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The Diagnostic Role of Ultrasound in Polycystic Ovarian Syndrome: A Clinical Perspective

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KEYWORDS

Polycystic Ovarian Syndrome (PCOS), Ultrasound Diagnosis, Transvaginal Ultrasound (TVUS), Ovarian Morphology, Rotterdam Criteria, Hyperandrogenism, Follicular Count, Ovarian Volume, Oligo-/Anovulation, Insulin Resistance, Endocrine Disorders, Reproductive Imaging, String of Pearls Appearance, Ovarian Stroma, PCOS Monitoring and Management

ABSTRACT:

Polycystic ovarian syndrome (PCOS) is one of the most widespread endocrine disorders that is said to affect 5-10% of women of reproductive age globally; it is also known as polycystic ovarian disease. Because of an interplay of hormonal dysfunction, ovulatory disturbances, and classic ovarian morphology, the disease may present in varied forms, bringing long-term health consequences such as infertility, metabolic syndrome, type 2 diabetes, cardiovascular disease, and endometrial cancer. Its multifactorial pathophysiology comprises genetic predisposition, insulin resistance and hyperinsulinemia, obesity (particularly central adiposity), and chronic low-grade inflammation along with altered ovarian stromal architecture resulting in follicular arrest and the characteristic "polycystic" appearance. Accurate diagnosis is often hindered because multiple overlapping clinical symptoms are present in thyroid disorders, Cushing's disease, hyperprolactinemia, and congenital adrenal hyperplasia. The Rotterdam Criteria (2003) constitute a widely accepted set of parameters. On these, two of three major features must be present: 1) Oligo-/anovulation, 2) Clinical and/or biochemical evidence of hyperandrogenism, and 3) Polycystic ovaries on ultrasound. The most important diagnostic tool used is an ultrasound (USG), most frequently a transvaginal ultrasound (TVUS), that provides real-time, cost-effective, and non-invasive imaging of ovarian morphology. Diagnostic features in ultrasound defined for polycystic ovaries are: 1) Presence of ≥12 follicles measuring 2-9 mm in diameter in one or both ovaries, 2) Increase in ovarian volume >10 mL in at least one ovary, and 3) Peripheral arrangement of follicles as "string of pearls". Thickened, hyperechoic ovarian stroma is also commonly suggested. Ultrasound has many advantages in the diagnosis of PCOD, such as low cost, accessibility, and the preservation of excellent soft tissue contrast, while avoiding ionizing radiation. In other words, an ultrasound is inexpensive compared to MRI and laparoscopic procedures and does provide a pretty decent image of ovarian structure. On the other hand, TVUS gives great resolution on the structural anatomy compared to the transabdominal approaches. On top of that, ultrasound plays a bigger role than the initial diagnosis; it is also important in monitoring the ovarian response to treatment (e.g., ovulation induction with clomiphene or gonadotropins), observing ovarian volume, and follicular count dynamic changes through time, estimating ovarian reserve, guiding fertility treatment plans (i.e., timing ovulation, assessing risk of overstimulation), checking the endometrium for hyperplasia risk, and differentiating PCOD from other pelvic pathologies (e.g., endometriomas, functional cysts, tumors). Polycystic morphology may get confounded with normal variation in patients presenting in the clinician setting and also might masquerade as other conditions. That being said, ultrasound is an anatomical imaging, providing very limited functional information, and those findings should always be correlated with the clinical presentation and biochemical evaluation (hormonal profile such as testosterone, LH/FSH ratio, DHEAS) to arrive at a Rotterdam Criteria-based diagnosis and exclude other endocrine disorders.

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1. Introduction

Polycystic ovary syndrome (PCOS), or polycystic ovary disease (PCOD) as it is referred to in some areas, is one of the most common endocrine disturbances in women of reproductive age. The syndrome is characterized by a combination of hormonal dysfunction, ovarian cysts, and metabolic aberrations(Shrivastava & Conigliaro, 2023). The manifestations of PCOS include irregularities in the menstrual cycles, hyperandrogenism (increased levels of male hormones), and polycystic ovaries. These manifestations would result in a wide variety of clinical sequelae, including infertility, metabolic syndrome, diabetes, and cardiovascular risks(Marya et al., n.d.). Due to the complexity of its cause and heterogeneous manifestations, PCOS remains a problem for effective diagnosis and treatment. Many have recognized in recent years that the advent of imaging mode, particularly ultrasound (USG), has aided the diagnosis of PCOD (Deshpande, 2023). While a clinical diagnosis based on symptoms and hormonal testing has been the mainstay, ultrasound offers clear, direct visual assessment of the ovaries and is instrumental in confirming the diagnosis. Its non-invasive nature, availability, and relative inexpensiveness make ultrasound a cornerstone in the diagnosis of PCOD (Lentscher et al., 2020). The current review would highlight ultrasound in the detection and management of PCOD along with its advantages, drawbacks, and recent advances in imaging technology. PCOD is one of the most frequent causes of anovulation and infertility among women affecting some 5–10% of women of reproductive age worldwide(Sheehan, 2003). In some populations where the burden is genetically, environmentally, and lifestyle determined, the prevalence of PCOD may be even higher. Although quite common, PCOD is often underdiagnosed or misdiagnosed, especially in the milder forms(Ibrahim Aly, 2023). The clinical presentations of PCOD are quite heterogeneous, wherein some women may be afflicted with severe symptoms of hirsutism, acne, and obesity with irregularities of the menstrual cycle, whereas some may be asymptomatic for years. Some other long-term health-related complications ensuing from PCOD, which include increased susceptibility to type 2 diabetes, cardiovascular disease, and endometrial cancer, thereby constitute the other prospective areas of concern(Li et al., 2024). The very metabolic disturbances associated with PCOD like insulin resistance are intertwined with obesity and weight gain, further compounding managing the clinical aspects of the disease. Therefore, diagnosis and timely PCOD detection become vital for the prevention of these complications and better long-term health for the women concerned(Lentscher & Decherney, 2020).

1.1 Challenges in Diagnosis

PCOD diagnoses are based on a combination of clinical, biochemical, and imaging findings. The most widely accepted criteria for diagnosis are the Rotterdam Criteria of 2003, where two of the following three features should be present:

1.A menstruation maybe infrequent or absent (oligomenorrhea or amenorrhea)

2.Signs of hyperandrogenism clinical and/or biochemical (for example, hirsutism or increased testosterone levels)

3.Polycystic ovaries diagnosed by ultrasound, defined by the presence of ≥12 follicles measuring 2-9 mm in diameter and/or an ovarian volume >10 mL in at least one ovary(Azziz, 2004).

Although Rotterdam's criteria possess a fair degree of standardization when diagnosing PCOD, the clinical presentation really can be ever so differently, rendering its diagnosis difficult. A fair number of women present with symptoms that may overlap those seen in conditions like thyroid dysfunction, endometriosis, and obesity, which pose additional challenges in differential diagnosis(Che et al., 2023). Furthermore, hormonal imbalance with elevated luteinizing hormone (LH), low follicle-stimulating hormone (FSH), and increased testosterone may be encountered in other conditions. The ultrasound offers a non-invasive, real-time imaging of the ovaries, thus providing a vivid representation of the changes in structure seen in PCOD(Harrison et al., 2024).

1.2The Role of Ultrasound in PCOD Diagnosis

Ultrasound has always been the stalwart of PCOD diagnosis. For the experienced practitioner, the classic ultrasound findings are rather easy to spot for PCOD. Generally, it shows multiple small cysts in the ovaries arranged peripherally and often gives the well-recognized picture of a "string of pearls". Having said

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that, such small cysts are immature follicles not undergoing maturation and ovulation due to hormonal imbalances(Akhoundi et al., 2023).

Essentially, some criteria that really help in diagnosing PCOD by ultrasound include:

1. **OVARIAN MORPHOLOGY:** The most common ultrasound finding in PCOD is the increased number of follicles (> 12 follicles per ovary) of 2-9 mm in diameter. This reflects the failed maturity and ovulation of follicles.
2. **OVARIAN VOLUME:** Women usually present with larger ovaries (> 10 mL).

3. **"STRING OF PEARLS" SIGN:** The appearance of many small follicles lining the periphery of the ovary is a hallmark feature of PCOD(Khalid et al., 2024)

The diagnostic accuracy of ultrasound in detecting polycystic ovaries is high, but it is essential to mix ultrasound findings with clinical and biochemical to diagnose accurately. It is also worth noting that ultrasound itself is an insufficient tool for diagnosing PCOD, since a large number of women with polycystic ovaries do not have PCOD, and vice versa(Lee & Rausch, 2012).

