive value of 90.91% indicated that among lesions scored as 4 or 5, approximately nine out of ten were confirmed as malignant on histopathology. The negative predictive value of 97.37% demonstrated that lesions assigned scores less than 4 had extremely low probability of malignancy, with only one malignant lesion among 38 cases categorized as low risk. The overall accuracy of 95% reflected correct classification of 57 out of 60 lesions. The area under the receiver operating characteristic curve was 0.976, indicating excellent discriminatory ability of the scoring system.

Correlation of MRI Features with Malignancy

Table 4: Correlation of Specific MRI Features with Histopathological Diagnosis

MRI Feature	Benign (n=39)	Malignant (n=21)	p-value
Mean lesion diameter (cm)	7.2 ± 2.8	9.8 ± 3.4	0.021
Bilateral lesions	4 (10.3%)	6 (28.6%)	0.088
Presence of solid tissue	12 (30.8%)	19 (90.5%)	<0.001
Irregular/thick septa (>3mm)	6 (15.4%)	15 (71.4%)	<0.001
Papillary projections	2 (5.1%)	11 (52.4%)	<0.001
Presence of ascites	3 (7.7%)	12 (57.1%)	<0.001
Peritoneal implants	0 (0%)	8 (38.1%)	<0.001
Restricted diffusion	5 (12.8%)	18 (85.7%)	<0.001
Enhancement Pattern (in solid tissue)*			
Type 1 curve (gradual enhancement)	10/12 (83.3%)*	0/19 (0%)**	<0.001
Type 2 curve (plateau)	2/12 (16.7%)*	6/19 (31.6%)**	0.435
Type 3 curve (washout)	0/12 (0%)*	13/19 (68.4%)**	<0.001

*Percentages calculated among 12 benign lesions with solid tissue components **Percentages calculated among 19 malignant lesions with solid tissue components

Several MRI features demonstrated statistically significant association with malignancy. Malignant lesions were significantly larger than benign lesions with mean diameters of 9.8 cm versus 7.2 cm (p=0.021). The presence of solid tissue components was strongly associated with malignancy, identified in 90.5% of malignant lesions compared to only 30.8% of benign lesions (p<0.001). Among benign lesions with solid components, these typically represented fibrous tissue in cystadenofibromas or fibromas, characterized by very low T2 signal and Type 1 enhancement patterns.

Irregular or thick septations greater than 3 mm were significantly more common in malignant lesions (71.4%) compared to benign lesions (15.4%, p<0.001). Papillary projections, defined as solid enhancing vegetations arising from the cyst wall or septations, were identified in 52.4% of malignant cases but only 5.1% of benign lesions (p<0.001). The presence of ascites showed strong association with malignancy (57.1% versus 7.7%, p<0.001), although moderate ascites was also observed in three cases of benign conditions including endometriosis and pelvic inflammatory disease.

Peritoneal implants representing metastatic disease were pathognomonic for malignancy, identified in 38.1% of malignant cases with no false positives among benign lesions. Restricted diffusion on diffusion-weighted imaging was highly sensitive for malignancy, present in 85.7% of malignant lesions compared to 12.8% of benign lesions (p<0.001). The few benign lesions demonstrating restricted diffusion included cellular lesions such as fibromas and inflammatory processes such as tubo-ovarian abscesses.

Among lesions with solid tissue components, the pattern of dynamic contrast enhancement showed strong correlation with histological diagnosis. Type 1 curves characterized by gradual progressive enhancement were exclusively associated with benign pathology, observed in 83.3% of benign lesions with solid tissue. Type 3 curves showing rapid initial enhancement followed by washout were highly specific for malignancy, identified in 68.4% of malignant lesions with no false positives. Type 2 curves with plateau enhancement pattern demonstrated intermediate and overlapping characteristics, present in 16.7% of benign and 31.6% of malignant lesions (p=0.435).

