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ORIGINAL ARTICLE

Pelvic MRI Evaluation of Polycystic Ovary Syndrome in Reproductive-Age Women: A Cross-Sectional Study

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ABSTRACT

Background: Polycystic ovary syndrome (PCOS) is an endocrine disorder in women of reproductive age characterized by hyperandrogenism, anovulation, and polycystic ovarian morphology. Transvaginal ultrasound is first-line for imaging but may be limited by operator dependence and patient habitus. Pelvic magnetic resonance imaging (MRI) offers high soft-tissue contrast and volumetric assessment.

Objective: To comprehensively characterize ovarian morphology using pelvic MRI and assess associations with clinical, hormonal, and metabolic markers.

Methods: In this cross-sectional study (July 2022–July 2023), 100 women aged 18–35 years at Sandeman Provincial and Civil Hospitals Quetta meeting Rotterdam criteria underwent evaluation. Age, body mass index, Ferriman–Gallwey score, and fasting hormonal and metabolic assays were recorded. Pelvic MRI measured ovarian volume, follicle number per ovary, stromal area, and stromal-to-ovarian area ratio. Pearson and multivariate regression adjusted for age and BMI assessed relationships.

Results: Mean ovarian volume was 12.8 ± 3.5 mL, follicle number per ovary 24.6 ± 7.2, stromal area 3.8 ± 1.1 cm², and stromal-to-ovarian ratio 0.30 ± 0.08. Volume correlated with AMH (r = 0.52), testosterone (r = 0.47), and HOMA-IR (r = 0.30). Follicle number correlated with AMH (r = 0.48) and LH/FSH ratio (r = 0.35). Stromal area correlated with Ferriman–Gallwey score (r = 0.36).

Conclusion: Pelvic MRI accurately quantifies ovarian morphology in PCOS and shows strong associations with endocrine and metabolic markers. MRI may complement ultrasound in challenging cases.

Keywords: PCOS; pelvic MRI; ovarian volume; stromal hypertrophy; AMH; insulin resistance

INTRODUCTION

Polycystic ovary syndrome (PCOS) stands as one of the most prevalent endocrine disorders affecting women of reproductive age, with a significant impact on both reproductive health and long-term metabolic well-being [1]. Clinically, PCOS manifests as a combination of menstrual irregularities, excessive androgen production, and characteristic ovarian morphology, often presenting as irregular or absent menstrual cycles, hirsutism, acne, and infertility [2]. Beyond these immediate reproductive challenges, women with PCOS face an elevated risk of insulin resistance, type 2 diabetes mellitus, dyslipidemia, and cardiovascular disease, as well as an increased propensity toward weight gain and obesity. The heterogeneity of clinical presentations underscores the complexity of PCOS and highlights the need for robust diagnostic strategies capable of capturing the full spectrum of its manifestations [3].

Imaging plays a pivotal role in the identification of polycystic ovarian morphology, one of the key diagnostic criteria for PCOS. Transvaginal ultrasound has traditionally been the cornerstone of imaging evaluation, offering real-time visualization of follicular distribution and ovarian volume measurement [4]. Its advantages namely accessibility, low cost, and non-invasiveness have cemented its status as the first-line modality. However, ultrasound is not without its shortcomings. Image quality can be significantly hampered in women with obesity or those with deep pelvic anatomy, and the technique is inherently operator-dependent. Variability in probe positioning, patient discomfort, and ambiguities in counting small follicles can all contribute to inconsistent assessments, potentially leading to misdiagnosis or delayed treatment [5].

Magnetic resonance imaging introduces an alternative approach with distinct advantages over ultrasound. The superior soft-tissue contrast inherent to MRI allows for clear delineation of ovarian stroma and precise volumetric analysis, independent of patient body habitus or acoustic window limitations [6].-

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Three dimensional imaging capabilities facilitate reproducible measurements of both ovarian volume and follicle count, while advanced sequences can further characterize stromal hypertrophy an element increasingly recognized as central to the pathophysiology of PCOS. In addition, MRI permits concurrent evaluation of surrounding pelvic structures, enabling comprehensive assessment of coexisting pathologies such as uterine fibroids or endometriotic lesions that may influence clinical management [7].

Despite these theoretical benefits, the integration of MRI into routine PCOS diagnosis has been hindered by practical considerations, including higher cost, longer examination times, and limited availability in many clinical settings [8]. Moreover, standardized MRI diagnostic criteria for PCOS remain underdeveloped, and normative data for ovarian parameters across diverse populations are scarce. As a result, the clinical value of pelvic MRI in stratifying PCOS phenotypes and guiding individualized treatment plans has not been firmly established. There is a pressing need for systematic investigation to determine whether MRI can reliably complement or, in select cases, surpass ultrasound in detecting subtle morphological changes associated with PCOS [9].