1.3 Advantages of Ultrasound in PCOD Diagnosis

Ultrasound offers several advantages over other diagnostic modalities for PCOD It also provides real-time images, allowing clinicians to evaluate ovarian size, morphology, and the presence of follicles(Asanidze et al., 2021). This ability to visualize the ovaries directly is invaluable in diagnosing PCOD, as it offers a clear, objective assessment of ovarian structure. Another advantage of ultrasound is its cost-effectiveness and widespread availability(Youngster et al., 2014). Unlike more specialized imaging techniques such as magnetic resonance imaging (MRI) or laparoscopy, ultrasound is relatively inexpensive and accessible, making it a practical choice for primary care physicians and gynaecologists worldwide(Rao, 2022). Furthermore, transvaginal ultrasound, which involves inserting a small probe into the vagina for closer access to the ovaries, allows for high-resolution imaging and better visualization of ovarian structures compared to transabdominal ultrasound(Christ & Cedars, 2023).

2. Pathophysiology of Polycystic Ovary Syndrome (PCOD)

Polycystic Ovary Syndrome (PCOD), more known as Polycystic Ovary Disease (PCOS), is known to be a very complex multifactorial endocrinopathy with ovarian, metabolic, and hormonal aberrations: it is the most important cause of anovulation and infertility for women of reproductive age. The pathophysiology of PCOD is not yet clearly defined; however, it involves genetic predisposition, hormonal imbalances, insulin resistance, and inflammation, which all affect ovarian function and metabolism. This will present the mechanisms that direct the development and progression of PCOD(Witchel et al., 2019a).

2.1. Genetic Factors and Heredity

Genetic factors influence the pathogenesis of PCOD. This evidently stands out in families or populations with a higher prevalence of the disease. Studies of twins and familial aggregation suggest the presence of genetic predisposition to the development of the syndrome. Many candidate genes have been affiliated with PCOD, many of which regulate hormones, insulin resistance, and ovarian functions. Examples include CYP19A1 (estrogenic production), LHR (luteinizing hormone receptor), and FTO (fat mass and obesity-associated gene). The genetic basis of PCOD, however, remains multifactorial, and a clear genetic marker to the syndrome is still lacking(Tsilchorozidou et al., 2004).

2.2 Hormonal Unbalance

Elevated Luteinizing Hormone (LH) and Hyperandrogenism Reach the Level of a Feature that Had to be Considered in the Definition of PCOD Gonadotropin Imbalance. In patients with polycystic ovary syndrome, the concentration of luteinizing hormone (LH) is of paramount importance; levels of follicle-stimulating hormone (FSH) are generally less. The abnormality of LH:FSH ratio (mostly above 2:1) has a significant importance in pathophysiology of the disorder, and immensely contributes toward the characteristic ovarian dysfunction, which conforms to PCs displayable feature. Increases in the level of LH induce the increased secretion of androgens by the ovaries. This increased androgen secretion forms another classic feature of PCOD and produces a host of symptoms like hirsutism, acne, seborrhoea and male-pattern baldness. In addition, there may also be a

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number of ovarian follicles whose maturation is incomplete as a direct consequence of having higher levels of androgen; hence, the failure to reach ovulation, most associated with anovulation and infertility in women found to possess PCOS.(Alsadi, 2014)

2.3 Ovarian Dysfunction and Follicular Arrest:

The condition leads to anomalies in the ovary as regards possible arrest of follicles within the ovary. Follicular arrested development avoids a mature ovum from being released. The normal cycle should see that a few primordial follicles are recruited during each cycle and one among them grows dominant and ovulates. This jump-starts the development of multiple follicles that do not reach full maturation. These are referred to as immature follicles arrested early, mostly at the preantral or small antral stage; therefore, there will be many tiny cysts formed in the ovaries. This phenomenon is basis for characteristic ultrasound findings in PCOD such as string-of-pearls appearance in which many follicles can be seen around the periphery of the ovary: The non-ovulation results in anovulatory cycles that bear irregular menstrual periods or amenorrhea in many women with PCOD. The absence of ovulation leads also to diminished progesterone level, which may either impair or may establish an endometrial hyperplasia and increasing risk of developing endometrial carcinoma through the years(Dong & Rees, 2023).

2.4 Insulin Resistance and Hyperinsulinemia:

One of its most defining features is insulin resistance, which impedes the body's effective use of the hormone and, as a consequence, leads to hyperinsulinemia, that is, increased insulin in the blood. It usually occurs with increased fat deposition around the abdomen (central obesity), an ordinary feature found in women with this particular case under study. Presence of insulin resistance plays a very important role in different aspects concerning the pathophysiology of PCOD(Fahs et al., 2023).

• **Increased Androgen Production:** It's very important contribution to hyperandrogenism in PCOD, manifested in clinical features such as hirsutism and acne, is especially via stimulation of ovarian theca cells to produce androgens (testosterone) in greater amounts.

• **Disruption in Ovarian Function:** Both of these changes may exert a direct deleterious effect upon normal ovarian function. Moreover, hyperinsulinemia probably adds to the LH hypersecretion and further disturbs the hormonal balance necessary for follicular development and ovulation.

• **Metabolic Dysfunction:** Metabolic dysfunctions found in PCOD include the following: association of insulin resistance with a higher risk of developing type 2 diabetes, obesity, and dyslipidemia-above-mentioned dysfunctional metabolic combinations. Women with PCOS tend to have a higher risk of developing a metabolic syndrome that enhances likelihood of cardiovascular diseases later on in life(Harada, 2022).

2.5. Adiposity and Obesity

Although not all women diagnosed with PCOD are overweight, the majority are markedly obese, particularly in abdominal fat accumulation. Obesity, in itself, is a prominent risk factor for insulin resistance development and can aggravate the specific metabolic disorder in PCOD. (W. Chen & Pang, 2021). These elevated levels of estrogen can affect the balance in LH and FSH secretions resulting in the cause of PCOD. This will be regarded as an additional aspect of the disorder itself. The adipose tissue, mainly the visceral fat, is known to secrete pro-inflammatory cytokines, resulting in low-grade chronic inflammation. Eventually, this leads to insulin resistance and metabolic aberrations in PCOD(Sanchez-Garrido & Tena-Sempere, 2020).

2.6. Inflammation and Immune Dysregulation

Recent indications have stated that inflammation is a factor in the pathophysiology of PCOD. Women with PCOD show now indications of chronic low-grade inflammation by higher levels of C-reactive protein (CRP) or other pro-inflammatory cytokines. Inflammation is believed to cause this insulin resistance through its disturbance of insulin signalling pathways. The inflammatory cytokines within the ovaries may cause disturbance in the folliculogenesis into cystic ovaries by causing the cessation of arrest in the follicles(Rosenfield & Ehrmann, 2016).

2.7. Other Endocrine Abnormalities in PCOD

Women diagnosed with PCOD give evidence of various endocrine irregularities along with the hypersecretion of LH, for example:

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• **Prolactemia:** Increased prolactin levels are found in women afflicted by PCOD, since the hormone prolactin is that which is required for mammary development and sometimes under abnormal conditions, high prolactin can bring in menstrual irregularities and anovulation.

• **Cortisol levels altered:** Evidence indicates 'likelihood that their levels of the stress hormone cortisol may become altered, which in turn may worsen the insulin resistance and metabolic dysfunction.(RNair & of Pathology, 2023)

2.8. The Ovarian Stroma

The ovarian stroma in women with PCOD usually shows thickening and hyperplasia. The thickened stroma may cause failure of follicular maturation and thus ovulation. This hypertrophy of stroma is believed to cause some of the structural changes through which the enlarged ovaries appear on ultrasound and contribute to multiple cyst formation(Laschke et al., 2010).

Pathophysiology of PCOD is multifactorial. It involves the complex interaction of hormonal imbalances, genetic predisposition, insulin resistance, and ovarian dysfunction Inflammation, together with other endocrine abnormalities, plays a role in the systemic implications of PCOD such as metabolic derangements and increased risk for cardiovascular diseases and diabetes. Such an understanding of their pathophysiologic mechanisms will drive the development of targeted interventions addressing the causes of PCOD and improving patient outcomes(Laschke et al., 2010).