Analysis of Diagnostic Errors

Table 5: Analysis of False Positive and False Negative Cases

Case	ADNEX Score	Histopathology	Key MRI Features	Reason for Misclassification
FP-1	4	Tubo-ovarian abscess	Solid-appearing inflammatory tissue, Type 2 enhancement	Inflammatory hypervascularity mimicked malignancy
FP-2	4	Ovarian torsion with hemorrhage	Heterogeneous signal, hemorrhage, Type 2 enhancement	Hemorrhagic infarction mimicked solid tumor
FN-1	3	Borderline mucinous tumor	Multilocular cystic mass, minimal solid tissue, Type 1 curve	Predominantly benign morphology, indolent biology

Three cases were misclassified by the ADNEX MR scoring system, resulting in an overall error rate of 5%. Two false-positive cases involved benign lesions incorrectly assigned Score 4, leading to overestimation of malignancy risk. The first false-positive case was a tubo-ovarian abscess in a patient presenting with pelvic pain and fever. MRI demonstrated a complex adnexal mass with predominantly solid appearance, thick irregular walls, and Type 2 enhancement pattern. The inflammatory nature was not fully appreciated on imaging, and the solid-appearing component represented inflamed granulation tissue and purulent material rather than neoplastic tissue. Clinical correlation with elevated inflammatory markers and fever might have aided in correct diagnosis.

The second false-positive case involved ovarian torsion with hemorrhagic infarction in a patient with acute pelvic pain. The affected ovary demonstrated heterogeneous signal intensity with areas of T1 hyperintensity reflecting hemorrhage, diffuse edema causing T2 hyperintensity, and solid-appearing component showing Type 2 enhancement. The combination of solid appearance and abnormal enhancement pattern mimicked malignancy. Recognition of the twisted vascular pedicle and correlation with acute clinical presentation would have suggested the correct diagnosis.

One false-negative case occurred in which a borderline mucinous tumor was assigned Score 3 rather than Score 4. This lesion presented as a large multilocular cystic mass with thin septa and minimal focal solid tissue demonstrating Type 1 enhancement curve. The histopathological examination revealed a borderline tumor with focal areas of epithelial proliferation and nuclear atypia, but without stromal invasion. The imaging features were predominantly benign in appearance, reflecting the indolent biology of borderline tumors that occupy an intermediate category between benign cystadenomas and invasive carcinomas. This case highlights the inherent challenge in distinguishing borderline tumors from benign lesions based on imaging alone.

V. DISCUSSION

This prospective study validates the diagnostic accuracy of the ADNEX MR scoring system in characterizing sonographically indeterminate adnexal masses in a tertiary care setting. Our findings demonstrate that the scoring system achieves excellent diagnostic performance with 95.24% sensitivity, 94.87% specificity, and 95% overall accuracy in distinguishing benign from malignant lesions. These results are consistent with previously published validation studies and support the clinical utility of standardized MRI reporting for adnexal masses.

The original study by Thomassin-Naggara and colleagues reported sensitivity of 93.5% and specificity of 96.6% for the ADNEX MR scoring system in a retrospective cohort of 168 adnexal masses.[7] Our prospective validation study yielded comparable results, with sensitivity of 95.24% and specificity of 94.87%, confirming the reproducibility of the scoring system across different populations and clinical settings. The slight variation in specificity may reflect differences in the spectrum of lesions encountered, with our cohort including more inflammatory and hemorrhagic lesions that can occasionally mimic malignancy.

A large prospective multicenter study by Basha and colleagues evaluated 572 sonographically indeterminate adnexal masses using the ADNEX MR scoring system and reported sensitivity of 91%, specificity of 95%, and area under the curve of 0.98.[8] Our study demonstrated even higher sensitivity at 95.24%, likely attributable to the standardized MRI protocol and inclusion of diffusion-weighted imaging in our assessment. The

area under the receiver operating characteristic curve in our study was 0.976, indicating excellent discriminatory ability comparable to previous reports.

A systematic review and meta-analysis by Cui and colleagues pooled data from five studies evaluating the MR-ADNEX scoring system and calculated pooled sensitivity of 91%, pooled specificity of 95%, and diagnostic odds ratio of 189.[9] Our single-center results align well with these pooled estimates, with slightly higher sensitivity potentially reflecting the expertise of dedicated gynecologic imaging radiologists at our tertiary referral center. The positive predictive value of 90.91% in our study indicates that approximately nine out of ten lesions classified as high risk (scores 4 or 5) were confirmed as malignant, providing confidence for planning appropriate oncologic intervention.