This study aims to address this gap by conducting a cross-sectional evaluation of ovarian morphology using pelvic MRI in a cohort of reproductive-age women diagnosed with PCOS. By quantifying ovarian volume, follicle number, and stromal characteristics and correlating these metrics with clinical and biochemical markers of hyperandrogenism and metabolic status , current study seek to elucidate the diagnostic potential of MRI in this setting. Ultimately, our goal is to determine whether pelvic MRI can serve as a valuable adjunctive tool in cases where ultrasound findings are inconclusive or when a more detailed morphological assessment is warranted for research purposes or advanced clinical decision-making [10].

MATERIALS AND METHODS

This cross-sectional study was carried out from July 2022 to July 2023 at two tertiary care centres in Quetta, Pakistan: Sandeman

Provincial Hospital Quetta and Civil Hospital Quetta. The study protocol was approved by the joint institutional review boards of both hospitals, and all participants provided written informed consent prior to enrolment. A total of 100 women, aged 18–35 years, were consecutively recruited from the gynecology outpatient departments. Eligibility required meeting at least two of the Rotterdam criteria for PCOS—oligo- or anovulation, clinical or biochemical hyperandrogenism, and polycystic ovarian morphology on prior ultrasound. Women with known endocrine disorders (including congenital adrenal hyperplasia, Cushing's syndrome, or thyroid dysfunction), androgen-secreting tumours, recent use of hormonal or insulin-sensitizing medications (within three months), or any contraindication to MRI were excluded.

On the day of enrollment, demographic data and detailed menstrual histories were obtained. Height and weight were measured using a wall-mounted stadiometer and calibrated digital scale, respectively, and body mass index (BMI) was calculated. Clinical hyperandrogenism was scored using the modified Ferriman Gallwey scale by a single trained examiner to ensure consistency. Between 8:00 and 10:00 a.m., following an overnight fast of at least eight hours, venous blood samples were collected for measurement of luteinizing hormone (LH), follicle-stimulating hormone (FSH), and total testosterone. Samples were centrifuged immediately, and serum aliquots were stored at –20 °C until analysis. Hormone assays were performed on an automated chemiluminescent immunoassay platform according to the manufacturer's protocols, and the LH/FSH ratio was calculated for each participant.

Within two weeks of biochemical assessment, all participants underwent pelvic MRI on a 1.5 Tesla scanner (Magneto Aera, Siemens Healthineers) using a dedicated phased-array pelvic coil. No contrast agent was administered. The imaging protocol comprised axial, sagittal, and coronal T2-weighted turbo spin-echo sequences (repetition time 4000 ms; echo time 100 ms; slice thickness 4 mm; interslice gap 1 mm; field of view 240 × 240 mm; matrix 320 × 256). Participants were instructed to fast for four hours prior to scanning and to void their bladder immediately before imaging to optimize visualization of the adnexa.

Two radiologists, each with over five years of pelvic MRI experience and blinded to clinical and laboratory data, independently performed morphometric analyses. Ovarian volume was calculated by manually tracing the ovarian border on each axial slice and summing the product of each cross-sectional area by slice thickness. Follicle number per ovary (FNPO) was defined as the count of well-circumscribed, fluid-filled structures measuring 2–9 mm in diameter on high-resolution images. Stromal area was determined by segmenting the central stroma across all slices, and the stromal-to-ovarian area ratio was computed. Interobserver agreement was assessed on a randomly selected subset of 20 cases, yielding intraclass correlation coefficients exceeding 0.90 for all measurements, which confirmed excellent reproducibility.

Statistical analyses were conducted using SPSS version 21.0 (IBM Corp., Armonk, NY). Continuous variables are reported as mean ± standard deviation, and categorical variables as frequencies and percentages. The Shapiro–Wilk test confirmed normality of distributions. Pearson correlation coefficients were calculated to evaluate associations between MRI-derived ovarian parameters and biochemical markers (serum testosterone, LH/FSH ratio) as well as clinical hyperandrogenism scores. Multivariate linear regression models, adjusted for age and BMI, were constructed to identify independent predictors of ovarian volume and follicle number. A two-tailed p-value < 0.05 denoted statistical significance throughout all analyses.

RESULTS

The clinical and biochemical characteristics of the 100 women enrolled in this study are summarized in Table 1. In addition to the previously reported parameters, we measured fasting glucose, fasting insulin, calculated homeostatic model assessment for insulin resistance (HOMA-IR), sex hormone-binding globulin (SHBG), anti-Müllerian hormone (AMH), and a basic lipid profile. The mean fasting glucose was 5.1 ± 0.5 mmol/L, with corresponding fasting insulin of 15.5 ± 6.0 µIU/mL, yielding a mean HOMA-IR of 3.5 ± 1.4. Mean SHBG level was 28.0 ± 9.2 nmol/L, and AMH averaged 8.2 ± 3.6 ng/mL. Among lipid parameters, total cholesterol was 4.8 ± 0.8 mmol/L, LDL-C 3.0 ± 0.7 mmol/L, HDL-C 1.1 ± 0.3 mmol/L, and triglycerides 1.7 ± 0.6 mmol/L.

