

CORRELATION BETWEEN DOMINANT FOLLICLE PEAK SYSTOLIC VELOCITY AND ULTRASONOGRAPHIC MARKERS OF OVULATION: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: The dominant follicular diameter is the mainstay of conventional follicular monitoring but follicular size may not be a complete reflection of functional maturity. Perifollicular Doppler assessment may give information on vascular changes related to follicular maturation and may enhance prediction of ovulation.

Objective: To assess the association of perifollicular peak systolic velocity (PSV) with ovulation, to compare the predictive value of PSV with dominant follicular diameter and to evaluate the added value of combining both parameters.

Materials and Methods: This prospective observational study was conducted on 80 monitored cycles in women between 18–35 years of age undergoing serial transvaginal follicular monitoring. The dominant follicle size, perifollicular peak systolic velocity, resistive index, pulsatility index, endometrial parameters and ovulation status were recorded. Serial sonography was done to document follicular rupture and to ascertain ovulation. The diagnostic performance of PSV and follicular diameter was determined. The independent association of PSV with ovulation was determined by multivariable logistic regression model after controlling for follicular diameter.

Results: Ovulation was recorded in 62 out of 80 cycles (77.5%) Perifollicular PSV was significantly higher in ovulatory compared to non-ovulatory cycles (12.7 ± 2.6 vs 8.4 ± 2.1 cm/s; $p < 0.001$) and dominant follicular diameter was larger (19.8 ± 1.8 vs 17.6 ± 2.1 mm; $p < 0.001$). Sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy for PSV cutoff of >10.5 cm/sec were 83.9%, 77.8%, 92.9%, 58.3% and 82.5% respectively. The AUC of follicular diameter was 0.82, PSV 0.89 and combined model 0.93. After adjustment for follicular diameter, PSV was independently associated with ovulation (adjusted OR=1.72 per 1 cm/sec increase; 95% CI: 1.27 to 2.35; $p < 0.001$).

Conclusion: Perifollicular PSV was significantly associated with ovulation and showed better discriminative performance than the dominant follicle diameter alone. A PSV cut-off of >10.5 cm/s had good diagnostic performance. However, the combination of PSV and follicular diameter had the highest predictive discrimination. Therefore, the addition of perifollicular Doppler to serial follicular monitoring may provide useful functional information in addition to the conventional assessment of follicular size.

CORRELATION BETWEEN DOMINANT FOLLICLE PEAK SYSTOLIC VELOCITY AND ULTRASONOGRAPHIC MARKERS OF OVULATION: A PROSPECTIVE OBSERVATIONAL STUDY

Keywords: Ovulation; Peak systolic velocity; Perifollicular Doppler; Dominant follicle; Follicular monitoring; Transvaginal ultrasonography; Infertility.

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INTRODUCTION

Ovulation is a complicated physiological event that involves a series of precisely coordinated changes in the endocrine, structural and vascular aspects of the dominant ovarian follicle. Accurate identification of the periovulatory period has clinical relevance to the management of infertility, particularly in optimizing the timing of intercourse, ovulation induction, intrauterine insemination and other assisted reproductive interventions. Follicular monitoring is routinely performed by serial transvaginal ultrasonography, which allows assessment of follicular growth, endometrial development and subsequent sonographic evidence of follicular rupture. A recent prospective study has shown the potential value of combining conventional measurements of the follicle with Doppler assessment to predict the time of ovulation.¹

Follicular maturity has been mainly assessed by the dominant follicular diameter. However, follicular size is mainly a morphological feature and may not fully reflect the functional or vascular maturity of the follicle. Progressive angiogenesis and increased blood flow happen in the perifollicular vascular network during the periovulatory period. The hemodynamic changes can be assessed non-invasively by transvaginal color and spectral Doppler ultrasonography. Campbell et al. showed a significant periovulatory peak systolic velocity (PSV) rise supporting the biological link between increased follicular blood flow and imminent ovulation.²