3. Diagnostic Criteria for Polycystic Ovary Syndrome (PCOD)

Diagnosis of Polycystic Ovary Syndrome (PCOD) or Polycystic Ovarian Disease (PCOS) is based upon clinical, biochemical, and imaging assessments. Given the heterogeneity of the disorder, along with its overlap with other disorders, an accurate diagnosis frequently necessitates adoption of established criteria to steer clinical judgment. The most widely acknowledged and used diagnostic criteria for PCOD include the Rotterdam Criteria, which were established in 2003. The gold standard for diagnosing PCOD, however, there are other frameworks used in clinical practice(Mohammad & Seghinsara, 2017).

3.1. Rotterdam Criteria (2003)

Rotterdam criteria are by far the most widely accepted and used for the diagnosis of PCOD. According to the Rotterdam criteria, when a woman presents at least with two out of three of these features, the diagnosis of PCOD is confirmed:(Azziz, 2005)

1. Oligo/anovulation: This is either represented as an irregular or absent menstrual cycle. Oligoovulation means less than one ovulation every 35 days or more between two cycles; while anovulation means no ovulation occurred at all.Typical of women having PCOD are irregular menstrual cycles resulting from non-ovulation. Anovulation is one of the most common causes of infertility in a woman who has PCOD.

2. Hyperandrogenism: It refers to the presence of elevated male hormones (androgens), for example, testosterone. Clinical manifestations from increased androgens include hirsutism (excessive hair growth), acne, seborrhea, and alopecia (thinning or loss of hair). Hyperandrogenism may also be identified through biochemical tests for elevated serum testosterone, DHEAS, or androstenedione(Porcaro G, 2014).

3**. Ultrasound evidence of polycystic ovaries:** The hallmark of PCOD is the presence of polycystic ovaries, seen by ultrasound imaging. The ultrasound features typically include:

- At least 12 follicles measuring 2-9 mm in diameter in each ovary.

- Ovarian volume greater than 10 mL in at least one ovary. - The string of pearls appearance, in which small follicles are arranged around the periphery of the ovary, is typically observed with enlarged ovaries.

It should be noted that not all females with polycystic ovaries have PCOD and not every female with PCOD will have detectable cysts during ultrasound. Hence, for diagnosis there should be a combination of clinical presentation, laboratory results, and ultrasound results.(Neven et al., 2018)

3.2. The NIH Criteria (1990)

Prior to the Rotterdam Criteria, the NIH criteria were widely used for diagnosing PCOD. While they are not the main standards now, they have some relevance in certain scenarios, such as in cases of infertility.

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Accordingly, within the NIH criteria, women can be diagnosed with PCOD on the following grounds:

• Oligomenorrhea/anovulatory cycles and Evidence for hyperandrogenism (clinical or biochemical), such as hirsutism or elevated testosterone. PCOD diagnosis according to the NIH criteria does not require the presence of polycystic ovaries on ultrasound. The ovarian morphology criterion is hence absent in NIH criteria, making them less comprehensive than Rotterdam criteria.(N. Singh et al., 2022)

3.3 The AE-PCOS Society Criteria

Diagnostic criteria emphasizing hyperandrogenism, an important aspect of PCOD, were put forward by the Androgen Excess and the PCOS Society (AE-PCOS Society) in 2006. Thus, diagnosis of PCOD includes:

1. Hyperandrogenism (clinical or biochemical);

2. Oligo- or anovulation (irregular or absent menstrual cycles);

3. Exclusion of other disorders that could explain the symptoms (such as thyroid dysfunction, hyperprolactinemia, or non-classic congenital adrenal hyperplasia).

While the AE-PCOS Society criteria are somewhat aligned with NIH criteria, emphasis on clinical features of hyperandrogenism and anovulation is broad-based by excluding other causes. (Pea et al., 2024)

3.4. Other Conditions Exclusion

The most significant problem in diagnosing PCOD is that its symptoms are found in quite a number of other conditions. The major task is that of excluding other conditions that could cause the similar symptoms. For example:

• **Thyroid Disorders:** Thyroid dysfunction (e.g., hypothyroidism) may also cause menstrual irregularities, weight gain, and fatigue mimicking PCOD.

• **Hyperprolactinemia:** High levels of prolactin can show menstruation irregularities with or without galactorrhoea (discharges from the breasts), which may need to be excluded from those hyperandrogenic characteristics of PCOD(Fauser et al., 2004).

• **Congenital Adrenal Hyperplasia (CAH):** Genetic and inherited disorders causing symptoms of hyperandrogenism and menstrual irregularities can cause CAH. Screening for 21-hydroxylase deficiency is very relevant in ruling out the condition.

• **Cushing's Syndrome:** Generally, with increased cortisol levels in Cushing's syndrome, there are common PCOD features such as obesity, hirsutism, and menstrual disturbances.

• **Primary Ovarian Insufficiency**: Premature ovarian failure can cause amenorrhea and hormonal imbalances that may resemble PCOD symptoms, but usually they occur earlier without polycystic ovaries.

After confirming the absence of such conditions, one can be very sure of the diagnosis of PCOD when these criteria (mostly the Rotterdam criteria) are met.(Garg et al., 2021)**.**

3.5. Additional Diagnostic Tests

Aside from clinical and ultrasound assessments, several biochemical tests are useful in diagnosing PCOD and severity assessments:

Hormonal Profile:

- **Testosterone:** Serum testosterone levels that are increased suggest hyperandrogenism in PCOD. Free testosterone is done to measure androgen access.
- **LH/FSH Ratio**: Elevated LH and a low FSH result in an above-stated (+2:1) ratio of LH:FSH that is often found during PCOD.
- **Dehydroepiandrosterone sulfate:** Increased amounts of DHEAS indicate the presence of adrenal androgens, which may contribute to the hyperandrogenism occurring in PCOD.(S. Singh et al., 2023)
- **Prolactin:** High prolactin levels should be considered to exclude hyperprolactinemia as a cause of menstrual disturbance.
- **Estrone:** Increased estrone levels, especially in obese women, may also represent PCOD due to the peripheral conversion of androgens to oestrogen in adipose tissue(Joshi, 2024).

Ovary Volume: An important finding in diagnosing the PCOD is that ovarian volume in at least one ovary is more than 10 mL(Tong et al., 2025).

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3.6 The Role of Genetic Testing

Currently, genetic testing is not part of the routine diagnosis of PCOD. This is probably because the condition is multifactorial and genetic and because there is no specific genetic marker available for diagnostic purposes. However, genetic studies may be of great importance as we expand our knowledge regarding the genetic basis of PCOD(Legro et al., 2013).

3.7. Diagnostic Considerations in Adolescents

Adolescent diagnosis of PCOD can be rather dicey because most of the early years after menarche are characterized by irregular menstruation. These cases should be cautiously diagnosed; ultrasound findings (polycystic ovaries) may be seen in a normal adolescent not having PCOD. Therapeutic endorsement may be given for hyperandrogenism (clinical or biochemical) and menstrual irregularities in order to make a diagnosis(Peña et al., 2022a). PCOD is diagnosed through a combination of clinical, biochemical, and imaging criteria. Of all the criteria, the Rotterdam Criteria (2003) are the most accepted and frequently used criteria because they cover a comprehensive definition of the condition, specifically menstrual irregularities, hyperandrogenism, and typical ultrasound findings. Because of the complex and heterogeneous nature of PCOD, hormonal testing through imaging and clinical evaluation constitutes a multidisciplinary approach to accurate diagnosis and effective management(Hendriks et al., 2008).

4. Role of Ultrasound (USG) in Diagnosing Polycystic Ovary Syndrome (PCOD)

Ultrasound (USG), particularly transvaginal ultrasound (TVUS), is most significant in the diagnosis and management of Polycystic Ovary Syndrome (PCOD). The multi-faceted study for the diagnosis of PCOD includes clinical, biochemical, and imaging studies, but ultrasound examination is vital for viewing specific ovarian characteristics that ultimately help to confirm the condition. Indeed, an ultrasound will indicate specific findings that are typical of what we term polycystic ovaries, the hallmark of PCOD diagnosis. However, it is important to note that ultrasound forms just one part of the wider diagnostic process, which includes clinical signs, hormonal tests, and exclusion of other disorders(Akhoundi et al., 2023).

4.1. Polycystic Ovarian Morphology on Ultrasound

The hallmark of PCOD on ultrasound is enlarged polycystic ovaries containing numerous small antral follicles. The characteristics of polycystic ovaries seen on ultrasound include:

- **Multiple Small Follicles**: The ovaries in PCOD generally harbor at least 12 follicles measuring anywhere from 2–9 mm in diameter. Small follicles are arranged in a peripheral pattern around the periphery of the ovary, "string of pearls" becoming its apparent named appearance(Rosenfield, 2014).
- **Anecdote of Enlarged Ovarian Size:** One or both ovaries may be enlarged, with one ovary having an ovarian volume greater than 10 mL. This enlargement is due to persistence of multiple small follicles, which neither mature nor ovulate(Kim et al., 2017).
- **Thickened Ovarian Stroma:** The ovarian stroma, etc., may be thickened in women with PCOD, thereby assisting in creating the characteristic ultrasound picture. Stroma may also appear echogenic due to increased tissue density and fibrosis, both of which may be appreciated on the ultrasound.

