Artificial Intelligence Applications in Ophthalmology

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INTRODUCTION

- Ophthalmology AND integration of artificial intelligence (AI): **Various imaging modalities:** Anterior segment photography, Fundus photography, OCT, High-resolution digital images.
- Provide rich datasets for training AI algorithms
- Enables precise diagnosis and monitoring of various ocular conditions.
- Retinal disease management heavily relies on image recognition.
- Cost-effective solution for screening and diagnosis.

INTRODUCTION

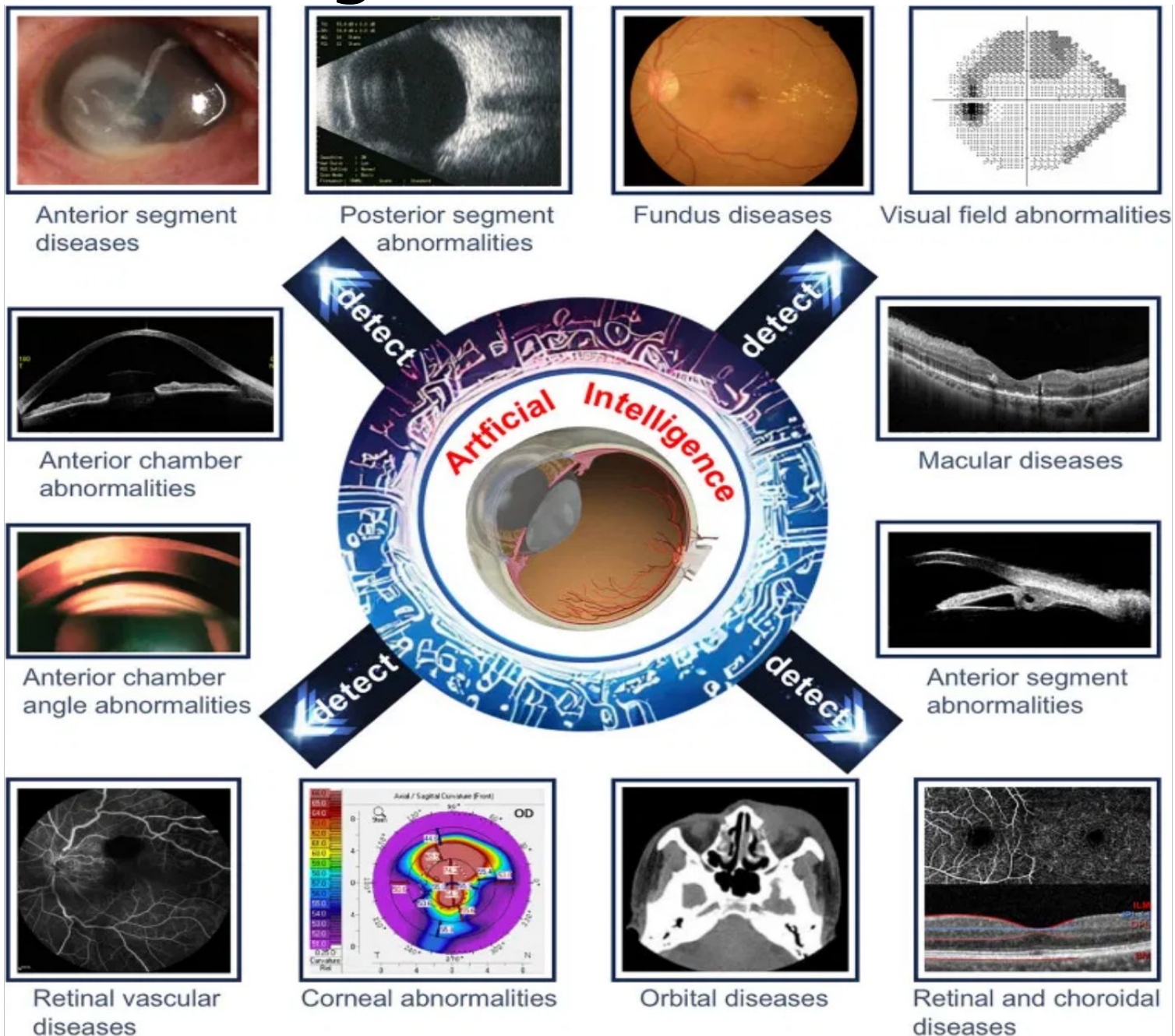
FDA AI ENABLED MEDICAL DEVICES APPROVAL

https://www.fda.gov/medical-devices/software-medical-device-samd/artificial-intelligence-enabled-medical-devices