The distribution of malignancy across ADNEX MR score categories in our study demonstrated clear risk stratification. All 18 lesions assigned Score 2 were benign, yielding 100% specificity for this category. Among Score 3 lesions, only one of 20 was malignant, corresponding to a malignancy rate of 5%. This finding is consistent with the study by Thomassin-Naggara reporting malignancy rates of 1.7% for Score 2 and 7.7% for Score 3 lesions.[11] The low malignancy rate in these categories supports conservative management or minimally invasive surgery for lesions with these scores. In contrast, 75% of Score 4 lesions and 100% of Score 5 lesions were malignant in our cohort, justifying referral to specialized oncology centers for comprehensive staging and treatment.

Our study identified specific MRI features that showed significant association with malignancy, providing insights into the pathophysiological basis of the ADNEX MR scoring system. The presence of solid tissue components demonstrated the strongest association with malignancy, identified in 90.5% of malignant lesions compared to 30.8% of benign lesions. This finding emphasizes the critical importance of carefully scrutinizing solid tissue when present and characterizing its enhancement pattern using dynamic contrast-enhanced imaging. The perfusion characteristics of solid tissue form the cornerstone of the ADNEX MR scoring system, with Type 3 curves showing rapid wash-in and wash-out being highly specific for malignancy.

Restricted diffusion on diffusion-weighted imaging was present in 85.7% of malignant lesions in our study, significantly higher than the 12.8% of benign lesions demonstrating this feature. A study by Hottat and colleagues demonstrated that incorporation of diffusion-weighted imaging and apparent diffusion coefficient mapping into a modified ADNEX MR scoring system improved specificity by reducing false-positive diagnoses.[10] While diffusion-weighted imaging is not formally part of the original ADNEX MR scoring system, its integration into the assessment provides valuable complementary information that enhances diagnostic confidence, particularly in distinguishing cellular benign lesions from malignancies.

The presence of peritoneal implants was pathognomonic for malignancy in our study, identified in 38.1% of malignant cases with no false positives. This finding aligns with the ADNEX MR scoring criteria that automatically assign Score 5 to lesions with definite peritoneal or omental involvement, regardless of other features. Recognition of peritoneal disease is critically important as it typically indicates advanced-stage disease requiring neoadjuvant chemotherapy followed by interval cytoreductive surgery in many cases. MRI demonstrates superior sensitivity compared to ultrasound in detecting small peritoneal deposits, particularly in the paracolic gutters, diaphragmatic surface, and bowel serosa.

Our analysis of diagnostic errors provides valuable insights into the limitations of the ADNEX MR scoring system and potential pitfalls in interpretation. Two false-positive cases involved benign inflammatory and hemorrhagic conditions that demonstrated features mimicking malignancy. Tubo-ovarian abscesses can present as complex masses with solid-appearing inflammatory tissue showing plateau or wash-out enhancement patterns due to hypervascularity of inflamed tissue.[12] Integration of clinical information including fever, elevated inflammatory markers, and acute presentation can aid in recognizing the inflammatory etiology and avoiding false-positive diagnosis.

Ovarian torsion with hemorrhagic infarction represents another diagnostic challenge, as the combination of hemorrhage, edema, and vascular compromise can create heterogeneous signal characteristics and abnormal enhancement patterns that mimic malignancy. Recognition of the twisted vascular pedicle, often best visualized on axial T2-weighted images, serves as a key diagnostic clue. Additionally, the clinical presentation with acute severe pelvic pain differing from the more insidious presentation of malignancy should prompt consideration of torsion in the differential diagnosis.

The single false-negative case in our study involved a borderline mucinous tumor that was assigned Score 3 due to predominantly benign morphological features and Type 1 enhancement pattern. Borderline tumors, also termed tumors of low malignant potential, represent a distinct category characterized by epithelial proliferation and nuclear atypia without stromal invasion. These lesions often demonstrate imaging features intermediate between benign cystadenomas and invasive carcinomas, creating inherent diagnostic challenges.[13] While the ADNEX MR scoring system performed well overall, distinguishing borderline tumors from benign lesions remains challenging based on imaging alone. Some studies have suggested that borderline tumors may demonstrate certain features such as larger size, presence of papillary projections, and bilaterality more frequently than benign cystadenomas, but significant overlap exists.

The clinical implications of implementing the ADNEX MR scoring system extend beyond diagnostic accuracy to impact patient management and surgical planning. Accurate preoperative risk stratification enables appropriate triaging of patients between general gynecologists and specialized gynecologic oncology teams. Lesions classified as low risk (scores 2 and 3) can be managed with conservative surveillance or minimally invasive surgery, potentially avoiding unnecessary radical procedures and their associated morbidity. In contrast, high-risk lesions (scores 4 and 5) should be referred to tertiary oncology centers where comprehensive staging including omentectomy, lymphadenectomy, and peritoneal assessment can be performed by experienced gynecologic oncologists, optimizing oncologic outcomes.

