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technologies for good*

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Global Summit



Clinically-Grounded and Human-Centric Machine Learning System for Personalized Fertility Diagnostics and Early Intervention Using Modular Clinical, Imaging, and Behavioral Biomarkers

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7th July 2026





Stuti Iyer

Student @ Vellore Institute of Technology

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Session #3.1

THE PROBLEM

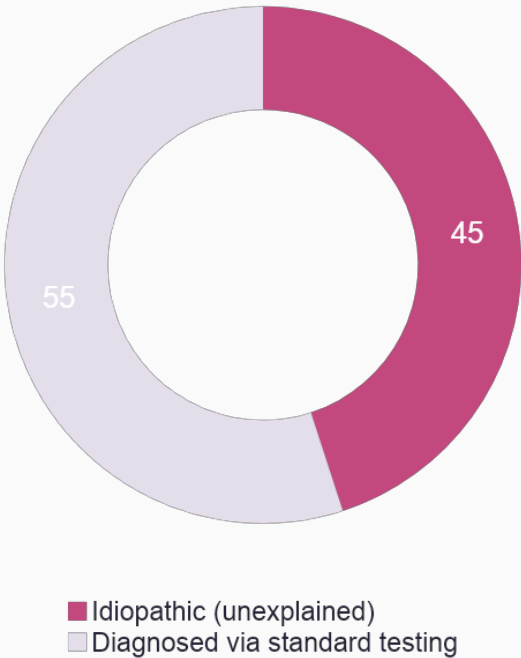
The Global Infertility Crisis

1 in 6

individuals globally are affected by infertility (WHO, 2023)

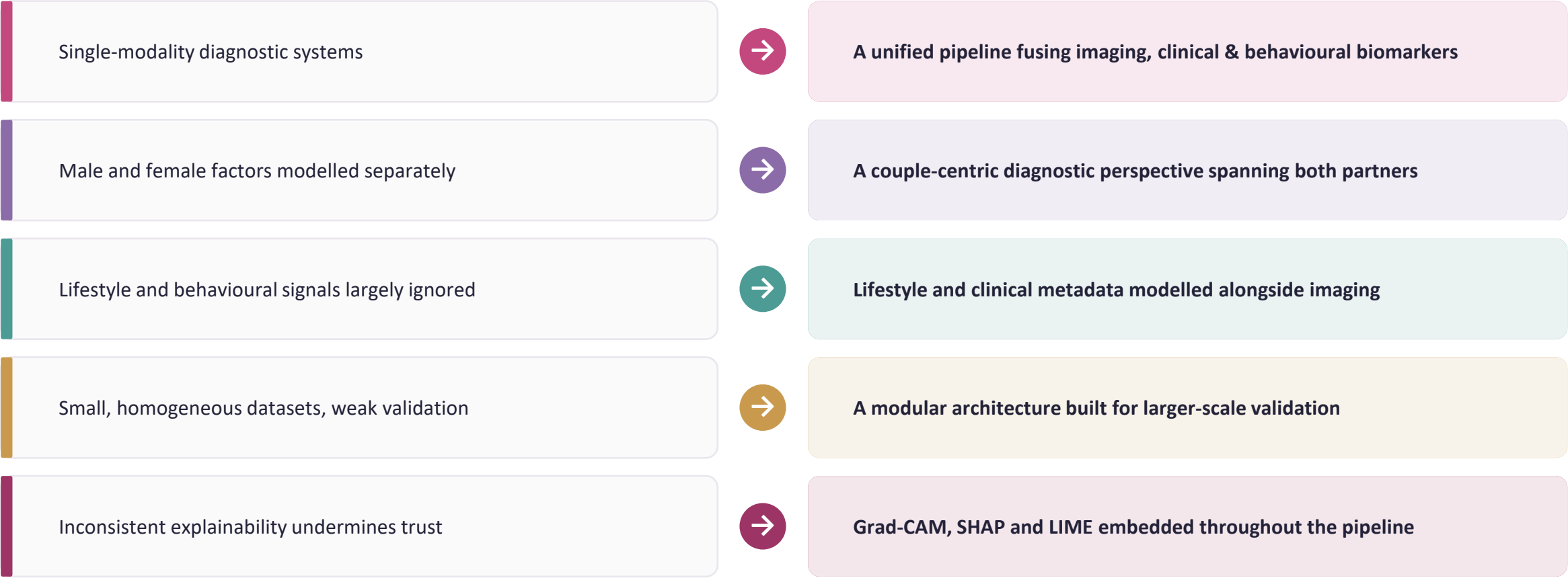
- **Massive Diagnostic Burden**
Infertility is a global health priority; diagnostics remain largely fragmented.
- **The Gap**
40–50% of cases remain idiopathic despite standard semen, hormonal and imaging tests.
- **Isolation**
Current workflows evaluate male and female fertility independently, rarely as a couple.