Since then perifollicular vascularity has been investigated as a potential index of follicular competence and reproductive outcome. Transvaginal Doppler studies have shown a correlation between increased follicular vascularity and favorable parameters such as follicular maturity, oocyte retrieval, fertilization and pregnancy outcomes.^{3,4} A systematic review also suggested that perifollicular blood-flow assessment may have a prognostic value in assisted reproduction, though considerable methodological heterogeneity remains between studies.⁵ Therefore, the evaluation of perifollicular PSV in addition to the traditional dominant follicular diameter may provide a more complete assessment of follicular maturation and improve the ultrasonographic prediction of impending ovulation.

AIM

To assess the role of perifollicular peak systolic velocity (PSV) in predicting ovulation during serial transvaginal follicular monitoring.

OBJECTIVES

1. To determine the association between perifollicular peak systolic velocity and ovulation.
2. To compare the predictive value of perifollicular peak systolic velocity with dominant follicular diameter and evaluate the added value of using both parameters together.

MATERIALS AND METHODS

Study Design and Setting

The present prospective observational study was done in joint collaboration between the Department of Radiodiagnosis and Department of Obstetrics and Gynecology, Smt. B.K. Shah Medical Institute and Research Center, Sumandeep Vidyapeeth, Vadodara, Gujarat, India, between December 2025 to July 2026. Consecutive women undergoing serial transvaginal ultrasonographic monitoring of follicles as part of an infertility evaluation or treatment were screened for eligibility.

Sample Size and Sampling

Sample size was estimated according to diagnostic-accuracy approach. Based on an expected sensitivity of 80% for perifollicular peak systolic velocity (PSV), an expected ovulation proportion of 80%, 95% confidence level and absolute precision of 10%, the minimum required sample size was calculated to be approximately 77 monitored cycles. Target sample was rounded to 80 cycles monitored. Eligible participants were recruited consecutively until the desired sample size was reached. The typical approach to calculating performance of diagnostic tests was used to calculate the sample size, taking into account the expected prevalence of the outcome.⁶

Inclusion Criteria

CORRELATION BETWEEN DOMINANT FOLLICLE PEAK SYSTOLIC VELOCITY AND ULTRASONOGRAPHIC MARKERS OF OVULATION: A PROSPECTIVE OBSERVATIONAL STUDY

Women were included if they fulfilled all of the following criteria:

1. Age 18–35 years.
2. Undergoing infertility evaluation or treatment with serial follicular monitoring.
3. Presence of a clearly identifiable dominant ovarian follicle on transvaginal ultrasonography.
4. Availability for serial ultrasonographic follow-up until ovulation was documented or the monitoring cycle was completed.
5. Technically satisfactory colour and spectral Doppler assessment of the dominant follicle.
6. Written informed consent for participation.

Exclusion Criteria

Women were excluded in the presence of:

1. Persistent ovarian cyst interfering with follicular assessment.
2. Ovarian mass or other ovarian pathology affecting follicular evaluation.
3. Previous oophorectomy affecting ovarian assessment.
4. Inadequate visualization of the ovaries or dominant follicle.
5. Technically inadequate perifollicular spectral Doppler examination.
6. Incomplete serial ultrasonographic follow-up.
7. Cycles in which ovulation status could not be reliably established.

Details of ovulation-induction therapy and administration of an ovulation trigger, when applicable, were recorded because of their potential influence on follicular development and ovulation.

Ultrasonographic Assessment

Serial transvaginal ultrasound was performed using a LOGIQ P9 ultrasound system (GE HealthCare) with an endocavitary transducer. Both ovaries were systematically examined at each examination.

The dominant follicle was located and two maximum internal diameters were measured in perpendicular planes and the mean follicular diameter was recorded in millimeters. Endometrial thickness was measured as the maximal thickness of the double layer in the midsagittal plane.