The standardization of MRI reporting through systems like ADNEX MR facilitates clear communication between radiologists and clinicians, reducing ambiguity and improving consistency in patient management. Rather than using descriptive terminology that may be variably interpreted, the five-point scoring system provides objective risk categorization that can guide evidence-based clinical decisions. Implementation of standardized reporting systems has been shown to improve interobserver agreement and reduce variability in interpretation.[14]

Our study has several strengths including the prospective design, standardized MRI protocol incorporating both morphological and functional sequences, histopathological confirmation for all cases, and blinded image interpretation. The inclusion of diffusion-weighted imaging and dynamic contrast-enhanced sequences provided comprehensive assessment of tissue characteristics. The sample size, while moderate, was adequately powered to evaluate diagnostic performance and included a representative spectrum of benign and malignant pathologies encountered in clinical practice.

However, certain limitations warrant acknowledgment. The study was conducted at a single tertiary referral center with dedicated gynecologic imaging radiologists, which may limit generalizability to community practice settings with less specialized expertise. The prevalence of malignancy in our cohort at 35% was higher than would be expected in an unselected population of adnexal masses, reflecting referral bias toward more complex and suspicious lesions at a tertiary care center. This higher prevalence may have influenced the positive predictive value, which is dependent on disease prevalence. The relatively small number of borderline tumors in our cohort limited detailed assessment of scoring system performance for this challenging diagnostic category.

Interobserver variability was not formally assessed in this study, although discrepancies between the two interpreting radiologists were resolved through consensus. Future studies should evaluate interobserver agreement, particularly between radiologists with varying levels of experience, to assess the reproducibility of the scoring system in routine clinical practice. The learning curve associated with implementing the ADNEX MR scoring system and the impact of specialized training on diagnostic performance merit investigation. Additionally, long-term follow-up of conservatively managed low-risk lesions would provide valuable information about the safety of non-operative management based on ADNEX MR scores.

In conclusion, our prospective validation study confirms that the ADNEX MR scoring system is a highly accurate tool for characterizing sonographically indeterminate adnexal masses. The standardized approach to MRI interpretation facilitates risk stratification, enabling appropriate clinical decision-making and patient management. Implementation of this scoring system in routine clinical practice can optimize the utilization of healthcare resources by reducing unnecessary surgical interventions for benign lesions while ensuring timely referral to specialized oncology centers for malignant disease. Future research should focus on refining the scoring system to improve characterization of borderline tumors, evaluating cost-effectiveness of MRI-based triaging strategies, and investigating the integration of emerging technologies such as radiomics and artificial intelligence to further enhance diagnostic performance.

VI. CONCLUSION

This prospective study validates the excellent diagnostic accuracy of the ADNEX MR scoring system in characterizing sonographically indeterminate adnexal masses, achieving 95.24% sensitivity, 94.87% specificity, and 95% overall accuracy in distinguishing benign from malignant lesions. The scoring system provides effective risk stratification with clear correlation between score categories and histopathological outcomes. Lesions assigned scores 2 and 3 demonstrated very low malignancy rates of 0% and 5% respectively, supporting conservative management approaches. In contrast, lesions with scores 4 and 5 showed malignancy rates of 75% and 100%, justifying referral to specialized oncology centers for comprehensive surgical staging and treatment.

The ADNEX MR scoring system integrates morphological features including lesion architecture, signal characteristics, and presence of solid tissue with functional parameters including dynamic contrast enhancement patterns and diffusion characteristics. This comprehensive multiparametric approach leverages the superior soft tissue contrast and functional capabilities of MRI to achieve accurate tissue characterization. Key MRI features significantly associated with malignancy included presence of solid tissue components, Type 3 perfusion curves, restricted diffusion, irregular thick septa, papillary projections, and peritoneal implants.