Idiopathic Infertility Share



Despite semen analysis (used in ~99% of male evaluations), hormonal profiling (~60–65%) and ultrasound (~50–55%), nearly half of all cases remain unexplained — pointing to a need for richer, multimodal evidence.

Why Existing Fertility AI Falls Short



Research Objective: a clinically grounded, explainable multimodal ML framework unifying reproductive imaging, hormonal biomarkers, behavioural indicators and clinical metadata.

DATASETS

Multimodal Datasets & Sources

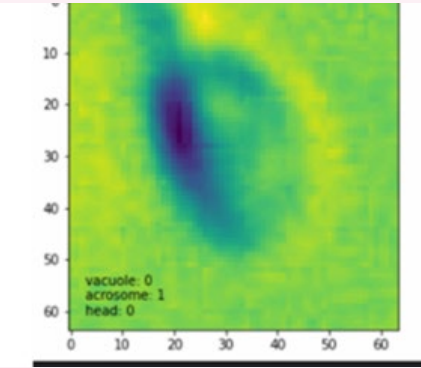
four publicly available, anonymised datasets spanning imaging, clinical and tracking modalities

MALE MORPHOLOGY

MHSMA

n = 235 patients

- Expert-labelled microscopic sperm images
- Annotations: acrosome, head, vacuole, tail defects
- Modality: sperm microscopy imaging

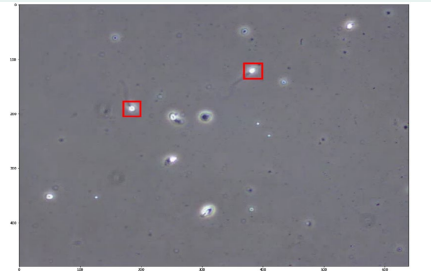


MALE MOTILITY

WISEM

n = 85 participants

- Sperm-tracking videos with bounding-box CSVs (CASA-style)
- Clinical biomarkers: conc., vitality, morphology, DFI, TZI
- Hormonal panel: AMH, FSH, LH, SHBG, estradiol, testosterone



MALE CLINICAL

UCI Fertility

n = 100 observations

- 10 demographic and lifestyle variables (WHO 2010)
- Semen quality labels: normal / altered (binary)
- Variables: age, smoking, alcohol, sitting hrs, fevers, surgery, accidents

	A	B	C	D	E	F	G	H	I	J
1	Season	Age	Childish diseases	Accident or serious trauma	Surgical intervention	High fevers in the last year	Frequency of alcohol consumption	Smoking habit	Number of hours spent sitting per day	Diagnosis
2	spring	30	no	yes	yes	more than 3 months ago	once a week	occasional		16 Normal
3	spring	35	yes	no	yes	more than 3 months ago	once a week	daily		6 Altered
4	spring	27	yes	no	no	more than 3 months ago	hardly ever or never	never		9 Normal
5	spring	32	no	yes	yes	more than 3 months ago	hardly ever or never	never		7 Normal
6	spring	30	yes	yes	no	more than 3 months ago	once a week	never		9 Altered
7	spring	30	yes	no	yes	more than 3 months ago	once a week	occasional		9 Normal
8	spring	30	no	no	no	less than 3 months ago	once a week	never		8 Normal
9	spring	36	yes	yes	yes	more than 3 months ago	several times a week	never		7 Normal
10	fall	30	no	no	yes	more than 3 months ago	once a week	never		5 Normal
11	fall	29	yes	no	no	more than 3 months ago	hardly ever or never	never		5 Normal
12	fall	30	yes	yes	no	less than 3 months ago	once a week	occasional		6 Normal