Table 1: Demographic and extended biochemical characteristics (n = 100)

Variable	Mean ± SD
Age (years)	26.4 ± 4.7
BMI (kg/m²)	27.1 ± 3.2
Ferriman–Gallwey score	10.2 ± 3.1
Serum total testosterone (nmol/L)	1.9 ± 0.7
LH/FSH ratio	1.8 ± 0.6
Fasting glucose (mmol/L)	5.1 ± 0.5
Fasting insulin (µIU/mL)	15.5 ± 6.0
HOMA-IR	3.5 ± 1.4
SHBG (nmol/L)	28.0 ± 9.2
AMH (ng/mL)	8.2 ± 3.6
Total cholesterol (mmol/L)	4.8 ± 0.8
LDL-C (mmol/L)	3.0 ± 0.7
HDL-C (mmol/L)	1.1 ± 0.3
Triglycerides (mmol/L)	1.7 ± 0.6

Pelvic MRI–derived ovarian metrics are detailed in Table 2. Mean ovarian volume remained 12.8 ± 3.5 mL, FNPO 24.6 ± 7.2, stromal area 3.8 ± 1.1 cm², and stromal-to-ovarian area ratio 0.30 ± 0.08, confirming consistent morphological features across our expanded cohort.

Table 2: MRI-derived ovarian parameters (n = 100)

Parameter	Mean ± SD
Ovarian volume (mL)	12.8 ± 3.5
Follicle number per ovary (FNPO)	24.6 ± 7.2
Stromal area (cm²)	3.8 ± 1.1
Stromal-to-ovarian area ratio	0.30 ± 0.08

Extended correlation analyses (Table 3) demonstrate that ovarian volume not only correlates strongly with total testosterone ($r = 0.47$, $p < 0.001$) and LH/FSH ratio ($r = 0.42$, $p < 0.001$), but also shows an even stronger association with serum AMH ($r = 0.52$, $p < 0.001$). There is a moderate correlation between ovarian volume and HOMA-IR ($r = 0.30$, $p = 0.002$), suggesting a link between morphological enlargement and insulin resistance. FNPO correlates with both LH/FSH ratio ($r = 0.35$, $p = 0.002$) and AMH ($r = 0.48$, $p < 0.001$), reflecting the interplay of gonadotropin excess and folliculogenesis. Stromal area correlates moderately with Ferriman–Gallwey score ($r = 0.36$, $p = 0.002$) and HOMA-IR ($r = 0.34$, $p = 0.001$), while the stromal-to-ovarian ratio inversely correlates with SHBG ($r = –0.31$, $p = 0.003$), consistent with hyperandrogenic suppression of SHBG synthesis.

Table 3: Pearson correlations between MRI parameters and biochemical/metabolic markers

MRI Parameter vs. Marker	r	p-value
Ovarian volume vs. Total testosterone	0.47	<0.001
Ovarian volume vs. LH/FSH ratio	0.42	<0.001
Ovarian volume vs. AMH	0.52	<0.001
Ovarian volume vs. HOMA-IR	0.30	0.002
Follicle number per ovary vs. LH/FSH ratio	0.35	0.002
Follicle number per ovary vs. AMH	0.48	<0.001
Stromal area vs. Ferriman–Gallwey score	0.36	0.002
Stromal area vs. HOMA-IR	0.34	0.001
S/O ratio vs. SHBG	–0.31	0.003

Finally, multivariate linear regression (Table 4) confirmed that serum AMH ($\beta = 0.29$, $p = 0.004$) and total testosterone ($\beta = 0.35$, $p < 0.001$) were independent predictors of ovarian volume after adjusting for age, BMI, and HOMA-IR, whereas HOMA-IR did not reach statistical significance in the adjusted model. For FNPO, both LH/FSH ratio ($\beta = 0.27$, $p = 0.007$) and AMH ($\beta = 0.26$, $p =$

0.010) remained significant predictors, underscoring the dual hormonal regulation of follicular proliferation.

Table 4: Multivariate regression of MRI outcomes on key predictors

Outcome	Predictor	β	SE	p-value
Ovarian volume	Total testosterone	0.35	0.08	<0.001
	AMH	0.29	0.10	0.004
	HOMA-IR	0.15	0.09	0.092
FNPO	LH/FSH ratio	0.27	0.10	0.007
	AMH	0.26	0.12	0.010

These extended results highlight the multifaceted biochemical milieu of PCOS, demonstrating that ovarian morphological changes on MRI are intimately linked not only with classic androgenic markers but also with ovarian reserve (AMH) and metabolic dysfunction (HOMA-IR), thereby reinforcing the value of comprehensive phenotyping in this population.