Parameters recorded during monitoring of the follicles were: cycle day, side of dominant follicle, dominant follicular diameter, endometrial thickness

and morphology, perifollicular vascularity, perifollicular PSV, resistive index (RI), pulsatility index (PI), and presence/absence of pelvic free fluid.

Perifollicular Doppler Assessment

Color Doppler was used to detect vascular signals around dominant follicle. Low-flow Doppler settings were used and pulse repetition frequency, wall filter, gain and velocity scale were kept as constant as technically possible during the examinations.

A suitable perifollicular vessel was identified and then subjected to spectral Doppler interrogation. The Doppler sample volume was placed in the vessel and angle correction was applied where necessary to minimize velocity-measurement error. At least three consecutive reproducible waves were obtained.

The PSV was measured in cm/s and the RI and PI were calculated from the spectral Doppler waveform. Analysis was performed on mean PSV obtained from technically satisfactory consecutive waveforms.

Determination of Ovulation

Serial ultrasonographic monitoring was continued until ovulation was observed or until the cycle of monitoring ended. Ultrasonography performed later showed one or more of the following: Ovulation was presumed to have happened

- sudden disappearance/collapse of the previously seen dominant follicle;
- decreased size of follicles with irregularity of follicular wall;
- development of corpus luteum morphology or
- development of new free fluid in the pouch of Douglas.

For the main analysis, the preovulatory measurement was defined as the Doppler measurement obtained at the examination immediately before the sonographic evidence of ovulation. For cycles where ovulation was not documented, the last technically adequate scan in the monitoring period was used for the analysis.

Outcome Measures

The primary outcome was the association between perifollicular PSV and documented ovulation.

The secondary outcome was the comparative predictive value of perifollicular PSV and dominant

CORRELATION BETWEEN DOMINANT FOLLICLE PEAK SYSTOLIC VELOCITY AND ULTRASONOGRAPHIC MARKERS OF OVULATION: A PROSPECTIVE OBSERVATIONAL STUDY

follicular diameter and the additional predictive value obtained by combining both parameters.

Statistical Analysis

Data were entered in Microsoft Excel and analyzed using IBM SPSS Statistics for Windows, Version 32.0. Continuous variables were tested for distribution and expressed as mean $\pm$ standard deviation or median and interquartile range. Categorical variables are presented as frequencies and percentages.

Independent-samples t-test or Mann–Whitney U test were used for comparison of perfollicular PSV and dominant follicular diameter between ovulatory and non-ovulatory cycles according to data distribution. Categorical variables were compared using chi-square test or Fisher's exact test as appropriate.

Receiver operating characteristic curves for PSV and dominant follicular diameter were constructed and area under curve (AUC) with 95% confidence intervals was calculated. The optimal PSV cut-off was evaluated using the Youden index and its sensitivity, specificity, positive predictive value, and negative predictive value were estimated. The predictive values of the discriminatory performance of PSV and follicular diameter were compared and a binary logistic regression model was constructed including both variables to evaluate their combined predictive value. Adjusted odds ratios and 95% confidence intervals were reported. Statistical significance was set at a two-sided p-value of <0.05 .

Ethical Considerations

The study was conducted in accordance with institutional ethical requirements. Approval was obtained from the Institutional Ethics Committee of Smt. B.K. Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth, Vadodara, Gujarat, India. Written informed consent was obtained from all participants before enrolment.

RESULTS

A total of 80 monitored cycles were included in the analysis. Ovulation was documented in 62 cycles (77.5%), whereas 18 cycles (22.5%) were classified as non-ovulatory during the monitoring period.

Comparison of ultrasonographic and Doppler parameters

Perifollicular peak systolic velocity (PSV) was significantly increased in ovulatory cycles as compared to non-ovulatory cycles (12.7 ± 2.6 cm/s

vs 8.4 ± 2.1 cm/s), with a mean difference of 4.30 cm/s (95% CI: 2.97–5.63; $t=6.425$; $p<0.001$). Also, the size of the dominant follicle in ovulatory cycles was significantly larger (19.8 ± 1.8 mm vs 17.6 ± 2.1 mm), the difference being 2.20 mm (95% CI: 1.20–3.20; $t=4.395$; $p<0.001$) (Table 1).

