RESEARCH ARTICLE

Superb microvascular imaging Doppler technique in the evaluation of ovarian stromal vascularity in women with polycystic ovary syndrome

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Abstract

Objective: To compare the assessment of intra-ovarian stromal vascularity through transabdominal ultrasonography with colour Doppler imaging, power Doppler imaging, colour superb microvascular imaging and monochrome superb microvascular imaging in polycystic ovary syndrome cases.

Method: The retrospective cross-sectional study was conducted at the Obstetrics and Gynaecology outpatient department of the Usak Training and Research Hospital, Turkey, from April 11 to June 18, 2018, and comprised grayscale colour Doppler imaging, power Doppler imaging, colour superb microvascular imaging and monochrome superb microvascular imaging of women with polycystic ovary syndrome. The recorded video images were evaluated by three radiologists and rated through consensus decision. Mean values for age, body mass index, follicle stimulating hormone and luteinizing hormone levels, luteinizing hormone-follicle stimulating hormone ratio, Ferriman Gallwey score, and mean ovarian volume of the subjects were evaluated. Data was analysed using Number Cruncher Statistical System.

Results: Of the 54 women evaluated, data of 42(77.8%) was included. There were a total of 83 ovaries, as the left ovary of 1(1.2%) patient was not visible. The mean age and body mass index were 24.02±5.8 years and 25.08±4.5kg/m^2. Mean follicle stimulating hormone and luteinizing hormone levels were 5.51±1.91 and 7.91±6.13m IU/mL. Luteinizing hormone/follicle stimulating hormone ratio and Ferriman Gallwey score were 1.4±0.8 and 8.67 ±6.94, respectively. The mean ovarian volume was 12.2±3.43 cm^3. The detection of vascularity was colour Doppler imaging 0.72±0.97, power Doppler imaging 0.96±1.08, colour superb microvascular imaging 2.47±1.25, and monochrome superb microvascular imaging 2.75±1.31. The techniques were significant for superb microvascular imaging Doppler than conventional Doppler ($p<0.001$). Hyper-ovarian stromal vascularity, like a 'stellate' sign, was detected in 17(20.5%) of the total 83 ovaries analysed.

Conclusions: Transabdominal ultrasonography-colour superb microvascular imaging was found to be more effective in detecting ovarian vascularity than conventional Doppler technique in women with polycystic ovary syndrome.

Keywords: Microvessels, Polycystic ovary syndrome, Ultrasonography, Doppler. (JPMA 73: 1992; 2023)

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Introduction

Polycystic ovary syndrome (PCOS) causes menstrual irregularities, hyperandrogenism (HA) and polycystic ovarian morphology (PCOM).[1] The prevalence of PCOS is 4-21%, depending on the diagnostic criterion used.[2] The presence of at least one ovary ≥12 follicles with a diameter of 2-9mm, and a greater ovarian volume >10cm^3 comprise the ultrasonographic (USG) criteria for PCOM.[3] Neoangiogenesis causes increased ovarian stromal blood flow in PCOS patients which is crucial for analysing clinical and laboratory results, medical treatment, follow-up, and ovarian hyperstimulation syndrome (OHSS) prediction.[4,5]

Conventional Doppler techniques detect vascularity. Colour Doppler imaging (CDI) is insufficient due to artefacts, while power Doppler imaging (PDI) is very sensitive to motion artefacts and is mainly used for external organs.[6] The superior microvascular imaging (SMI) approach surpasses conventional Doppler techniques and decreases artifacts.[7,8] SMI includes two distinctive qualities: monochrome SMI (mSMI), like CDI, has a black ground image to more sharply highlight vascular structures, while colour SMI (cSMI) is a grayscale blend of SMI and B Mode.[9] Many studies have evaluated ovarian stromal vascularity with Doppler techniques, such as conventional and 3D Doppler techniques, in PCOS women, but the SMI Doppler imaging technique is not widespread.[10]

The current study was planned to evaluate intra-ovarian stromal vascularity measurement by CDI, PDI, cSMI and mSMI with transabdominal ultrasonography (TAUSG) in PCOS women. The null hypothesis was that there would be no significant differences between conventional and SMI Doppler techniques in assessing intra-ovarian stromal vascularity.