FEMALE IMAGING

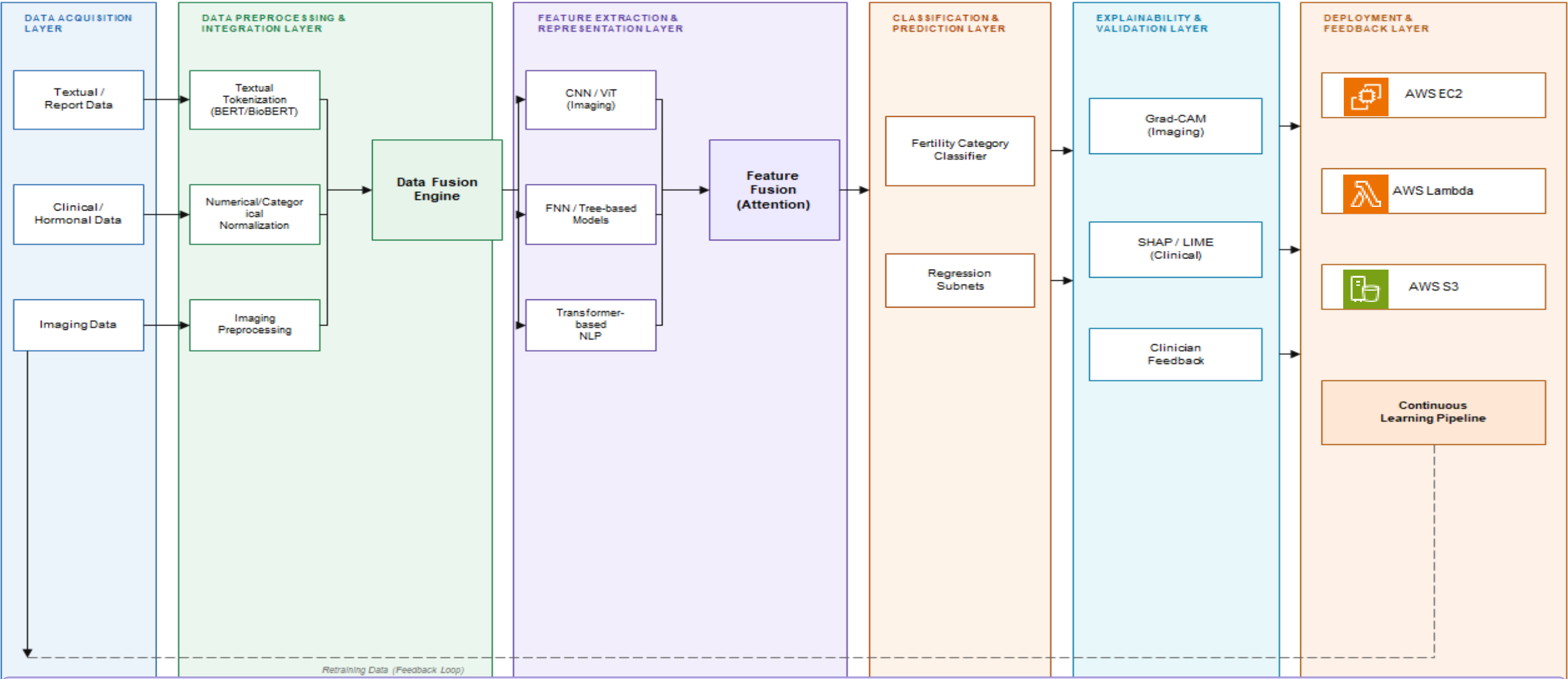
PCOS Ultrasound

~3,800 labelled images

- Ovarian ultrasound: PCOS vs. healthy labels, augmented
- Test set: n = 1,922 (781 PCOS, 1,141 healthy)
- Used as research benchmark (limited provenance metadata)



System Architecture



MODALITY-SPECIFIC MODELING

Modality-Specific Modeling & Fusion



Hormonal Signals

Temporal Fusion Transformer (TFT)

- Captures short- & long-term endocrine patterns
- Handles irregular sampling intervals
- Built-in interpretability for clinical time series