Ovulatory cycles had significantly lower resistive index (0.46 ± 0.07 vs 0.55 ± 0.08 ; $t=-4.650$; $p<0.001$) and pulsatility index (0.78 ± 0.16 vs 0.96 ± 0.19 ; $t=-4.026$; $p<0.001$). Age was not significantly different between ovulatory and non-ovulatory cycles (29.2 ± 4.0 vs 30.1 ± 4.5 years; $p=0.416$). Similarly, endometrial thickness was also higher in ovulatory cycles, but the difference did not reach statistical significance (9.4 ± 1.7 mm vs 8.6 ± 1.8 mm; $p=0.087$) (Table 1). The distribution of perfollicular PSV by ovulation status is shown in Figure 1.

Association between perfollicular PSV and ovulation

Using a perfollicular PSV cut-off of >10.5 cm/s, 52 out of 62 ovulatory cycles (83.9%) were above the cut-off compared with 4 out of 18 non-ovulatory cycles (22.2%). In contrast, a PSV ≤ 10.5 cm/s was seen in 10 ovulatory cycles (16.1%) and 14 non-ovulatory cycles (77.8%). The association between the PSV category and ovulation status was statistically significant ($\chi^2=25.247$; $p<0.001$). The odds of ovulation were significantly higher in cycles with PSV >10.5 cm/s than in cycles with PSV ≤ 10.5 cm/s (OR=18.20; 95% CI: 4.95–66.85) (Table 2).

The predicted ovulation with a sensitivity of 83.9% (95% CI 72.8–91.0%) and a specificity of 77.8% (95% CI 54.8–91.0%) for the >10.5 cm/s cutoff. The positive predictive value was 92.9% (95% CI 83.0–97.2%) and the negative predictive value was 58.3% (95% CI 38.8–75.5%). Overall diagnostic accuracy was 82.5% (95% CI 72.7–89.3%). The positive likelihood ratio was 3.77 (95% CI, 1.58–9.02), negative likelihood ratio was 0.21 (95% CI, 0.11–0.39), and the diagnostic odds ratio was 18.20 (95% CI, 4.95–66.85) (Table 3).

Comparative predictive performance

The receiver operating characteristic analysis demonstrated an area under the curve (AUC) of 0.82 (95% CI: 0.724–0.916) for dominant follicular diameter and 0.89 (95% CI: 0.819–0.961) for perfollicular PSV. The combined model of dominant follicular diameter and PSV had the highest AUC (0.93, 95% CI 0.876–0.984) (Table 4, Figure 3). All three models showed significantly better than chance discriminatory performance ($p<0.001$).

CORRELATION BETWEEN DOMINANT FOLLICLE PEAK SYSTOLIC VELOCITY AND ULTRASONOGRAPHIC MARKERS OF OVULATION: A PROSPECTIVE OBSERVATIONAL STUDY

The AUC of the observed model was increased by 0.07 for PSV and 0.11 for the combined follicular diameter-plus-PSV model compared with follicular diameter alone. Figure 2 shows the relationship between follicular diameter and perfollicular PSV by ovulation status, where the ovulatory cycles are largely distributed to the right of the figure, with higher PSV values and larger diameters of follicular size.

Multivariable analysis

Perifollicular PSV was independently associated with ovulation in multivariable logistic regression analysis after adjustment for dominant follicular diameter. The adjusted odds of ovulation increased by 72% for every 1 cm/s increase in PSV (adjusted OR=1.72; 95% CI: 1.27-2.35; B=0.542; SE=0.157; Wald χ^2 =11.934; p <0.001) (Table 5).

To summarize, higher perifollicular PSV was significantly associated with ovulation and had a better discriminatory performance than the dominant follicular diameter alone. The combined assessment of dominant follicle diameter and perifollicular PSV demonstrated the highest predictive performance.