Patients and Methods

The retrospective study was conducted at the Obstetrics

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and Gynaecology outpatient department (OPD) of the Usak Training and Research Hospital, Turkey, from April 11 to June 18, 2018 and we worked on the data from June 8 to September 18, 2022. After approval from the institutional ethics review committee, clinical notes and electronic patient records were retrieved and evaluated. Data related to women who came to the clinic due to ovulatory dysfunction. Data included the ovulatory cycle, ovulatory dysfunction (OD) (oligomenorrhea/amenorrhea) lasting at least 6 months, Ferrimane Gallway score (FGS), early proliferative phase of the menstrual cycle, the levels of follicle stimulating hormone (FSH) and luteinizing hormone (LH), the LH/FSH ratio, and PCOM found on TAUSG. Amenorrhoea was taken as the absence of vaginal bleeding for more than three months in subjects who had previously experienced periodic menstruation for at least 6 months. Oligomenorrhoea was defined as a cycle duration of more than 35 days. In terms of hirsutism, alopecia, acne and seborrhea, FGS>7 was considered significant.[11] Regarding the ovulatory cycle, LH/FSH ratio was evaluated as 1 and 2.[12] PCOM showing either ≥12 follicles (2-9 mm) or increased ovarian volume (>10 cm^3) was significant.[11] All patients' clinical and biochemical profiles were examined. Data excluded was related to patients with endocrinologic disorders (Cushing's syndrome, thyroid disease etc.), ovarian tumours and surgeries, hyperprolactinaemia, pregnancies and post-menopausal phase, and contraceptive pill usage. Finally, women categorised by PCOS phenotype were included.[9,13]

A USG tool (Toshiba, Aplio 500, Tokyo, Japan) was used in the Radiology Policlinic USG Unit, with a 1-6 MHz convex probe. After scanning the lesion with TAUSG, 5-12-second video pictures were recorded. The ovarian stromal vascularity was defined according to the International Ovarian Tumour Analysis (IOTA) group criteria.[14] Four categories of endometrial blood flow were identified: No colouration=grade 1, one or more punctate colourations= grade 2, one linear colouring or several (>5) punctate colourations = grade 3, and multiple linear colourations = grade 4.[14] Vascularisation rating was done independently, using CDI, PDI, cSMI and mSMI techniques. In all patients, the ovarian morphological features were recorded for both the ovaries. Three radiologists analysed the captured video pictures and assigned a consensus rating and they also investigated the shape of ovarian stromal vascularity.[15]

Data was analysed using the Number Cruncher Statistical System (NCSS). Data was expressed as mean and standard deviation as well as frequencies and percentages, as appropriate. Data distribution was assessed using Shapiro-Wilk test. Kruskal-Wallis test was used for the comparison of quantitative data across three or more groups. Mann-Whitney U test was used to compare two groups. P<0.05 was taken as statistically significant.

Sample size calculation was done using G*Power latest version 3.1.9.7, taking mean mean CDI 0.4±0.9, PDI 0.8±1.2, cSMI 1.4±1.8, and mSMI 3.1±2.3.[16] The effect size was 0.8, power 94%, and alpha (α) error 0.05.

Results

Of the 54 women evaluated, data of 42(77.8%) was included. There were a total of 83 ovaries, as the left ovary of 1(1.2%) patient was not visible. The mean age and body mass index (BMI) were 24.02±5.8 years and 25.08±4.5 kg/m^2. Mean FSH and LH levels were 5.51±1.91 and 7.91±6.13 m IU/mL. LH/FSH ratio and FGS were 1.4±0.8 and 8.67 ±6.94, respectively. The mean ovarian volume was 12.2±3.43 cm^3.