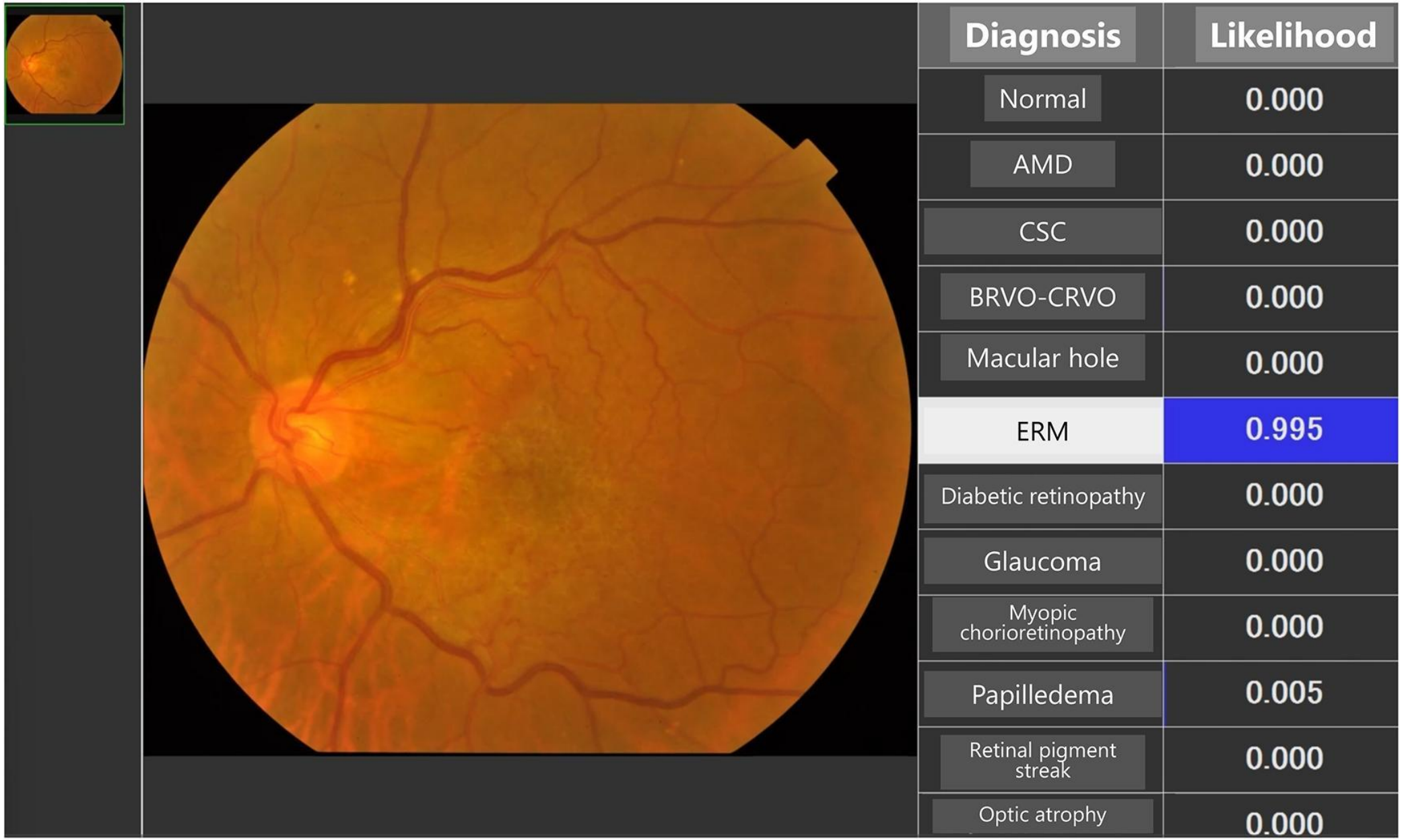
AI for Diagnosis of Retinal Diseases

- **High Precision Diagnosis**: Accurately distinguishes retinal diseases, aiding optimal treatment.
- **Improved Access**: Cost-effective screening in underserved and high-volume settings.
- **Automated Analysis**: Detects subtle, invisible changes in retinal images.
- **Multiple Disease Detection**: Screens for various conditions from a single image.

AI for Diagnosis of Retinal Diseases



AI for Diagnosis of Retinal Diseases

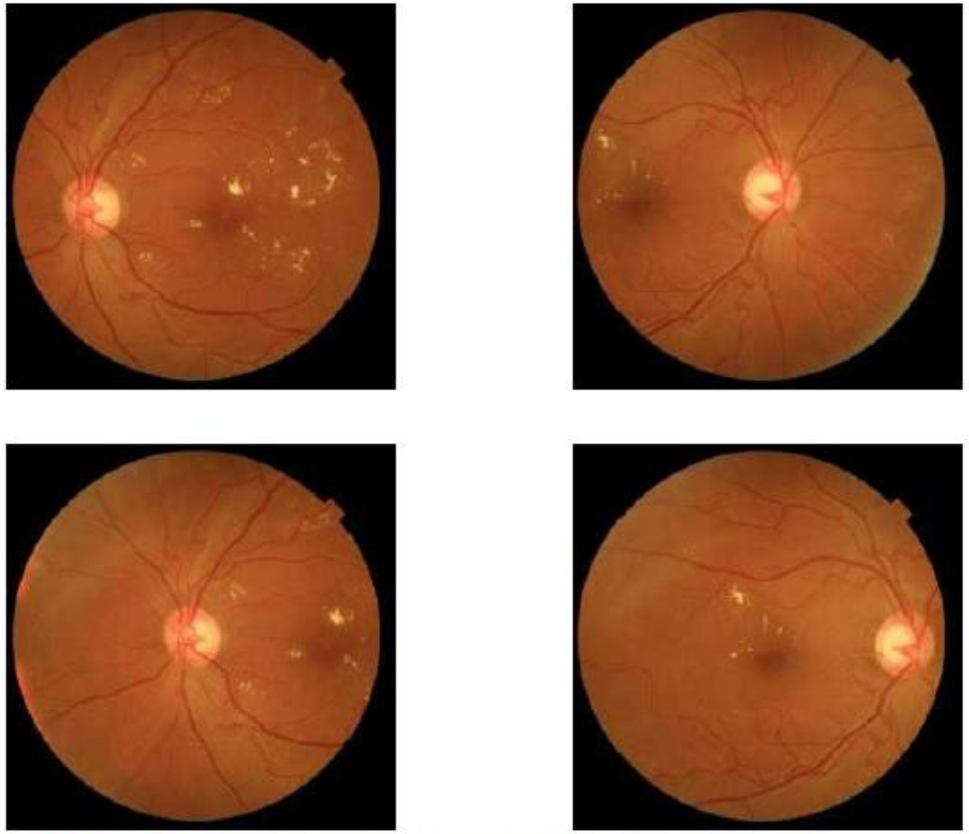


Diagnosis	Likelihood
Normal	0.000
AMD	0.000
CSC	0.000
BRVO-CRVO	0.000
Macular hole	0.000
ERM	0.995
Diabetic retinopathy	0.000
Glaucoma	0.000
Myopic chorioretinopathy	0.000
Papilledema	0.005
Retinal pigment streak	0.000
Optic atrophy	0.000

IDx-DR

IDx-DR Analysis Report

Patient ID:	VTDR
IDx Submission ID:	22-30
Exam Analysis Date:	2017-04-06
Exam Analysis Time:	11:09:15 PM
Exam Result:	Vision-threatening diabetic retinopathy detected



RNING: The above images are reduced resolution, compressed versions of the original images used by IDx-DR Client
Do NOT use these images for diagnostic purposes.

