# Clinically Oriented Lesion Biomarkers for Vision-Threatening Diabetic Retinopathy Detection

## A Comparison with End-to-End Deep Learning

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## INTRODUCTION

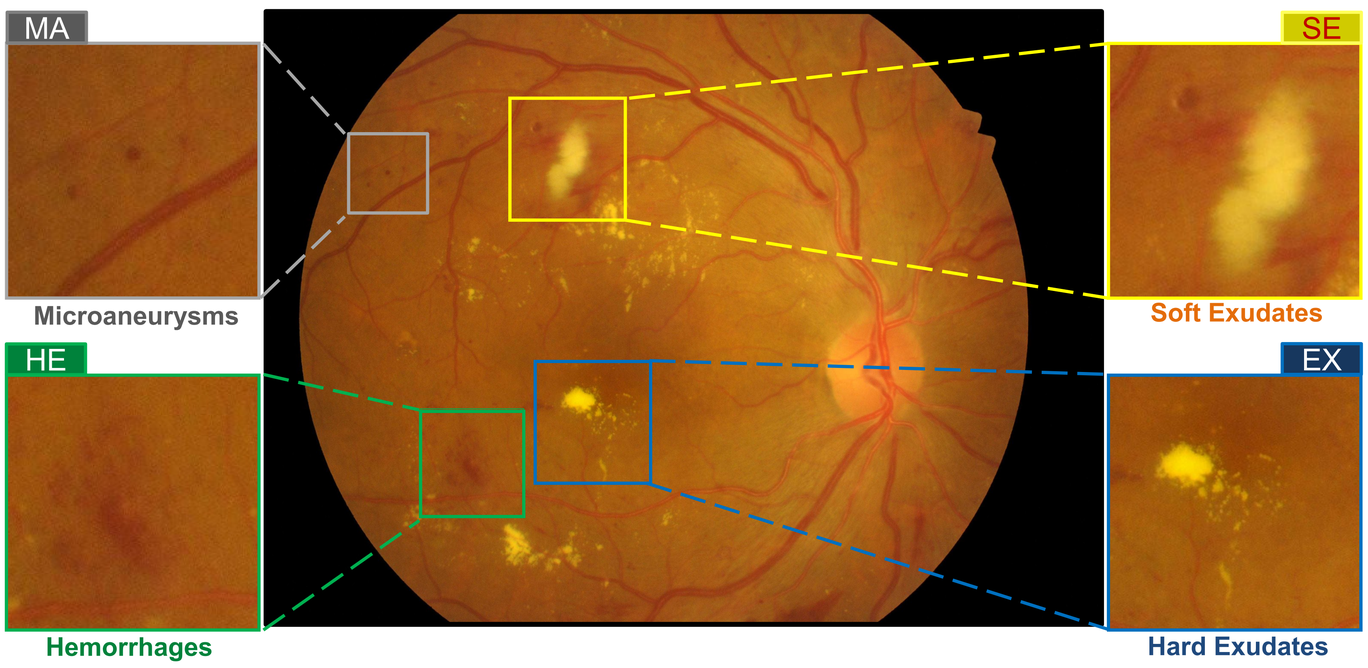
**Clinical motivation and research gap:**

- Diabetic retinopathy (DR) can progress to vision-threatening diabetic retinopathy (VTDR), making reliable detection essential.
- End-to-end deep learning can classify DR severity from retinal fundus images but offers limited insight into the pathological features underlying its predictions.
- Clinically oriented lesion biomarkers quantify lesion morphology and spatial distribution, offering a more interpretable basis for classification.

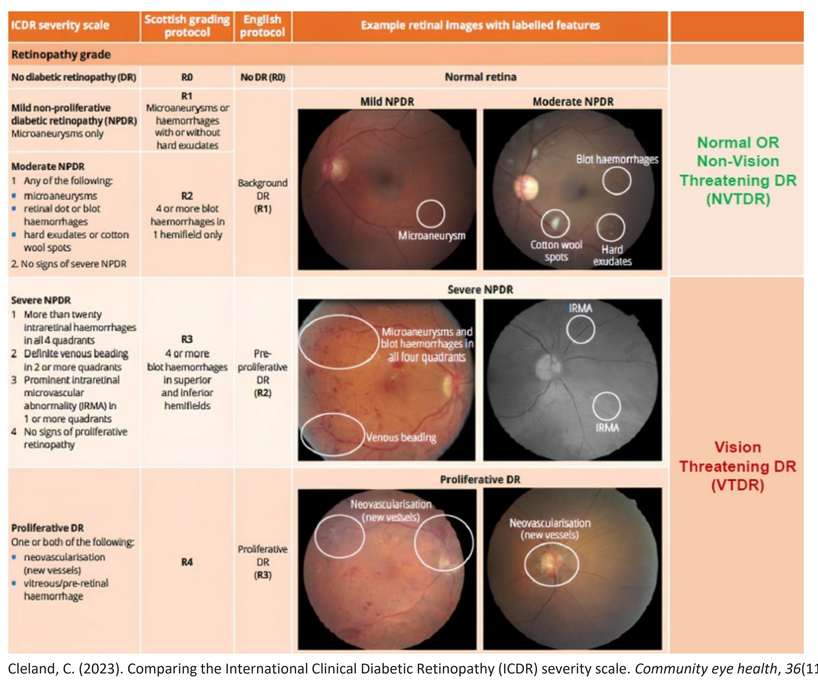
**Objective:**

To compare end-to-end deep learning with machine learning based on clinically oriented lesion biomarkers for VTDR detection