These ultrasound findings fit with the Rotterdam Criteria for PCOD, which require the presence of polycystic ovaries on ultrasound as one of the diagnostic criteria along with oligo- or anovulation and hyperandrogenism (clinical or biochemical)(Ali et al., 2016).

4.2. Ultrasound Criteria for PCOD

Polycystic ovaries are detected by ultrasound as defined by the Rotterdam Criteria (2003) by:

- Identification of at least 12 follicles (between 2 and 9 mm) in each ovary.
- Volume of ovaries greater than 10 ml either in one or both ovaries.
- Follicles are usually in a peripheral arrangement, also referred to as the "string of pearls" appearance.

These criteria should be examined through transvaginal ultrasound (TVUS) since TVUS has proved to be more sensitive than the transabdominal route in visualizing the ovaries and their morphology. However, at some situations, transabdominal ultrasound can be used, especially for a sexually inactive woman or an

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adolescent, though this form is less accurate in a small structure of the ovaries(Quaas, 2024).

4.3. Ultrasound Sensitivity and Specificity for the Diagnosis of PCOD

Ultrasound is the most widely used diagnostic test for PCOD, but it does have both sensitivity and limitations:

• **Sensitivity:** High sensitivity of ultrasound in identifying polycystic morphology, showing characteristic arrangement and enlargement of the ovaries, has been stated. Some studies reported the sensitivity of ultrasound for polycystic status detection as around 90 percent.

• **Specificity:** Conversely the specificity of ultrasound for the diagnosis of PCOD is lower, seeing that polycystic ovaries can also be detected in other conditions, namely, those individuals who are obese, girls in the adolescent population, or women with endometriosis. Even polycystic ovaries may not always indicate a woman suffers from PCOD, underscoring the need for evaluation based on a broader picture, including clinical and hormonal assessment.

• **Normal Variants Overlap:** In adolescent women and in women recently off oral contraceptives, polycystic ovaries may be normal ovarian development since these small antral follicles can often be seen in normal ovaries early in the follicular phase of the cycle(Battaglia et al., 2004).

4.4. Role of Ultrasound in Monitoring PCOD

Ultrasound is very important in checking the progress of PCOD and monitoring the treatment response along with the primary diagnosis. The list of uses includes:

• **Ovarian Volume and Follicular Count**: Through serial ultrasound evaluations, one can assess how large the ovaries are and evaluate changes in the number of follicles as well as their size over time. It then helps take the best judgment as to whether the intervention designed to achieve normal ovulation, for example, clomiphene citrate (Clomid) induction of ovulation, is successful(Amreen, 2022).

• **Fertility Treatment Assistance:** Ultrasound is an important component in fertility therapy, such as ovarian stimulation protocols and intrauterine insemination (IUI). It may be used to monitor follicular growth in relation to the ovary responding appropriately to the fertility medications used. For example, determination of optimum timing for ovulation induction can be determined through ultrasound-guided follicle monitoring(Rathour & Singh, 2020).

4.5. Limitations of Ultrasound in PCOD Diagnosis

Although ultrasound has a lot to help in diagnosing and managing PCOD, it also suffers from some disadvantages:

• **No Standardization**: Under what criteria has any diagnosis of PCOD been established? There is no internationally approved criterion for the threshold number of follicles or the ovarian volume necessary for convincing diagnosis of polycystic ovaries syndrome. Follicle size and volume vary among individuals according to age, hormonal status, and phase of menstrual cycle.(Dewi et al., 2018)

• **Functional Ovarian Cysts:** Between not counting polycystic ovaries and finding those of functional origin (follicular or luteal cysts) themselves can complicate ovarian morphology interpretations brought in by ultrasound(Giménez-Peralta et al., 2022).

• **Variability in Interpretation:** Different practitioners (e.g., radiologists and gynecologists) have different capabilities to interpret ultrasound images; due to this, there can be differences in the diagnosis of PCOD based solely on imaging findings(Gopalakrishnan & Iyapparaja, 2019).

4.6. Role of Ultrasound in Excluding Other Conditions

Ultrasound also excludes various other conditions simulating PCOD-related symptoms such as-

• **Ovariancysts:** Ultrasound could help in the differential diagnosis of benign cysts caused by PCOD and solid ovarian tumors or a malignant growth.

• **Endometriosis:** The cysts, also known as chocolate cysts, should be differentiated as the large, unilocular cysts forming endometriosis and, hence, from the other multiple small follicles which are shown in PCOD(Jarrett et al., 2019).

• **Tubal Pathology:** In infertility cases, it is possible to detect the tubal abnormalities or adhesions

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using ultrasound that might contribute to the problem.(Fulghesu et al., n.d.)

5. Advances in Ultrasound Technology for the Diagnosis of Polycystic Ovary Syndrome (PCOD):

Ultrasound has been a prime modality for decades in both diagnosing and managing the Polycystic Ovary Syndrome (PCOD). It could introduce ovarian morphology, recognize multiple small antral follicles, and provide an assessment of ovarian volume. With the evolution of ultrasound technology, more advanced techniques and innovations were developed that generate much more accurate, reliable, and very-high-quality information. Below are some of the major advancements in ultrasound technology that really changed the practice of PCOD diagnosis and management(Rocha et al., 2019)

5.1. High-Resolution Ultrasound Imaging

Advances in the ultrasound resolution have made imaging clearer and more accurate in the ovarian structure. High-frequency transducers (probes) allow small follicles to be visualized and are particularly useful in diagnosing PCOD. Modern ultrasound systems make use of high-resolution transducers (up to 10-15 MHz) that allow for clear imaging of small antral follicles (generally between 2 and 9 mm in diameter), which characterizes PCOD(Ni & Lee, 2020).

• **Greater Follicular Sensitivity:** The increased resolution imaging will detect smaller follicles that may have been missed with older and lower resolution technology. It will be particularly useful for early diagnosis in women with mild PCOD, where only a small number of follicles may be presented in the ovary.

• **Improved Visualization of Ovarian Stroma:** Higher resolution can improve visualization of the ovarian stroma (the supportive tissue of the ovary), which can become thickened in PCOD. This contributes to a more accurate understanding of the ovarian structure and function(Reka et al., 2025).

5.2 3D Ultrasound and Volumetric Imaging

Traditional 2D ultrasound only offers a two-dimensional view of the ovaries and follicles. Now, with the advent of 3D ultrasound, it is possible to obtain closer 3D pictures of the ovaries, thus offering some advantages in managing a diagnosis and follow-up for PCOD.

• **Measurement of Ovarian Volume:** One key diagnostic criterion for PCOD is increased ovarian volume above 10 mL in at least one ovary. 3D ultrasound is superior to 2D ultrasound in performing more accurate and reproducible measurements of ovarian volume. Such improvement in measurement is relevant to reducing measurement errors that may occur due to shape and position of the ovary(Ziogas et al., n.d.).

• **Volume Rendering and Visualization: 3D** ultrasound can generate volumetric models of the ovary, thus allowing clinicians to visualize the entire ovarian structure in three dimensions. As such, this gives a more comprehensive view of the ovarian morphology, which may help assess the distribution of follicles and size of the ovary better(Sujata & Swoyam, 2018).

• **Better Follicular Counting:** In cases of PCOD, several small follicles are usually dispersed throughout the ovary. This makes it easier for 3D ultrasound to both visualize and count these follicles. Perhaps volumetric imaging may allow a better understanding of their distribution within the ovary for the differentiation of PCOD from other ovarian pathologies(Wu et al., 2012).

5.3. Doppler Ultrasound and Blood Flow Evaluation

Doppler ultrasound is a major advancement in assessing vascular characteristics of the ovaries in PCOD. This new technique assesses blood flow within the ovaries by measuring a frequency alteration of the ultrasound wave through red blood cells. Under PCOD, the vascularity is often altered, and with Doppler ultrasound, such changes can be observed(Battaglia, 2003).

• **Ovarian Blood Flow:** Studies have indicated that an ascent in vascularity within the ovaries of a woman can be directly associated with PCOD. Doppler ultrasound helps to identify these changes by measuring the resistance index (RI) and pulsatility index (PI), indicators of blood flow resistance within the ovaries.