Of the total, 24(57%) women had no ovulatory dysfunction. Their mean FGS and ovarian volume were 12.5±5.06 and 14.95±5.78 cm^3. They had phenotype C. The remaining 18(43%) subjects were evaluated as possible PCOS phenotypes, and they had no ovulatory dysfunction. Among them, 6(33.3%) women's mean FGS and ovarian volume were 10.67±4.68 and 7.35±1.71 cm^3, while 12(66.6%) others had corresponding values of 0 and 14.3±4.4 cm^3.

The detection of mean ovarian stromal vascularities was CDI 0.72±0.97, PDI 0.96±1.08, cSMI 2.47±1.25 and mSMI 2.75±1.31 SMI Doppler imaging value was significant compared to conventional Doppler (*p*=0.001) (Table 1).

During ovarian stromal SMI Doppler analysis, a 'stellate' sign image due to hypervascularity was found in 17(20.5%) of the 83 ovaries analysed, in 14(33.3%). Among them, 10(%) women were phenotype C and the other 4(%) were possible PCOS phenotypes (Table 2, Figure).

Table-1: Doppler findings of PCOS women (n=83).

	Intra ovarian vascularity		*p*-value
	Min-max	Mean ±SD	
CD	0-4	0.72±0.97	<0.001
PD	0-4	0.96±1.08	
cSMI	0-4	2.47±1.25	
mSMI	0-4	2.75±1.31	

PCOS: Polycystic ovary syndrome, SD: Standard deviation, CD: Colour Doppler, PD: Power Doppler, c:colour, m: Monochrome, SMI: Superb microvascular imaging.

Discussion

PCOS is diagnosed by clinical or biochemical HA, chronic OD, and PCOM after secondary reasons have been ruled out. It separates phenotypic classification, which is related to the characterisation of the PCOS population and assessment of metabolic syndrome risk. Phenotype A

Table-2: Ovarian vascular grading and 'stellate' sign of 14 women.

S.No.	Right Ovary Vascular grading					Left Ovary Vascular grading					Phenotypes
	Volume (cm^3)	CD	PD	cSMI	mSMI	Volume (cm^3)	CD	PD	cSMI	mSMI	
1	20	2	2	3	4(stellat)	16.7	2	2	4 (stellat)	4(stellat)	C
2	22.5	1	1	4 (stellat)	4 (stellat)						C
3						13	3	4	4 (stellat)	4(stellat)	C
4						20.4	2	3	4 (stellat)	4(stellat)	C
5						19.8	3	4	4 (stellat)	4(stellat)	other
6	13.9	2	3	4 (stellat)	4 (stellat)						C
7						17.8	1	1	4 (stellat)	4 (stellat)	C
8						13.6	0	0	3	4 (stellat)	other
9	11.8	2	3	4 (stellat)	4 (stellat)	9.2	0	0	4 (stellat)	4 (stellat)	other
10	19.5	2	2	4 (stellat)	4 (stellat)	27.6	4	4	4 (stellat)	4 (stellat)	C
11	8.6	0	0	4 (stellat)	4 (stellat)						Other
12	10.9	0	0	3	4 (stellat)						C
13						33	1	1	4 (stellat)	4 (stellat)	C
14						15	1	1	4 (stellat)	4 (stellat)	C

CD: Colour Doppler, PD: Power Doppler, c: Colour, m: Monochrome, SMI: Superb microvascular imaging.