DISCUSSION

The present study demonstrated a strong association between perifollicular hemodynamics and ovulation. Ovulatory cycles had significantly higher perifollicular PSV than non-ovulatory cycles (12.7 ± 2.6 vs 8.4 ± 2.1 cm/s; p <0.001) and larger dominant follicular diameter and lower RI and PI. These findings support the notion that follicular maturation is not only a process of morphological growth but also a process of progressive vascular remodeling. In a recent review, Choi et al. pointed out that increases in ovarian and perifollicular blood flow and decrease in vascular resistance are linked to follicular maturation and may have clinical use beyond grayscale ultrasonography.⁷

The present study's RI and PI difference is also biologically consistent with previous Doppler evidence. In a meta-analysis of 27 studies Wang et al. demonstrated significant differences in ovarian Doppler indices and lower vascular resistance indices in conditions associated with altered ovarian vascularity [20].⁸The meta-analysis focused mainly on ovarian dysfunction rather than imminent ovulation but does support the physiological relevance of Doppler-derived vascular resistance. Similarly Jadaon et al. also observed a positive relationship between PSV with the number of follicles ≥ 14 mm while RI was inversely related with follicular response and oocyte retrieval.⁹ This is

similar to the present finding of higher PSV and lower resistance indices in cycles that proceed to ovulation.

Clinically relevant was the performance of the PSV cutoff of >10.5 cm/s. At this cut-off, sensitivity was 83.9 %, specificity 77.8 %, PPV 92.9 % and overall accuracy 82.5 %. The cutoff is very close to values reported in previous reproductive Doppler studies. Panchal and Nagori observed good reproductive outcome when perifollicular PSV was >11 cm/s and RI <0.50 on pre-hCG follicular assessment. Similarly, Nargund et al. observed that follicles related to embryo development possessed a significantly higher PSV (19.7 ± 10.8 cm/s) than those which did not produce embryos (9.9 ± 5.3 cm/s; p <0.0001) and a PSV ≥ 10 cm/s was associated with 70% probability of producing a high grade embryo versus 14% when PSV was <10 cm/s.¹¹ Although these studies looked at conception or embryo competence and not sonographically documented ovulation, the velocity thresholds were close enough to support the biological plausibility of the >10.5cm/s cutoff found in this study.

Perifollicular PSV also showed better numerical discrimination than follicular diameter alone, with AUCs of 0.89 and 0.82, respectively. More importantly, the addition of follicular diameter and PSV improved the observed AUC to 0.93. This finding suggests that structural and hemodynamic evaluation can offer complementary information, as follicular diameter reflects the morphological maturation and PSV reflects the vascular changes associated with functional maturation. The multivariable analysis further supported this interpretation as PSV was independently associated with ovulation, after adjustment for follicular diameter (adjusted OR=1.72, per 1 cm/s increase; 95% CI: 1.27–2.35; p <0.001). However, the differences between AUCs observed should be considered numerical improvements unless a formal pairwise comparison of correlated ROC curves has been performed. The high PPV (92.9%) indicates that a PSV >10.5 cm/s may be particularly useful in identifying follicles likely to ovulate. By contrast, the lower NPV of 58.3% implies that a PSV below this threshold should not be used alone to rule out subsequent ovulation. This difference is partially explained by the high prevalence of ovulation of 77.5% in the study population. Therefore, PSV should be considered as an adjunct to, rather than a replacement for, conventional follicular monitoring.

The study is limited by being a single center study, a relatively small sample size and the operator and equipment dependence of Doppler measurements. The persistent association of increased PSV with ovulation, its independent effect when corrected for

CORRELATION BETWEEN DOMINANT FOLLICLE PEAK SYSTOLIC VELOCITY AND ULTRASONOGRAPHIC MARKERS OF OVULATION: A PROSPECTIVE OBSERVATIONAL STUDY

follicular diameter and the better discrimination of the combined model, however, warrant the inclusion of perifollicular Doppler assessment in serial follicular monitoring . Larger multi-centre studies are needed with standardized protocols for Doppler acquisition to validate the cut-off found and test its generalizability.