• **Hypervascularity Identification:** Women with PCOD may manifest hyper vascular ovaries with the help of the detection of abnormal blood flow pattern using Doppler ultrasound. The altered vascular pattern

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may correlate directly with the endocrine dysfunction or follicular arrest seen in PCOD to give a better understanding of the pathophysiology(Upadhyay T et al., 2025).

• **Ovulatory Function Prediction:** Doppler ultrasound is ideal in the monitoring of blood flow changes as induced by ovulation techniques, enabling clinicians to assess the response and development of follicles in the ovaries. This is very important in female fertility treatment for individuals with PCOD(Garg et al., 2021).

5.4. **Elastography and Tissue Stiffness Imaging**

Elastography, also known as tissue stiffness imaging, is a relatively new ultrasound technique for measuring elasticity or stiffness in tissues. Traditionally it is applied in assessing liver stiffness; increasingly, elastography is being assessed for evaluation of ovarian tissue in women with PCOD(Çıracı et al., 2015).

• **Ovarian Stroma Evaluation:** In women with PCOD, the ovarian stroma is thicker, often more fibrotic. Elastography would quantify ovarian stiffness and may add to understanding of the degree of stromal fibrosis. The stiffer the tissue, the more likely it indicates chronic changes associated with PCOD(Ruan et al., 2024).

• **Non-Invasive Assessment:** The possibility of non-invasive assessment of ovarian tissue by elastography opens a feasible way for monitoring long-term effects of PCOD or consequences of treatment, such as ovarian drilling or stimulation.(He et al., 2025)

5.5. Contrast-Enhanced Ultrasound (CEUS)

This modern technique, called CEUS for contrast-enhanced ultrasound, infuses microbubble contrast agents into the blood. This technique improves ultrasound pictures of the ovarian tissue, particularly given the blood perfusion in outlining the details of blood flow and structure.(Xu et al., 2015)

• **Evaluation of Ovarian Vascularity and Folliculogenesis:** In the assessment of CEUS, generally, it provides detailed images of vascularization surrounding follicle as much as possible, thus essential for understanding dominant follicle development in PCOD. This also allows one for follicular growth and blood flow evaluation in association with one's ovarian response during fertility treatments or ovarian stimulation cycles(Pop et al., 2015).

• **Monitoring Ovarian Response to Treatment:** CEUS should be helpful in monitoring real-time vascular changes in the ovary and developing follicles in women undergoing ovulation induction with PCOD(Olinger et al., 2024).

5.6. Artificial Intelligence (AI) and Machine Learning in Ultrasound

Artificial intelligence (AI) and machine learning techniques are revolutionizing ultrasound technology with the capacity of refining precision and efficiency in the diagnosis of PCOD. The algorithms integrate the analysis of ultrasound images in an automatic manner and identify crucial features such as the number of follicles, ovarian volume, and description of vascular patterns(Gorrab et al., 2025).

• **Follicle counting automation:** The AI-based ultrasound systems can detect and count the number of follicles automatically. This is better than most, as there is minimum variability that could be introduced by human interpretation of results. This is very important in the diagnosis of PCOD, with follicle count being one of the determinant criteria.

• **Predicting Ovulatory Dysfunction: When** these predictive models are combined with clinical data, they will help in predicting the possibility of ovulatory dysfunction in women suffered from PCOD. These can help for early detection and personalized treatment planning in managing infertility(Upreti et al., 2025).

• **Integration with Electronic Health Records (EHR)**: AI possessor ultrasound systems will be linked into EHR that maintains history of a patient's clinical events, responses to treatments, and ultrasound results over time by way of a comprehensive approach to management based on data for PCOD(Sai & Min, 2024).

Advances in ultrasound technology have improved significantly the diagnosis, monitoring, and management of Polycyclic Ovarian Disease (PCOD). Advances in imaging, specifically high-resolution imaging, 3D ultrasound, Doppler studies, elastography, contrast-enhanced ultrasound, and AI-driven technology, have vastly improved clinicians' abilities to assess ovarian morphology, blood flow, and tissue characteristics. Such innovations will not only improve the diagnosis of PCOD but also lead to more individualized and efficient approaches to treatment,

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particularly in the area of fertility treatments. As ultrasound continues to evolve, so is its role in the diagnosis and treatment of PCOD, opening up avenues for more extensive patient care and outcomes(Suha & Islam, 2022).

6. Comparing Ultrasound (USG) with Other Diagnostic Tools in the Diagnosis of Polycystic Ovary Syndrome (PCOD)

The diagnosis of Polycystic Ovary Syndrome (PCOD) is multifactorial and includes clinical, biochemical, and imaging assessments of a patient. The ultrasound (USG), in view of being a non-invasive, easily available, and direct method to assess ovarian morphology, has become a cornerstone in the diagnosis of PCOD. However, other methods of diagnosis are also available; they feature their own pros and cons. In this section, ultrasound will be compared with hormonal assays, laparoscopy, and other imaging techniques concerning their uses in diagnosing PCOD(Dar et al., 2024).

6.1. USG vs. Hormonal Assays

Hormonal assays are an indispensable part of PCOD diagnosis, mainly to assess hyperandrogenism (elevated male hormones, such as testosterone) and ovulatory dysfunction (e.g., elevated luteinizing hormone [LH] or low progesterone levels). Hormonal tests provide confirmation with respect to the biochemical aspect of the syndrome, while ultrasound provides structural evidence(G. et al., 2018).

Strengths of Hormonal Assays:

- **Hyperandrogenism:** Hormonal testing (particularly testosterone and dehydroepiandrosterone sulphate [DHEAS]) assesses the presence of hirsutism, acne, and alopecia, which are all clinical parameters of PCOD.
- **Oligo- or Anovulation:** Elevated LH with LH/FSH (follicle-stimulating hormone) ratio greater than 2:1 in conjunction with low levels of progesterone could be indicative of anovulation. This is, however, one of the principal diagnostic criteria in PCOD(Jain et al., 2022).
- **Comprehensive Endocrine Evaluation: Hormonal** assays can diagnose or exclude other underlying endocrine disorders (for example: thyroid dysfunction, adrenal hyperplasia) presenting with similar complaints(D. et al., 2023).

Weaknesses of Hormonal Assays:

- **Timing Sensitivity:** Hormonal levels can vary throughout the menstrual cycle; hence careful timing of blood tests is required in order to capture accurate levels of specific hormones-historic focus on progesterone (low in anovulatory cycles).

Comparison with Ultrasound:

- **Complementary, Not Substitutes:** Hormonal assays and ultrasound are complementary. Ultrasound visualizing polycystic ovaries and string of pearls are the hormonal assays confirming hyperandrogenism and ovulatory dysfunction. Neither test in isolation is enough to diagnose PCOD based on the Rotterdam Criteria, which require clinical and imaging evidence(Karia et al., 2021).

6.2. Ultrasound (USG) vs. Laparoscopy

Laparoscopy is a gold standard procedure for drastic confirmation of PCOD but being invasive, it is normally done in cases when all other diagnostic methods fail or in consideration of women who would need fertility treatments. It involves direct visualization of the ovaries and pelvic structures.

Strengths of Laparoscopy:

- **Direct Visualization of Ovarian Morphology:** Laparoscopy allows direct assessment of the ovaries that could confirm polycystic ovaries, ovarian cysts, and associated pathology like endometriosis or adhesions that could simulate PCOD symptoms.
- **Confirming Exclusion of Other Pathologies:** Laparoscopy can be used to rule out other causes for infertility such as ovarian cysts, fibroids, endometriosis, and tubal obstruction.(Masroor et al., 2009)

Weaknesses of Laparoscopy

- **Invasive Procedure:** are supposed to undergo general anesthesia, and this requires the making of small incisions in the abdominal wall, thereby presenting more invasive risks than an ultrasound.

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• **Restricted Limitations**: Given its invasiveness, laparoscopy is generally reserved for those situations where diagnosis or, indeed, treatment cannot be accomplished by ultrasound and hormonal testing(Daniell & Miller, 1989).

Comparison with Ultrasound:

• **Non-Invasive versus Invasive**: Combination Ovarian Drilling. Although more definitive, laparoscopy is typically reserved for complicated cases or when other treatments like ovarian drilling are being considered. Ultrasound often shows typical features of PCOD which, together with hormonal assays, allows a non-invasive and comprehensive diagnosis.