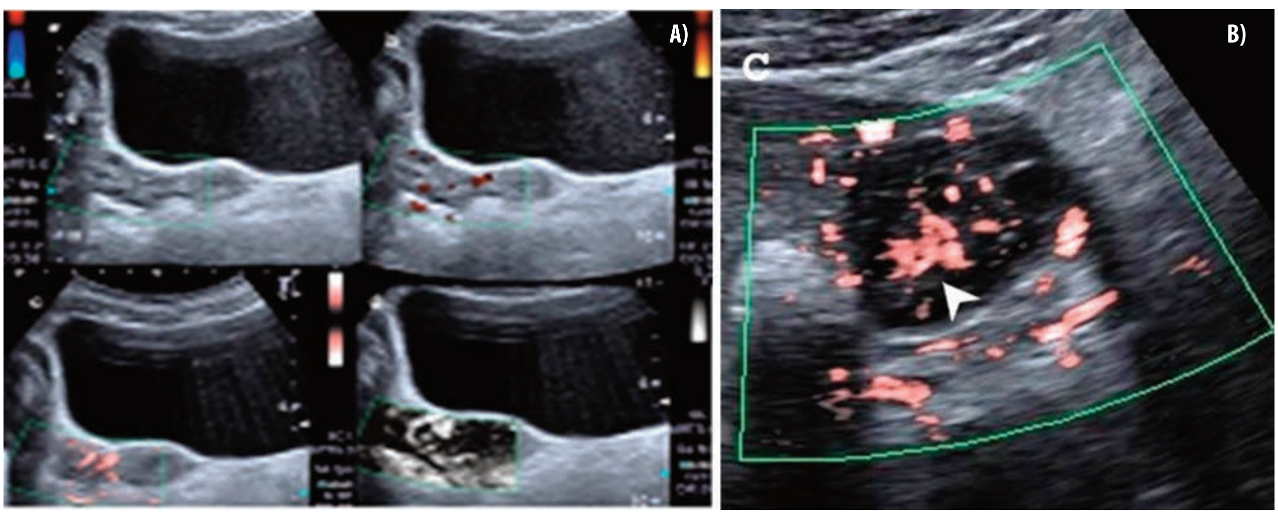

Figure: SMI, conventional Doppler and 'stellate 'sign images: **A)** Superb microvascular imaging (SMI) and conventional imaging. a: colour Doppler imaging (CDI), Power Doppler imaging (PDO), colour superb microvascular imaging (cSMI) and monochrome superb microvascular imaging (mSMI). **B)** Stellate sign imaging. c: Colour superb microvascular imaging (cSMI), arrow: Stellate sign.

means HA+OD+PCOM, phenotype B means HA+OD, phenotype C means HA+PCOM, phenotype D means OD+PCOM, and other possible types.[2,13] The PCOS subjects in the current study consisted of type C and other possible types.

Pathologically, the ovaries are frequently expanded with a thicker capsule and hyperplastic stroma, as well as many subcortical cysts grouped in a rosary pattern.[11] İncrease in stromal volume arises from excess follicular maturation and ensuing atresia.[17] Under the influence of androgens, increased ovarian volume, theca cell hyperplasia, and an increased rate of follicular atresia, polycystic alteration takes place in the ovaries.[11] USG assessment of PCOM is controversial.[4] Although ovaries >10 cm^3 were linked to polycystic morphology, setting the ovarian volume criterion at 7 cm^3 resulted in the highest specificity-to-sensitivity ratio (91.2:67.5%) in a study.[4] In contrast, specificity and sensitivity were 98.2% and 45%, with a threshold of 10 cm^3.[18] Ovarian volume of 6.6 cm^3 demonstrated 91% sensitivity and 91% specificity for PCOS.[19] Ovarian volume, stromal vascularity, echogenicity and follicular numbers should be considered, according to the studies.[4] On the other hand, minor PCOS phenotypes were found by USG in PCOS-affected patients who had granulosa cell abnormalities that were clinically quiet.