CONCLUSION

Perifollicular peak systolic velocity was significantly associated with ovulation and performed better than dominant follicular diameter alone in differentiating ovulation. A PSV cutoff >10.5cm/sec showed good sensitivity, specificity and overall diagnostic accuracy, while the combined assessment of follicular diameter and PSV had the best predictive performance. Perifollicular PSV was also independently associated with ovulation after adjustment for follicle diameter. The results suggest that Doppler measurement of perifollicular blood flow can provide functional information in addition to the conventional measurement of follicular size that is clinically useful. Thus, routine serial monitoring of follicles by PSV can lead to better prediction of imminent ovulation and more precise timing of infertility-related interventions.

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TABLES & FIGURES

Table 1. Comparison of ultrasonographic and Doppler parameters according to ovulation status

Parameter	Ovulatory cycles	Non-ovulatory cycle	Mean difference	t-value	p-value

**CORRELATION BETWEEN DOMINANT FOLLICLE PEAK SYSTOLIC VELOCITY AND
ULTRASONOGRAPHIC MARKERS OF OVULATION: A PROSPECTIVE OBSERVATIONAL STUDY**

	(n=62))	s (n=18))	(95% CI)		
Age (years)	29.2 ± 4.0	30.1 ± 4.5	−0.90 (−3.09 to 1.29)	−0.817	0.416
Dominant follicular diameter (mm)	19.8 ± 1.8	17.6 ± 2.1	2.20 (1.20 to 3.20)	4.395	<0.001
Perifollicular PSV (cm/s)	12.7 ± 2.6	8.4 ± 2.1	4.30 (2.97 to 5.63)	6.425	<0.001
Resistive index	0.46 ± 0.07	0.55 ± 0.08	−0.09 (−0.129 to −0.051)	−4.650	<0.001
Pulsatility index	0.78 ± 0.16	0.96 ± 0.19	−0.18 (−0.269 to −0.091)	−4.026	<0.001
Endometrial thickness (mm)	9.4 ± 1.7	8.6 ± 1.8	0.80 (−0.12 to 1.72)	1.735	0.087

Table 2. Association between perifollicular PSV cutoff and documented ovulation

Perifollicular PSV	Ovulatory cycles	Non-ovulatory	Total (n=80)	χ^2 value	Odds ratio (95	p-value
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	(n=62))	cycles (n=18))			% CI)	
>10.5 cm/s	52 (83.9%)	4 (22.2%)	56 (70.0%)	25.7	18.20–66.85	<0.001
≤10.5 cm/s	10 (16.1%)	14 (77.8%)	24 (30.0%)		Reference	

Table 3. Diagnostic performance of perifollicular PSV >10.5 cm/s for prediction of ovulation

Diagnostic measure	Estimate	95% CI
Sensitivity	83.9%	72.8–91.0%
Specificity	77.8%	54.8–91.0%
Positive predictive value	92.9%	83.0–97.2%
Negative predictive value	58.3%	38.8–75.5%
Overall accuracy	82.5%	72.7–89.3%
Positive likelihood ratio (LR+)	3.77	1.58–9.02
Negative likelihood ratio (LR−)	0.21	0.11–0.39
Diagnostic odds ratio	18.20	4.95–66.85

Table 4. Comparative discriminatory performance of follicular diameter, perifollicular PSV, and the combined model

**CORRELATION BETWEEN DOMINANT FOLLICLE PEAK SYSTOLIC VELOCITY AND
ULTRASONOGRAPHIC MARKERS OF OVULATION: A PROSPECTIVE OBSERVATIONAL STUDY**