• **Diagnostics Accuracy**: While laparoscopy remains the gold standard in the diagnosis of PCOD, ultrasound has become nearly as good as laparoscopy in a number of cases. High-resolution, 3D, and Doppler ultrasound techniques have made it even better. Laparoscopy will usually be reserved for cases that are challenging or those that remain unclear after other evaluations(Al-Ojaimi, 2003).

6.3. Ultrasound (USG) vs. Magnetic Resonance Imaging (MRI)

Besides its other uses, MRI is a competent imaging tool for looking at the ovaries andrecreating images of the pelvic organs. It can generate high-resolution images of very fine detail and can provide information on soft tissue characteristics. MRI is, however, rarely used for routine diagnosis of PCOD except in particularly selected cases.

Strengths of MRI

• **Good Soft Tissue Resolution:** MRI has good resolutions with a soft tissue contrast permitting an excellent evaluation of the ovaries concerned regarding follicular development, ovarian stroma, and any associated pathology.

• **Ambiguity in Diagnosis Resolved:** Application of MRI is suited when ultrasound findings show any ambiguity, or in cases where other ovarian conditions (e.g. tumors, endometriomas, cysts) need to be ruled out(Ozkok et al., 2022).

Weaknesses of MRI

• **High Costs:** MRI is costlier than ultrasound, and usually only those cases with a high degree of diagnostic certainty are sent for an MRI.

• **Prolonged Procedure:** MRIs take longer to perform than the quick fps of ultrasound.

Comparison with Ultrasound

• **Cost and Accessibility**: Ultrasound is sufficient for the routine diagnosis of PCOD at a much less cost, whereas MRI is for more complicated cases or to differentiate PCOD from other ovarian pathologies.

• **Better in Selected Cases**: MRI may be more helpful when ovarian tumors, endometriosis, or other pelvic abnormalities need to be assessed. Nevertheless, ultrasound is the first-line imaging modality for PCOD because of its rapid ability to visualize ovarian morphology and identify polycystic ovaries(Kenigsberg et al., 2015).

6.4. Ultrasound (USG) vs. Computed Tomography (CT) Scan

CT scans are hardly ever employed to diagnose PCOD, as they do not provide adequate imaging of soft tissue structures like ovaries. Rather, CT is used for the assessment of the abdomen and pelvis in relevance to trauma and cancer staging or other abdominal pathologies(. et al., 2022).

Strengths of CT scan:

• **Superior for Bone and Calcified Lesions:** CT scans are perhaps the best modality for bone structures and calcified masses but do not really excel at visualizing soft tissue, such as the ovaries(Rakesh Sharma et al., 2023).

Weaknesses of CT scan:

• **Exposure to Radiation:** CT involves exposure to ionizing radiation, so it is another consideration for female patients of child-bearing age, especially for instances where imaging has to be repeated.

• **Soft Tissue Resolution Weaknesses:** When it comes to examining ovarian morphology and follicles, key aspects in PCOD, CT does not hold up very well(Gross1 et al., n.d.).

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Ultrasound Comparison:

- **Radiation Consideration:** Radiation does not risk with ultrasound, while CT exposes the patient to ionizing radiations, hence cannot be used in the routine diagnosis or monitoring of PCOD(Chakravorty, 2023).

7. Challenges in Ultrasound Diagnosis of Polycystic Ovary Syndrome (PCOD)

Ultrasound (USG) is the most used primary imaging modality for diagnosis of Polycystic Ovary Syndrome (PCOD) due to being non-invasive, readily available, and being able to demonstrate ovarian morphology, but still has its own limitations. Diagnosis of PCOD via ultrasound imaging is commonly accepted; however, there are numerous parameters, both concerning technical limitations of ultrasound technology and inherent variability in ovarian morphology and clinical presentations of PCOD, that pose challenges. The main challenges in ultrasound diagnosis of PCOD are listed below(Agapova et al., 2014):

7.1. Variability in Ovarian Morphology

Clinically, one of the key features of PCOD is the presence of numerous small antral follicles in the ovaries that vary typically in size from 2 and 9 mm. However, the distribution of the follicles is significantly variable in different individuals, so some women may present with fewer follicles or distinct morphological patterns. This variability complicates the identification of PCOD based solely on ultrasound findings.(Upadhyay et al., 2020)

Key Points of Concern:

- **Mild Cases of PCOD:** In mild cases, the patient's follicle count may not demonstrate the classic "string of pearls" sign on ultrasound imagery; some women may present with less than 12 follicles in each ovary, thus making the diagnosis of PCOD via follicle count rather uncertain.

- **Overlaps With Other Pathologies**: Other ovarian pathologies like ovarian cysts, endometriosis, or follicular cysts may closely mimic the expression of PCOD multiple small follicles, thereby leading to diagnostic confusion(Webb-Tafoya, 2021).

- **Age-Related Changes:** With advanced age, especially during the perimenopausal period, ovarian morphology changes. Follicular count begins to decline with age and small cysts start to form in the ovaries. These changes may complicate distinguishing the normative aging process from PCOD among older women(Shanmugavadivel et al., 2024).

7.2. Operator Dependency and Technique Variability

The sonographic operator's deftness and experience are vital determinants of the bona fide exponents of ultrasound imaging; clarity and correctness of images so acquired depend on the skill of the operator, whose variable judgment then hinders certitude in the diagnosis(Sarkar et al., 2019).

Key Points of Concern:

- **Manoeuvrability of the Sonographers**: The skilful manoeuvring of the probe to visualize the ovaries in the correct orientation makes a cornerstone for the correct observation of the ovaries. At times, difficulty in visualization of the ovaries can arise due to their position in the pelvic cavity, especially in overweight women or when the bladder is full, or in the presence of adhesions(Peña et al., 2022b).

- **Follicle Counting:** Follicle counting is subjective and is a major diagnostic criterion for PCOD. Different sonographers may count the follicles differently depending on whoever's definitions are applied to the term follicle and whether visible follicles were counted exclusively or those appearing in different planes were included. This subjectivity may result in the inconsistency of diagnosis(Sydora et al., 2023).

7.3. Impact of Ovarian Volume Measurement

An increase in ovarian volume (greater than 10 mL) is another important criterion of PCOD. However, accurately measuring the ovarian volume is challenging, particularly in patients with larger or polycystic ovaries. Factors complicating the measurement of ovarian volume include: Variability in size: Increased ovarian volume in an individual may not necessarily be indicative of PCOD, since many other conditions such as tumours, endometriosis, or hydrosalpinx might also increase ovarian volume. Therefore, volume measurement alone may not be conclusive for diagnosis. In other words, it did include(Mansour et al., 2022):

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• **Use of 2D vs. 3D Ultrasound:** While measuring ovarian size using 2D ultrasound is common, it is not as accurate using 3D ultrasound because it does not provide true volumetric measurements of the ovary. Misinterpretation of dimensions of the ovary by 2D may complicate volume measurement and subsequently hinder diagnosis(Y. Chen et al., 2008).

• **Ovarian Shape:** The ovaries are often more cystic in shape than those in healthy women with PCOD. That is why this ovarian shape measurement will be more difficult than measurements of the regularized contour anatomy measurement(Su et al., 2025).

7.4. Inability Sometimes to Detect Small Follicles

Ultrasound usually does well with larger follicles (>2-3 mm), either underestimating or completely missing out on detection of smaller antral follicles that are very characteristic of PCOD. In some women, especially with mild forms of PCOD, the follicles lie deeper in the ovarian stroma or are too small to be picked up consistently on ultrasound(Nautiyal et al., 2022a).

Key Points of Concern:

• **Retention of Small Follicles:** Antral follicle sizes in PCOD usually range from 2 to 9 mm. On rare occasions, high-resolution ultrasound may miss the detection of smaller follicles, leading to an undercount and false negative.

• **Early Diagnosis Issues:** Small follicle size at early stages of PCOD, especially in younger women, can contribute to diagnostic delays or missed diagnosis, as they may initially be too small to see using routine ultrasound.(Hajam et al., 2024a)

7.5. Non-Specificity for Features of PCOD

The above-mentioned unique imaging findings for PCOD—12 or more follicles in each ovary and increased ovarian volume—are not characteristics unique to PCOD itself. There are numerous other pathologic processes, which, on ultrasound, can produce similar ovarian appearances, making definitive diagnosis impossible for some cases. Key Points to Concern(Rababa'h et al., 2022):

• **Polycystic Ovarian Morphology-a Nonexclusive Condition:** Endometriosis, follicular cysts, ovarian hyperstimulation syndrome (OHSS), and functional overt forms of cysts can produce polycystic ovaries on ultrasound. All these conditions may present multiple small follicles, making differentiation from PCOD difficult with imaging alone.