Lifestyle & Text

GPT-4 Embeddings + Fine-tuned BERT

- Free text embedded via transformer models
- Categorical vars one-hot encoded
- Continuous vars normalized



Genetic Markers

Graph Neural Network + DeepSEA

- GNN models gene–gene interaction structure
- DeepSEA captures sequence-level regulation
- Critical for heritable fertility risk



Imaging (US & Microscopy)

Hybrid ViT–CNN Architecture

- CNN layers extract fine-grained textural cues
- ViT learns global spatial dependencies
- Attention-based interpretability

Multimodal Integration



Multimodal Transformer

Unified latent space across all 4 modalities



Patient Autoencoders

Dynamic embeddings for longitudinal tracking



Patient Graph GNN

Relational patterns across lifestyle, hormones, genetics



Contrastive Learning

Self-supervised embeddings via similar/dissimilar profiles

RESULTS

Model – by - Model Performance

strong predictive accuracy achieved across every reproductive health task

99.7%

PCOS
Detection

Custom CNN / Ovarian Ultrasound

89.6%

Morphology
Accuracy

Hybrid ViT-CNN / MHSMA

0.141

Motility
RMSLE

XGBoost Regressor / VISEM

R²=0.41

Concentration
Modelling

XGBoost / UCI Fertility

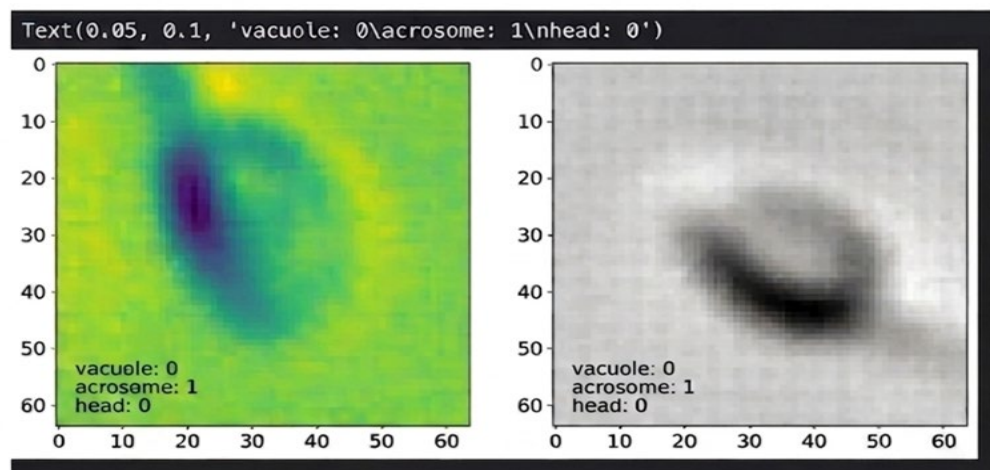
Task	Model / Modality	Metric	Our Result	Prior SOTA
PCOS Detection	Custom CNN / Ovarian Ultrasound	Accuracy	99.7%	98.96% (Zhao et al., 2025)
Morphology Classification	Hybrid ViT-CNN / MHSMA	Accuracy	89.6%	Manual feature eng. (Dai et al., 2025)
— Normal sperm	precision / recall / F1	—	0.98 / 0.92 / 0.95	—
— Abnormal sperm	precision / recall / F1	—	0.39 / 0.75 / 0.51	—
Motility Prediction	XGBoost Regressor / VISEM	RMSLE	0.141	RMSLE 0.337 (manual feat.)
Concentration Modelling	XGBoost / UCI Fertility	R ²	0.41	R ² ~0.30 (lifestyle only)

Acronyms: RMSLE = Root Mean Squared Logarithmic Error • R² = Coefficient of Determination • SHAP = SHapley Additive exPlanations • Grad-CAM = Gradient-weighted Class Activation Mapping • AUC-ROC = Area Under the Receiver Operating Characteristic Curve • F1 = F1-Score (harmonic mean of precision & recall) • PCOS = Polycystic Ovary Syndrome