## RETINAL LESIONS



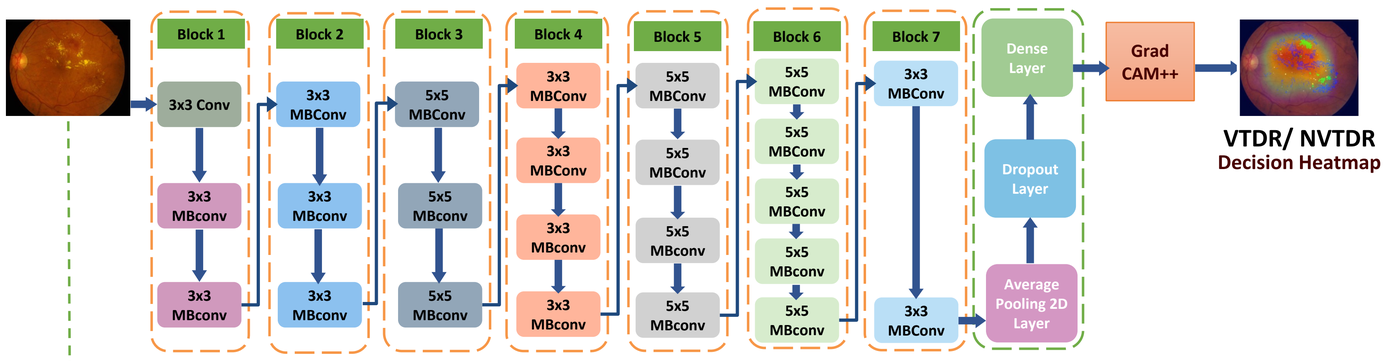

## VTDR CLASSIFICATION



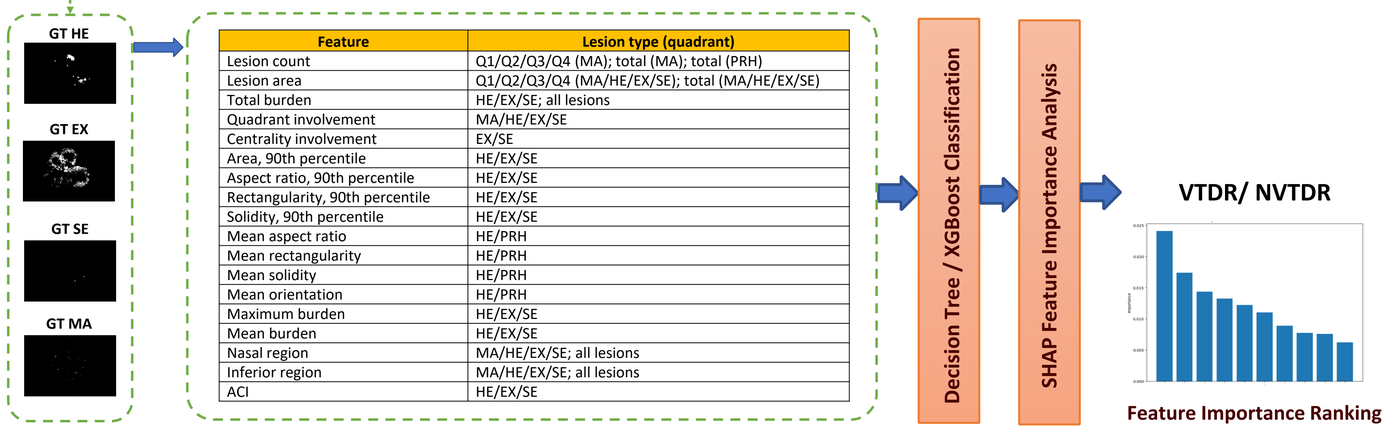

Cleland, C. (2023). Comparing the International Clinical Diabetic Retinopathy (ICDR) severity scale. *Community eye health*, *36*(119), 10