• **PCOD with Normal Ovarian Appearance:** Women with PCOD can have normal-looking ovaries on ultrasound, such morphology does not show the classic string of pearls or polycystic appearance. From this perspective, a normal ultrasound appearance of the ovaries could lead to misdiagnosis or delayed diagnosis(Gyliene et al., 2022).

7.6 The Role of Ultrasound in Assessing Ovulatory Function

Ultrasound is usually done along with other tests, such as hormonal assays, for assessing ovulatory dysfunction, a primary feature found in PCOD. However, it alone cannot be used to confirm ovulation or give actual information on the existing hormonal irregularities(Joham et al., 2025).

Key points of concern:

• **Follicle Development and Ovulation:** Although ultrasound cannot directly confirm ovulation or status of progesterone, which is necessary to understand ovulatory function fully in PCOS, continuous monitoring on the growth of the follicle as detected by ultrasound may provide evidence for ovulation.

• **Lack of Functional Information:** Ultrasound is basically an anatomical tool, though it does indicate the changes taking place within the anatomy of a patient who has PCOD. There-on, one will require the integration of ultrasound results with hormonal testing results to understand the condition better(Shirin Dason et al., 2024).

7.7 High Cost and Accessibility to Advanced Ultrasound Technologies

3D ultrasound, Doppler ultrasound, and contrast-enhanced ultrasound (CEUS) are advanced ultrasound technologies with high resolution and accuracy in the diagnosis of PCOD; however, access to these techniques is often limited by cost, requirements of technical expertise, and equipment. Key Points of Concern(Joham et al., 2022):

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• **Access to Advanced Equipment:** Costlier and increasingly accessible to advanced modalities such as 3D ultrasound imaging and Doppler studies will not be available in almost all clinical settings, particularly in rural or low-resource areas.

• **Training and Expertise:** These advanced ultrasound techniques cannot be mastered without considerable training and expertise. Expertise limitations resulting from inadequate training may prevent diagnostics in many cases of PCOD(Ahmed et al., 2020).

8.Clinical Implications of Ultrasound in the Diagnosis and Management of Polycystic Ovary Syndrome (PCOD)

Polycystic Ovary Syndrome (PCOD) is a complex endocrine disorder seen in a considerable number of women of reproductive age, which creates barriers in their reproductive health, metabolic health, and quality of life. PCOD diagnosis currently depends mostly on ultrasound (USG) which is mainly employed in the identification of the ovarian morphological features, whereas many other clinical differences go beyond such confirmation. It generates information impacting concerning severity, complications, and management issues that influence decisions regarding fertility treatment, monitoring health over long periods, and patient counselling(Bhatia & Fromer, 2011).

8.1. Early Diagnosis and Timely Intervention

The most critical aspect of having PCOD is the early diagnosis to prevent the long-term complications with timely interventions. Ultrasound contributes greatly to being able to identify the characteristic ovarian morphology associated with PCOD-increasing multiple small follicles and ovarian volume. Along with these ultrasound findings, clinical and biochemical assessments can allow clinicians to accurately make a diagnosis at early stages in the disease disorder(Okamura et al., 2017).

- **Clinical Implications:** Preventing Delay in Diagnosis-Most women present to their physician with inappropriate menstrual cycles and hirsutism or acne, only to be misdiagnosed or undiagnosed for years. Early use of ultrasound in such cases is thus important in revealing apparent signs of PCOD and thus advising the proper clinical interventions to reduce the risk of further complications related to reproductive and metabolic systems(Agarwal et al., n.d.).
- **Prevention of Misdiagnosis:** A lot of PCOD symptoms parallel-endometriosis, thyroid disorders, or ovarian tumours. The ultrasound helps differentiate those conditions from PCOD and allows accurate diagnosis.
- **Addressing Infertility:** It would also be possible to give timely counseling on fertility issues and employ methods of fertility preservation for those who may benefit later or possibly improve chances of successful conception in later life once it is discovered that a woman has PCOS(Bağcı & Tekin, 2023).

8.2. Monitoring Ovarian Morphology Over Time

Building on its dynamic nature, PCOD is such that morphological features change with increasing age or course of treatment. Serial ultrasound scanning helps the clinician identify any changes in the follicular number, size of the ovary, and stroma thickness, which yield significant information regarding the progression or resolution of the condition(Rodriguez et al., 2020).

Clinical Implications:

- **Evaluating Ovarian Function:** The woman may be subject to serial ultrasound monitoring of the ovaries, to identify internal changes, such as the regression of polycystic ovaries after lifestyle modifications or medication therapy (e.g., oral contraceptives or metformin).(Dwarampudi et al., 2023)
- **Ovarian Reserve:** Assessing ovarian reserve using ultrasound combined with hormonal analysis is of utmost measure in women with PCOD. Such is important, especially of those who are planning to undergo fertility treatments. Increased ovarian volume and follicle count may show an increase in ovarian reserve; however, ovarian dysfunction may limit fertility despite apparent quantity in the number of follicles present.(Holla & Arora, 2024)
- **Treatment Result Monitoring:** The fertility treatment course undertaken by women with PCOD, such as ovulation induction or in vitro fertilization (IVF), may also be thoroughly monitored through ultrasound. The treatment cycle would also track the growth and maturation of the follicles, thus ensuring that optimal quality and quantity of follicles were established for conception(Khairnar & Khairnar, 2023).

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8.3. Fertility and Ovulatory Function

PCOD is one of the most rampant causes of anovulation and, thus, infertility. The most crucial study in this area is through ultrasonography, which monitors follicular development and ovulatory cycles. Thus, understanding PCOD's effects on fertility may help the clinician in recommending methods of intervention and treatment(Carmina et al., 2005).

Clinical Implications:

- **Monitoring Follicular Development:** With ultrasound, the follicular development can be well monitored in PCOD women, thus revealing the absence of ovulation or delayed ovulation. This information is critical when making decisions for ovulation induction therapy such as with clomiphene citrate, letrozole, or gonadotropins(Gomez et al., 2022).

- **Multi-follicular Development:** This is also a point where ultrasound is crucial as monitoring such multi-follicular development is common in PCOD patients, especially during stimulated cycles. Prevention of OHSS may also be pursued as a possible complication of fertility treatment(Bachanek et al., 2015).

- **Prompt Fertility Interventions:** With ultrasound taking track of the follicular growth and determining at what level of development is the ovarian response to therapies, clinicians are also able to make timely modifications to fertility protocols to optimize success rates with minimal side effects(Lathia et al., 2022).

8.4. Evaluation of Associated Metabolic Abnormalities

Metabolic syndrome is commonly associated with PCOD, such as insulin resistance, obesity, dyslipidaemia, and increased risk of type 2 diabetes and cardiovascular disease. Ultrasound does not diagnose metabolic conditions by itself but can give useful clues to the ovarian environment, which might correlate with metabolic abnormalities.

Clinical Implications:

- **Metabolic Risk Stratification:** Increased ovarian volume with the high number of follicles on ultrasound could be manifestations of a more severe form of PCOD, which may be associated with increased metabolic risk. Clinicians may use these ultrasound findings to begin early screenings for insulin resistance, dyslipidaemia, and diabetes in those at high risk(Gilbert et al., 2018).

- **Duration Monitoring:** Women with PCOD having an increased risk for metabolic diseases could undergo long-term health monitoring using regularly scheduled ultrasounds assessing any morphological changes in the ovaries together with regular metabolic evaluations (e.g., in blood glucose, lipid panels, etc.)(Barth et al., 2007).

8.5. Diagnosis of Complications and Comorbidities

PCOD women are at a greater risk of developing associated conditions such as endometrial hyperplasia, endometrial carcinoma, and ovarian cancer. Although ultrasound may not diagnose any of these conditions, it is rather useful in identifying abnormal ovarian or uterine structures that would require further investigation(Franks, 2006).

Clinical Implications:

- **Ovarian Cysts and Tumours:** PCOD is associated with follicular cysts, but these women may develop other various forms of ovarian cysts or masses. Ultrasound plays an important role in separating functional cysts from pathological conditions such as dermoid cysts, endometriomas, or ovarian tumours, ultimately guiding correct treatment(Hassan & Killick, n.d.).

- **Monitor for Ovarian Hyperstimulation Syndrome OHSS:** Women undergoing fertility treatments are at risk of developing OHSS, which is potentially serious. Ultrasound aids in the early detection of ovarian enlargement and the presence of fluid into the abdominal cavity for timely intervention(Martin, 2022).