DISCUSSION

In this study of 100 reproductive-age women with PCOS, pelvic MRI provided a comprehensive assessment of ovarian morphology and its relationship with a broad panel of hormonal and metabolic biomarkers [11]. The observed mean ovarian volume of 12.8 mL and mean follicle count of 24.6 per ovary are consistent with the diagnostic thresholds for polycystic morphology, but our MRI-based measurements likely offer superior precision compared to conventional ultrasound [12]. The strong correlations between ovarian volume and both total testosterone and anti-Müllerian hormone (AMH) underscore the dual contributions of stromal hyperplasia and follicular proliferation to ovarian enlargement. Whereas testosterone reflects the net androgenic drive from hypertrophied stroma, AMH serves as a marker of granulosa cell activity and overall follicle pool. The independent predictive value of these two markers in multivariate analysis suggests that MRI-derived volume integrates information on both stromal and follicular compartments [13].

The moderate association between ovarian volume and insulin resistance (HOMA-IR) further highlights the metabolic underpinnings of PCOS. Although HOMA-IR did not remain an independent predictor when adjusted for androgenic and ovarian-reserve indicators, its univariate correlation suggests that metabolic dysfunction may contribute to the severity of morphological change [14]. Our finding that stromal area correlates with clinical hirsutism scores reinforces the notion that stromal hypertrophy drives hyperandrogenic manifestations. Conversely, the inverse relationship between the stromal-to-ovarian area ratio and sex hormone-binding globulin implies that increased free androgen availability may both reflect and exacerbate stromal expansion [15].

These results build upon prior investigations by providing a more granular phenotyping of PCOS patients using high-resolution imaging. Unlike ultrasound, MRI is not limited by operator skill or patient body habitus, and the volumetric approach minimizes sampling error inherent in two-dimensional measurements [16]. In clinical practice, MRI could therefore serve as a problem-solving tool in cases where ultrasound is inconclusive, such as in obese patients or when adnexal anatomy is difficult to visualize. Moreover, MRI's ability to quantify stromal and follicular components separately may facilitate phenotypic sub-classification of PCOS distinguishing patients with predominant stromal hypertrophy from those with more follicular arrest thereby guiding individualized treatment strategies, such as targeted anti-androgen therapy versus ovulation-induction protocols [17].

Despite these strengths, our study has several limitations. First, the cross-sectional design precludes causal inference between morphological changes and biochemical markers. Longitudinal follow-up would be needed to determine whether alterations in ovarian volume or stromal composition predict clinical outcomes such as menstrual regularity, fertility, or metabolic complications [18]. Second, we did not include a healthy control group; inclusion of age- and BMI-matched women without PCOS would strengthen the specificity of MRI thresholds. Third, manual tracing of ovarian and stromal areas, although reproducible between observers, is time-consuming; future work should explore automated segmentation algorithms to enhance efficiency and reduce user dependence. Finally, the cost and availability of MRI may limit its utility in resource-constrained settings; cost–benefit analyses are warranted to identify which patient subgroups derive the greatest clinical value from MRI evaluation [19].

Future research should aim to establish normative MRI ovarian metrics across diverse populations and to integrate advanced imaging techniques such as diffusion-weighted and dynamic contrast-enhanced sequences for functional characterization of stromal vascularity. Investigations correlating MRI phenotypes with genetic, transcriptomic, and proteomic profiles may also illuminate the molecular drivers of PCOS heterogeneity. Ultimately, a multimodal approach combining imaging, biochemical, and clinical data will be essential for refining diagnostic criteria and tailoring therapies to individual PCOS phenotypes [20, 21].

CONCLUSION

Pelvic MRI offers a reliable, reproducible method for detailed evaluation of ovarian morphology in women with PCOS, capturing both stromal hypertrophy and follicular proliferation with precision. The strong associations between MRI-derived metrics and key hormonal markers total testosterone and AMH highlight MRI's potential to integrate endocrine and ovarian-reserve information into a single morphological assessment. Although routine use of MRI is not indicated for all PCOS patients, its application in diagnostically challenging cases and in research settings can enhance phenotypic characterization and inform personalized management strategies. Further longitudinal and comparative studies are needed to standardize MRI thresholds and to define its role alongside ultrasound in the comprehensive care of women with PCOS.

Availability of data and materials: The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: SN and ST conceptualized the study and designed the protocol. AAK and AI recruited participants and collected clinical and biochemical data. SS and MM performed MRI acquisition and image analyses. SN and MM conducted the statistical analyses. SN drafted the manuscript. All authors critically revised the manuscript for important intellectual content and approved the final version.

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