## METHODOLOGY

### Deep Learning – EfficientNet B2 + GradCAM++




### Machine Learning – Lesion Biomarkers + Decision Tree/ XGBoost + SHAP Analysis

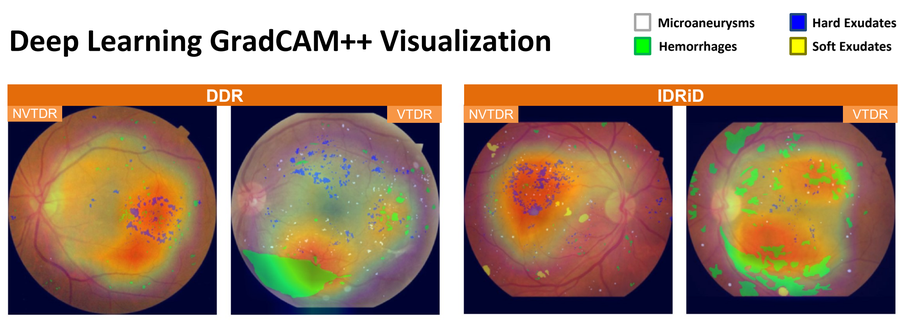



| Feature | Lesion type (quadrant) |
|---|---|
| Lesion count | Q1/Q2/Q3/Q4 (MA); total (MA); total (PRH) |
| Lesion area | Q1/Q2/Q3/Q4 (MA/HE/EX/SE); total (MA/HE/EX/SE) |
| Total burden | HE/EX/SE; all lesions |
| Quadrant involvement | MA/HE/EX/SE |
| Centrality involvement | EX/SE |
| Area, 90th percentile | HE/EX/SE |
| Aspect ratio, 90th percentile | HE/EX/SE |
| Rectangularity, 90th percentile | HE/EX/SE |
| Solidity, 90th percentile | HE/EX/SE |
| Mean aspect ratio | HE/PRH |
| Mean rectangularity | HE/PRH |
| Mean solidity | HE/PRH |
| Mean orientation | HE/PRH |
| Maximum burden | HE/EX/SE |
| Mean burden | HE/EX/SE |
| Nasal region | MA/HE/EX/SE; all lesions |
| Inferior region | MA/HE/EX/SE; all lesions |
| ACI | HE/EX/SE |

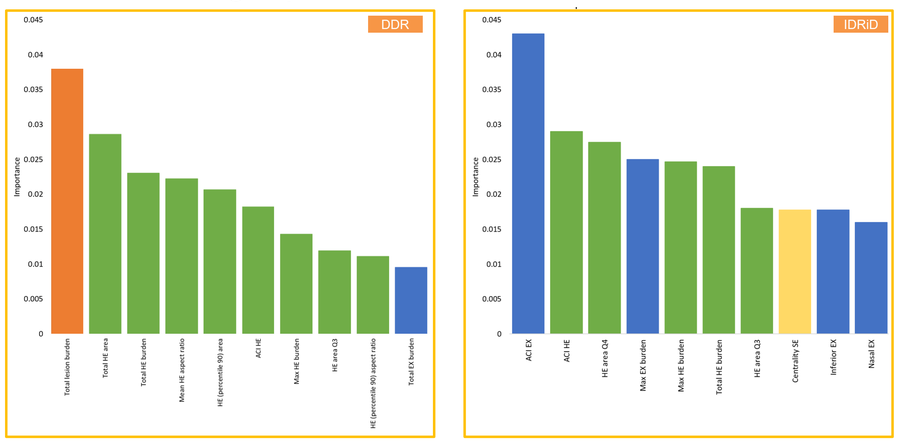
*MA = microaneurysms; HE = hemorrhages; EX = hard exudates; SE = soft exudates; PRH = preretinal hemorrhages; Q1–Q4 = retinal quadrants 1–4; All lesions = MA+HE+EX+SE; ACI = Area Concentration Index.*

## INTERPRETABILITY

### Deep Learning GradCAM++ Visualization




### Machine Learning Top-10 SHAP Lesion Biomarkers




- GradCAM++ heatmaps often miss relevant VTDR features and are less consistent across datasets.
- SHAP analysis consistently ranks hemorrhage-derived biomarkers among the most important in both datasets.

## DETECTION PERFORMANCE

| Dataset | Model | Number of Features | Performance | | |
|---|---|---|---|---|---|
| | | | Accuracy | F1 Score | QWK |
| DDR† | EfficientNet-B2 | 1408 | 84.09% | 79.90% | 72.98% |
| IDRiD* | EfficientNet-B2 | 1408 | 85.44% | 82.85% | 75.71% |
| DDR† | XGBoost | 75 | 90.01% | 91.35% | 83.77% |
| IDRiD* | Decision Tree | 10 | 92.09% | 92.24% | 84.07% |

† Li, T., Gao, Y., Wang, K., Guo, S., Liu, H., & Kang, H. (2019). Diagnostic assessment of deep learning algorithms for diabetic retinopathy screening. Information Sciences, 501, 511–522.

*Porwal, P., Pachade, S., Kamble, R., Kokare, M., Deshmukh, G., Sahasrabuddhe, V., & Mériaudeau, F. (2018). Indian Diabetic Retinopathy Image Dataset (IDRiD): A database for diabetic retinopathy screening research. Data, 3(3), 25.

## CONCLUSIONS

- **Superior classification performance:** Lesion-derived features achieved higher VTDR detection accuracy than EfficientNet-B2 on DDR and IDRiD datasets.
- **Improved interpretability:** Explicit morphological and spatial features reveal lesion characteristics associated with VTDR classification.
- **Clinical potential:** Lesion-based biomarkers offer a promising foundation for more transparent, clinically interpretable DR decision-support systems.