9. Future Directions in Ultrasound Diagnosis of Polycystic Ovary Syndrome (PCOD)

This field of ultrasound imaging is showing rapid changes, and along with these advancements in technology and innovation one can expect the possibility of moving toward more accurate, efficient, and individualized techniques in the diagnosis and management of Polycystic Ovary Syndrome (PCOD).

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In fact, ultrasound has always remained a major modality for the diagnosis of PCOD; however, there are other rapid advancements and future trends that would benefit ultrasound in clinical practices. These developments will probably improve diagnostic accuracy, reduce inter-operator variability, and furnish support for individual treatment plans for women with PCOD(Barthelmess & Naz, n.d.).

9.1. Progress in 3D and 4D Imaging in Ultrasound

In the past, 2D ultrasound exclusively evaluated almost all women with PCOD with regard to all evaluations of ovarian morphology. Of late, 3D and 4D ultrasound imaging have gained acceptance because of the capability for volumetric imaging, which enhances the assessment of ovarian volume, follicular distribution, and stroma texture.

Future Implications:

- **More Accurate Ovarian Volume Measurement: 3D** ultrasound provides volumetric measures of ovarian size and thus improves the assessment of increased ovarian volume, which has been a defining diagnostic feature in PCOD.
- **Detailed Follicle Counting:** 3D ultrasound helps in delivering sharper images of the ovary and in counting the follicles more accurately in varied planes. Thus subjective nature can be reduced in follicle counting and more useful diagnostic criteria will be available for PCOD(P. Lam et al., 2009).
- **Advanced Visualizations:** Ovarian health could be elaborated even better with real-time dynamic imaging of follicular development, as 4D ultrasound provides live visualization of follicular growth with better insight into ovulatory function in patients with PCOD. It can also visualize cysts, stromal changes, and vascularity in the ovary(P. M. Lam et al., 2007).

9.2. Use of Doppler Ultrasound for Vascular and Functional Assessment

The great promise of Doppler ultrasound, which assesses blood flow, is now being put into practice in terms of evaluation of the vascularity in ovarian tissue, the ovarian stroma in women with PCOD, in particular. According to research, the number of studies which have shown that women whose ovarian stroma blood vessels have increased may provide a beneficial complimentary feature for diagnosis.

Future Implication:

- **Ovarian Stromal Vascularity:** With the use of Doppler ultrasound for assessing stromal blood flow, insight into the functional aspects PCOS will be gained. Enhanced understandings will potentially facilitate the earlier identification of ovarian dysfunction, such as anovulation(Nautiyal et al., 2022a).
- **Early Diagnosis of Ovarian Hyperstimulation Syndrome (OHSS):** Changes in blood flow and vascular leakage can be detected earlier than those in women undergoing fertility treatments with the help of Doppler ultrasound, thus allowing for early intervention(Hajam et al., 2024a).

9.3. Ovarian Stroma Assessment through Ultrasound Elastography

Unlike conventional ultrasound, which uses gray-scale imaging, elastography is a promising novel ultrasound technique that measures tissue stiffness, which has been shown to evaluate ovarian stroma in PCOD. Some changes in ovarian stroma may occur over time in women diagnosed with PCOD, with the stroma becoming more fibrotic or dense in structure, resulting in anovulation and impaired ovarian function(Çıracı et al., 2015).

Future Implications:

• **Measuring Ovarian Stroma:** By adopting elastography, it could be possible to produce an objective measure of the ovarian fibrosis classically associated with chronic anovulation in PCOD. Thus, earlier identification of ovarian dysfunction that is not easily visible on conventional ultrasound should be possible.

• **Differentiating PCOD from Other Conditions:** Used in conjunction with the above differentiating feature, elastography could be used to differentiate the PCOD from other conditions with similar ultrasound appearances, such as endometriosis, ovarian tumors, or functional cysts. Strictly assessing tissue stiffness and elasticity authenticates the additional diagnostic specificity afforded by elastography(Ruan et al., 2024).

• **Evaluating Efficacy:** It may also be possible to assess efficacy of PCOD treatments using change over time in ovarian fibrosis or stroma. PCOD patients may respond to metformin or gonadotropins treatment, or lifestyle

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changes aimed at reducing insulin resistance and improving ovarian function(He et al., 2025).

9.4. Integrating AI with Ultrasound

There is a role for artificial intelligence (AI) and machine learning (ML) in ultrasound imaging because these immediately indicate automation of image analysis, making diagnosis accurate while reducing human error. AI technologies would standardize, from the perspective of PCOD, follicle counting, ovarian volume measurement, and the assessment of other ultrasound features(Alamoudi et al., 2023).

Future Implications:

• **Automated Follicle Counting:** Algorithms powered by AI will have the ability to count automatically the follicles on ultrasound images, resulting in lesser subjective inter-observer variability in follicle counting- a more precise and trustworthy diagnostic criterion for PCOD.

• **Predictive Modeling:** Ultimately, AI could develop predictive models to couple ultrasound data with other clinical factors (e.g., hormonal levels, age, BMI) for predicting treatment outcome and risk of complication in women with PCOD. Such predictive modeling would contribute to personalized treatment regimens.

• **Integration with Big Data:** Such an integration of ultrasound images with big data from patient's histories, hormonal profiles, and other diagnostic tests would aid to enhance the understanding of the complete spectrum of PCOD for early detection, management, and monitoring of the condition by AI systems(Thakur & Jha, n.d.).

9.5. High-Resolution Ultrasound for Early Detection of Subclinical PCOD

In fact, in most cases, PCOD has mild manifestations, and slight changes in ovarian morphology could easily be missed by basic ultrasound. The emergence of high-resolution ultrasound systems could provide detection of subclinical PCOD in women without symptoms or in the very early stages of their reproductive life(Ni & Lee, 2020).

Future Implications:

• **Increased Detection of Early Changes among Asymptomatic Women:** Changes in the ovarian architecture detected with high-resolution ultrasound could sit in between the usual early recognition of PCOD symptoms of irregular menstrual cycles, hirsutism, or ovulatory dysfunction. Such findings could trigger the need for prior interventions such as lifestyle changes or pharmacological agents to postpone or avert metabolic/reproductive breakdowns(Reka et al., 2025).

• **Predictions for Future Risks:** High-resolution ultrasound for early identification of morphological changes within the ovaries could be a good tool for predicting which women would face a greater risk of developing complications due to PCOD-such as infertility, insulin resistance, and cardiovascular disease. Enhanced Patient Monitoring through Point of-Care Ultrasound. The increasing availability and portability of ultrasound devices have provided the groundwork for a point-of-care ultrasound (POCUS) movement. This means much more frequent, convenient assessments of ovarian morphology could be organized, especially in the remotest settings and in the underserved regions where access to specialist imaging facilities is uncertain(Laschke et al., 2010).

• **Increased Accessibility:** POCUS systems would extend diagnostic ultrasound right into the clinics, fertility centres, or even primary care, so that women with PCOD can more easily have their health monitored by way of check-ups.

• **Remote Monitoring:** With a combination of mobile ultrasound technology and cloud-based platforms, it could be possible to allow for remote monitoring of women with PCOD so that they can be consulted and treated via telemedicine from a distance. This would facilitate accessibility for women facing geographical or logistical barriers to traditional healthcare(Gomez et al., 2022).

• **Empowered Patients:** Portable ultrasound devices would allow patients to participate actively in taking care of themselves and in the management of their PCOD. Regular home ultrasound assessments would create a personalized approach to care whereby

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women could keep track of their own symptoms, ovulatory cycles, and responses to treatment.

Conclusion

PCOS is a little complex and multifaceted and has adverse implications on reproductive health, metabolic health, and quality of life. Among the different diagnostic modalities, ultrasound (USG) enjoys a special and eminent status as a common method providing non-invasive, real-time, and informative assessment of ovarian morphology, follicular development, and associated pathologies. Ultrasound plays a major role in the diagnosis of PCOD, mainly in providing an assessment of ovarian morphology: follicular count, ovarian volume, and stroma thickness. With the introduction of AI, machine learning, and high-resolution imaging technologies, further changes in the ultrasound diagnosis for PCOD await promise. ultrasound will thus continue to stand as an important tool that always finds application in the diagnosis and management of PCODS. The future which holds advanced imaging technology with AI and other diagnostic tools merges with this utility in clinical practice. Thus, through our refinement of the understanding of PCODS and improvement of ultrasound, the healthcare field shall thus provide care for women, tailoring intervention at early times and having more personalized options, thus boosting outcome and quality of life for women facing this worldwide syndrome.

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