These polycystic ovaries had an ovarian look without pathological significance.20 In the current study, women with clinical HA and ovarian volume <10 cm^3 were evaluated in terms of stromal and follicular findings, and women with isolated USG polycystic ovaries were assessed as possible phenotypes, as per the literature.[13]

Most studies found that women with PCOS had higher intra-ovarian stromal arteries and peak systolic blood flow velocities than healthy women with normal ovarian morphology.[20] Increased stromal vascularisation is due to LH, oestrogen and androgen levels, neoangiogenesis, catecholaminergic stimulation, leukocyte and cytokine activation.[11,21,22] Vascularisation of the ovaries is vital for USG examination because it can provide information on PCOS prognosis and predict response to treatment and OHSS.[17,23]

Sahu et al. reported decreased ovarian stromal blood flow values with oral contraceptives, metformin and ovarian drilling treatments, decreased LH and androgen levels, and improved insulin resistance with conventional Doppler imaging.[1] The current study detected demonstrative hypervascularity, like a 'stellate' sign, in 14 women's ovaries. Most of these women were phenotype C, which could be related to androgens, immune activity, etc. The relationship between intra-ovarian hypervascularity and PCOS phenotypes needs to be clarified and will require more biochemical investigations supported by SMI.

In the Doppler ovarian assessment by the transabdominal route in a study, approximately 42% of cases were not entirely evaluated because of adipose tissue, limited resolution, full bladder distorting the pelvic anatomy, bowel loop covering the ovary, etc.[21] Furthermore, conventional Doppler USG may be insufficient due to weak tissue penetration of Doppler echos.[6] Guerriero et al. reported that CDI's ovarian vascularity detection rate was 65(21%) and with PDI, this rate increased.[24] Due to artifacts, such as colour confusion and noise, CDI cannot display all Doppler spectrums and is mostly employed in heart and vascular tissues.[25] On the other hand, PDI is more practical for assessing weak low-flow vessels because of advantages, including less colour confusion, high flow detection sensitivity, uniform backdrop colour, etc. However, because it is particularly sensitive to motion artifacts, it is mostly utilised in examining superficial organs, such as the thyroid and testicles.[25] The SMI Doppler technique is preferable to traditional Doppler methods for presenting low-velocity blood flows in vessels with tiny diameters because it eliminates artifacts based on by tissue movement. Some studies have mentioned the SMI Doppler technique's high diagnostic value.[6]

A few studies used TAUSG-SMI Doppler imaging in gynaecology cases.[6,9,26] In uterine pathologies, Samancı et al. reported the outcomes of embolisation treatment of uterine leiomyoma in premenopausal normal weight women. They evaluated the vascularity of the leiomyoma by SMI and PDI by the transabdominal route. The positive predictive value (PPV), negative predictive value (NPV), sensitivity, specificity, and accuracy of SMI and PDI were 100-100%, 64-42%, 73.6-36.8%, 100-100%, and 82.1-57.1%, respectively. They concluded that the SMI Doppler technique can be useful, but may not be feasible for deeply located myomas and obese women.[26] Senyuva et al. demonstrated that evaluating endometrial vascularity with the TAUSG-SMI Doppler technique in postmenopausal overweight women was not superior to TAUSG-traditional Doppler imaging using weight, postmenopausal status, and deeply located organs.[6] In ovarian imaging, Ayaz et al. evaluated ovarian vascularity with conventional and SMI Doppler by transabdominal route in paediatric age groups, and reported that in terms of detecting vascularity, SMI Doppler was more effective than conventional Doppler ($p<0.001$).[9]

The findings of the current study negated the null hypothesis. Although the study population consisted of overweight women, ovarian stromal vascularity could still be more effectively detected with TAUSG-SMI than the conventional Doppler technique in PCOS women. It can explain reproductive age, high ovarian volume, and lateral localisation of the ovary in the pelvis.[25]

The current study has limitations as it was a pilot, single-centre, retrospective study with a small sample size.

Conclusion

The SMI Doppler technique by transabdominal route was found to be more effective than conventional approaches in detecting ovarian stromal vascularity in PCOS women. It might be a practical tool to understand PCOM better and may assist the differential diagnosis of phenotypes and treatment follow-up.

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