

SicklePrenatal: Biometric-Guided Deep Learning For Early Sickle Cell Risk Detection From Fetal Ultrasound

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Abstract:

Sickle Cell Disease (SCD) is one of the most prevalent inherited disorders in Sub-Saharan Africa, yet limited prenatal screening leads to high infant mortality. We present SicklePrenatal, an attention-based deep learning framework for early, non-invasive SCD risk prediction from fetal ultrasound in low-resource settings.

Our approach integrates two complementary streams: (1) a structure-preserving encoder enhanced with Sobel-Laplacian filters for vascular edge detection, and (2) a biometric encoder informed by gestational age and key fetal measurements (head circumference, femur length, abdominal diameter). A cross-attention module fuses both branches, capturing clinically relevant patterns under weak supervision.

To address the lack of labeled datasets, we design a proxy-based annotation pipeline grounded in clinical heuristics and literature-backed thresholds [1]. We further pretrain with a contrastive self-supervised objective [2] on grayscale ultrasound frames, and fine-tune on a dataset of 3,382 scans from a regional health clinic.

SicklePrenatal achieves 76.2% accuracy, surpassing baseline CNNs (63.7%) and ResNet classifiers (69.1%), while preserving interpretability through saliency maps localized around high-risk vascular zones. The model is optimized for edge deployment, enabling inference on low-compute devices. The table below summarizes the performance of all evaluated models.

Model	Accuracy	Macro F1	Silhouette Score
Metadata Only	61.4%	59.2%	0.41
Image Only	64.8%	61.5%	0.46
Multimodal (Ours)	76.2%	73.9%	0.59
Multimodal + SCL	76.2%	73.9%	0.65 (+12.3%)

Our work contributes a scalable, low-cost framework for prenatal SCD screening, with potential to generalize to other hemoglobinopathies and fetal-risk disorders, advancing maternal-fetal healthcare in underserved populations.

References

- [1] Nature Medicine. Genetic screening for sickle cell disease in Sub-Saharan Africa. *Nature Medicine*, 28:1773–1784, 2022. doi:10.1038/s41591-022-01968-4.
- [2] F. C. Ghesu, B. Georgescu, A. Mansoor, Y. Yoo, D. Neumann, P. K. Patel, R. S. Vishwanath, J. M. Balter, Y. Cao, S. Grbic, and D. Comaniciu. Contrastive self-supervised learning from 100 million medical images with optional supervision. *Journal of Medical Imaging*, 9(6):064503, 2022. doi:10.1117/1.JMI.9.6.064503.