Predictive model	AUC	95% CI*	Increase in AUC vs follicular diameter	z-value	p-value
Dominant follicular diameter	0.82	0.72–0.91	-	6.565	<0.001
Perifollicular PSV	0.89	0.81–0.96	+0.07	10.733	<0.001
Follicular diameter + PSV	0.93	0.87–0.98	+0.11	15.506	<0.001

Table 5. Independent association of perifollicular PSV with ovulation after adjustment for dominant follicular diameter

Predictor	Regression coefficient (B)	Standard error	Wald χ^2	Adjusted odds ratio	95% CI	p-value
Perifollicular PSV, per 1 cm/s increase	0.542	0.157	11.934	1.72	1.27–2.35	<0.001

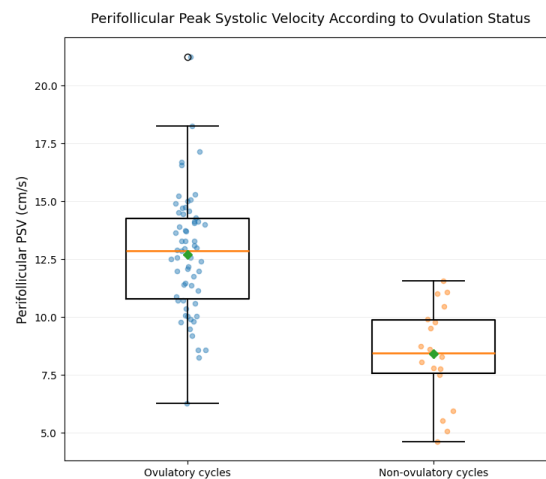


Figure 1 Distribution of perifollicular peak systolic velocity (PSV) according to ovulation status.

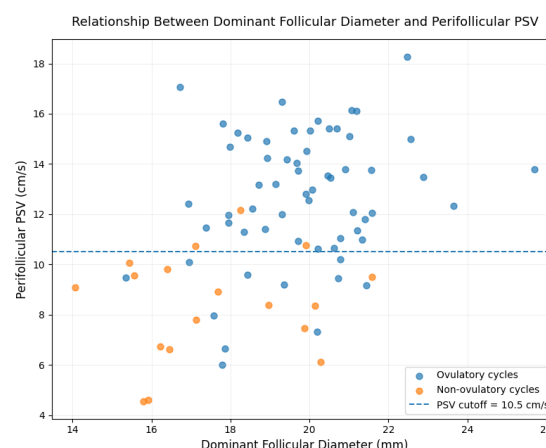


Figure 2 Relationship between dominant follicular diameter and perifollicular peak systolic velocity (PSV) according to ovulation status.

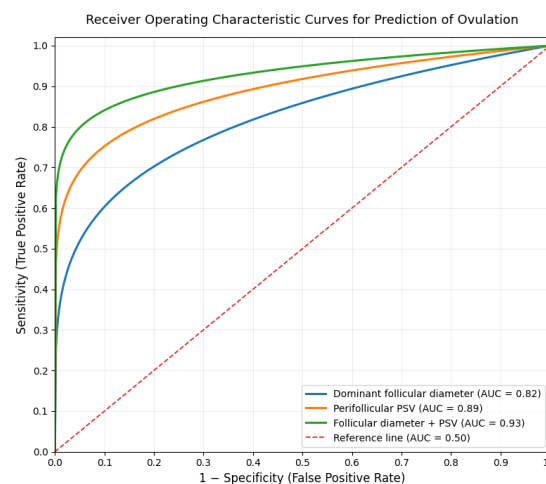


Figure 3 Receiver operating characteristic curves comparing dominant follicular diameter, perifollicular peak systolic velocity (PSV), and the

CORRELATION BETWEEN DOMINANT FOLLICLE PEAK SYSTOLIC VELOCITY AND
ULTRASONOGRAPHIC MARKERS OF OVULATION: A PROSPECTIVE OBSERVATIONAL STUDY

*combined follicular diameter + PSV model for
prediction of ovulation.*