Implementation of standardized MRI reporting using the ADNEX MR scoring system facilitates clear communication between radiologists and clinicians, reduces interpretive variability, and enables evidence-based

clinical decision-making. The scoring system can optimize patient management by identifying low-risk lesions suitable for conservative surveillance or minimally invasive surgery while ensuring appropriate oncologic intervention for high-risk lesions. Future research should focus on multicenter validation studies, assessment of interobserver reproducibility, refinement of criteria for borderline tumors, and evaluation of cost-effectiveness to support widespread clinical adoption of this valuable diagnostic tool.

REFERENCES

[1]. Hottat NA, Van Pachterbeke C, Vanden Houte K, Denolin V, Jani JC, Cannie MM. Magnetic resonance scoring system for assessment of adnexal masses: added value of diffusion-weighted imaging including apparent diffusion coefficient map. Ultrasound Obstet Gynecol. 2021;57(3):478-487.

[2]. National Cancer Institute. Cancer Stat Facts: Ovarian Cancer. Surveillance, Epidemiology, and End Results Program. 2025. Available from: https://seer.cancer.gov/statfacts/html/ovary.html

[3]. Reid BM, Permuth JB, Sellers TA. Epidemiology of ovarian cancer: a review. Cancer Biol Med. 2017;14(1):9-32.

[4]. Torre LA, Trabert B, DeSantis CE, Miller KD, Samimi G, Runowicz CD, et al. Ovarian cancer statistics, 2018. CA Cancer J Clin. 2018;68(4):284-296.

[5]. Pereira PN, Sarian LO, Yoshida A, Araújo KG, Barros RHO, Baião AC, et al. Accuracy of the ADNEX MR scoring system based on a simplified MRI protocol for the assessment of adnexal masses. Diagn Interv Radiol. 2018;24(2):63-71.

[6]. Sadowski EA, Robbins JB, Rockall AG, Thomassin-Naggara I. A systematic approach to adnexal masses discovered on ultrasound: the ADNEx MR scoring system. Abdom Radiol. 2018;43(3):679-695.

[7]. Thomassin-Naggara I, Aubert E, Rockall A, Jalaguier-Coudray A, Rouzier R, Daraï E, et al. Adnexal masses: development and preliminary validation of an MR imaging scoring system. Radiology. 2013;267(2):432-443.

[8]. Basha MAA, Metwally MI, Gamil SA, Khater HM, Aly SA, El Sammak AA, et al. Validity and reproducibility of the ADNEX MR scoring system in the diagnosis of sonographically indeterminate adnexal masses. J Magn Reson Imaging. 2020;53(1):292-304.

[9]. Cui L, Xu H, Zhang Y. Diagnostic accuracies of the ultrasound and magnetic resonance imaging ADNEX scoring systems for ovarian adnexal mass: systematic review and meta-analysis. Acad Radiol. 2022;29(6):897-908.

[10]. Hottat NA, Van Pachterbeke C, Vanden Houte K, Denolin V, Jani JC, Cannie MM. Magnetic resonance scoring system for assessment of adnexal masses: added value of diffusion-weighted imaging including apparent diffusion coefficient map. Ultrasound Obstet Gynecol. 2021;57(3):478-487.

[11]. Thomassin-Naggara I, Toussaint I, Perrot N, Rouzier R, Cuenod CA, Bazot M, et al. Characterization of complex adnexal masses: value of adding perfusion- and diffusion-weighted MR imaging to conventional MR imaging. Radiology. 2011;258(3):793-803.

[12]. Forstner R, Thomassin-Naggara I, Cunha TM, Kinkel K, Masselli G, Kubik-Huch R, et al. ESUR recommendations for MR imaging of the sonographically indeterminate adnexal mass: an update. Eur Radiol. 2017;27(6):2248-2257.

[13]. Goff BA, Agnew K, Neradilek MB, Gray HJ, Liao JB, Urban RR. Combining a symptom index, CA125 and HE4 (triple screen) to detect ovarian cancer in women with a pelvic mass. Gynecol Oncol. 2017;147(2):291-295.

[14]. Sadowski EA, Thomassin-Naggara I, Rockall A, Maturen KE, Forstner R, Jha P, et al. O-RADS MRI risk stratification system: guide for assessing adnexal lesions from the ACR O-RADS Committee. Radiology. 2022;303(1):35-47.

[15]. Zhang H, Zhang GF, He ZY, Li ZY, Zhang GX. Prospective validation of O-RADS US risk stratification and malignancy rate of O-RADS US risk categories: an analysis of 1054 adnexal lesions. Radiology. 2021;300(2):341-350.