Explainable AI

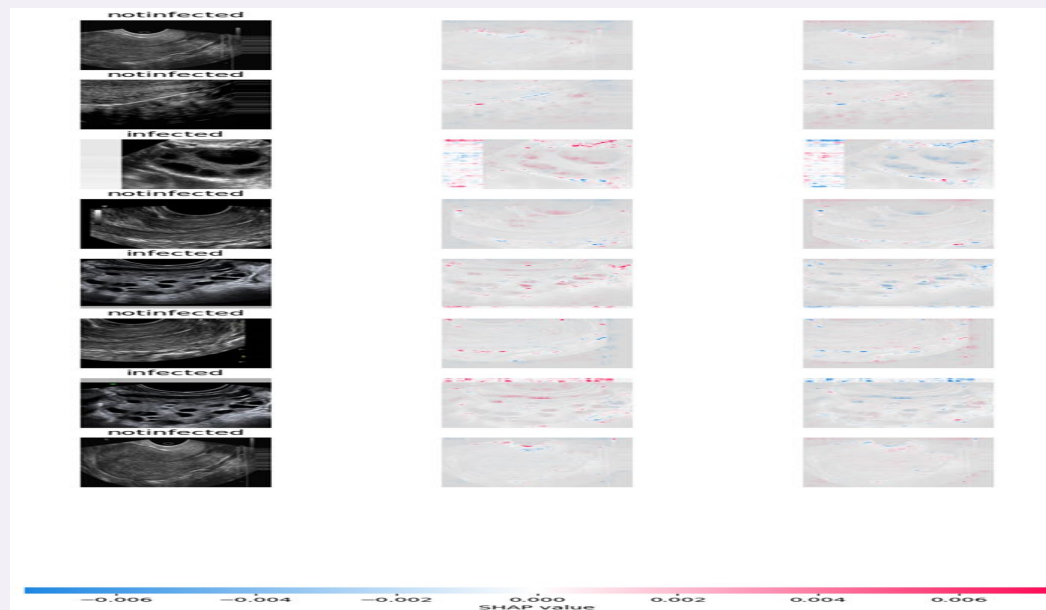
Grad-CAM and SHAP confirm that predictions track biologically meaningful structures

Grad-CAM — Sperm Morphology



Heatmaps localise attention on the acrosome, vacuole and head regions — the same structures WHO semen-analysis protocols treat as clinically critical, confirming the model attends to real morphology rather than arbitrary pixels.

SHAP — PCOS Ultrasound



Attributions consistently highlight follicle clusters, cystic density and stromal echogenicity — the textbook sonographic markers of PCOS — improving transparency and supporting clinician trust in the model's recommendations.

CONCLUSION

AI for Good — A Blueprint for Human-Centred Fertility Diagnostics

clinically grounded · equitably accessible · explainable by design · privacy-preserving

SDG 3

Serving Humanity

1 in 6 people worldwide are affected by infertility. This framework reduces diagnostic delays, lowers the burden of subjective testing, and supports timely, personalised intervention — advancing Good Health and Well-Being for all.

SDG 10

Bridging Diagnostic Inequity

Scalable AI-assisted diagnostics extend clinically grounded reproductive assessment to resource-constrained and underserved settings globally — reducing inequalities in access to fertility care across regions and income levels.

SDG 5

Human-Centred by Design

Designed to augment, not replace, clinical expertise. Grad-CAM, SHAP and LIME provide transparent, interpretable outputs. Privacy-preserving architecture ensures responsible AI deployment aligned with UN values and ethical principles.

SDG 3 — Good Health & Well-Being	SDG 5 — Gender Equality	SDG 9 — Industry, Innovation & Infrastructure	SDG 10 — Reduced Inequalities
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Responsible AI in reproductive health is not just a technical ambition — it is a humanitarian imperative. This blueprint sets the stage for personalised, data-driven, and equitably deployable fertility intelligence.

◆ **Multimodal Framework**

Imaging + clinical + hormonal unified in one pipeline

◆ **Measured Performance**

PCOS 99.7% · Morphology 89.6% · RMSLE 0.141

◆ **Explainable AI**

Grad-CAM · SHAP · LIME embedded throughout

◆ **Ethical & Private**

Anonymised data · no PII · responsible AI principles

Thank you