DR-EU_2.0.2

Approved by FDA in 2018

https://www.healthvisors.com/en/idx-dr/

IDx-DR

Test	Indication	Population, age range, and frequency	Cost*
IDx-DR	Screening for diabetic retinopathy	Adults 22 years and older with diabetes mellitus who have no history of diabetic retinopathy† Annual unless retinopathy detected	Patient: $101 Practice: The Topcon TRC-NW400 camera costs approximately $15,000 to $22,000 IDx-DR software (the fee charged per analyzed image is unavailable)

*—Payment rate according to Healthcare Bluebook and Lombart Instrument Co.

†—This is the population indicated for IDx-DR software use. It is not indicated for diabetic retinopathy screening in general.

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†—This is the population indicated for IDx-DR software use. It is not indicated for diabetic retinopathy screening in general.

Approved by FDA in 2020

- https://www.eyenuk.com/en/products/eyeart/

EYENUK

EyeArt
Diabetic Retinopathy Analysis Report

Patient Information		General Information	
Patient ID:	**p001**	**Referring Location:**	Diab Clinic
Patient Name:	**Ryan Sangolli**	**Referring Provider:**	Dr. John Doe
Date of Birth:	1971-Apr-05	**EyeArt Control ID:**	88178
Gender:	Male	**Dilation Status:**	Not Dilated
Encounter ID:	e001	**Exam Analysis Date:**	2020-Feb-25 14:29

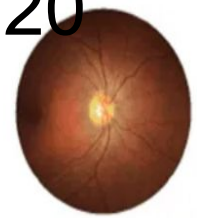
EyeArt Diabetic Retinopathy (DR) Exam Result Summary

Negative for more than mild DR in both eyes. Retest in 12 months.

Right Eye Results	Left Eye Results
mtmDR Result: Negative for more than mild DR	**mtmDR Result:** Negative for more than mild DR
vtDR Result: Negative for vision-threatening DR	**vtDR Result:** Negative for vision-threatening DR


Macula Centered, Right Eye


Macula Centered, Left Eye


ONH Centered, Right Eye


ONH Centered, Left Eye

*Do not use the above thumbnail images for diagnostic purposes.

Notes

A negative result indicates a low risk for moderate non-proliferative DR, severe non-proliferative DR, proliferative DR, and clinically significant diabetic macular edema.

EYENUK

EyeArt
Diabetic Retinopathy Analysis Report

Patient Information		General Information	
Patient ID:	**p004**	**Referring Location:**	Diab Clinic
Patient Name:	**Leon Wescott**	**Referring Provider:**	Dr. John Doe
Date of Birth:	1958-Jan-15	**EyeArt Control ID:**	88181
Gender:	Male	**Dilation Status:**	Not Dilated
Encounter ID:	p004	**Exam Analysis Date:**	2020-Feb-25 14:30

EyeArt Diabetic Retinopathy (DR) Exam Result Summary

Vision-threatening DR detected in both eyes. Refer to an eye care professional for evaluation (with preferential scheduling if possible).

Right Eye Results	Left Eye Results
mtmDR Result: More than mild DR detected	**mtmDR Result:** More than mild DR detected
vtDR Result: Vision-threatening DR detected	**vtDR Result:** Vision-threatening DR detected


Macula Centered, Right Eye


Macula Centered, Left Eye


ONH Centered, Right Eye


ONH Centered, Left Eye

*Do not use the above thumbnail images for diagnostic purposes.

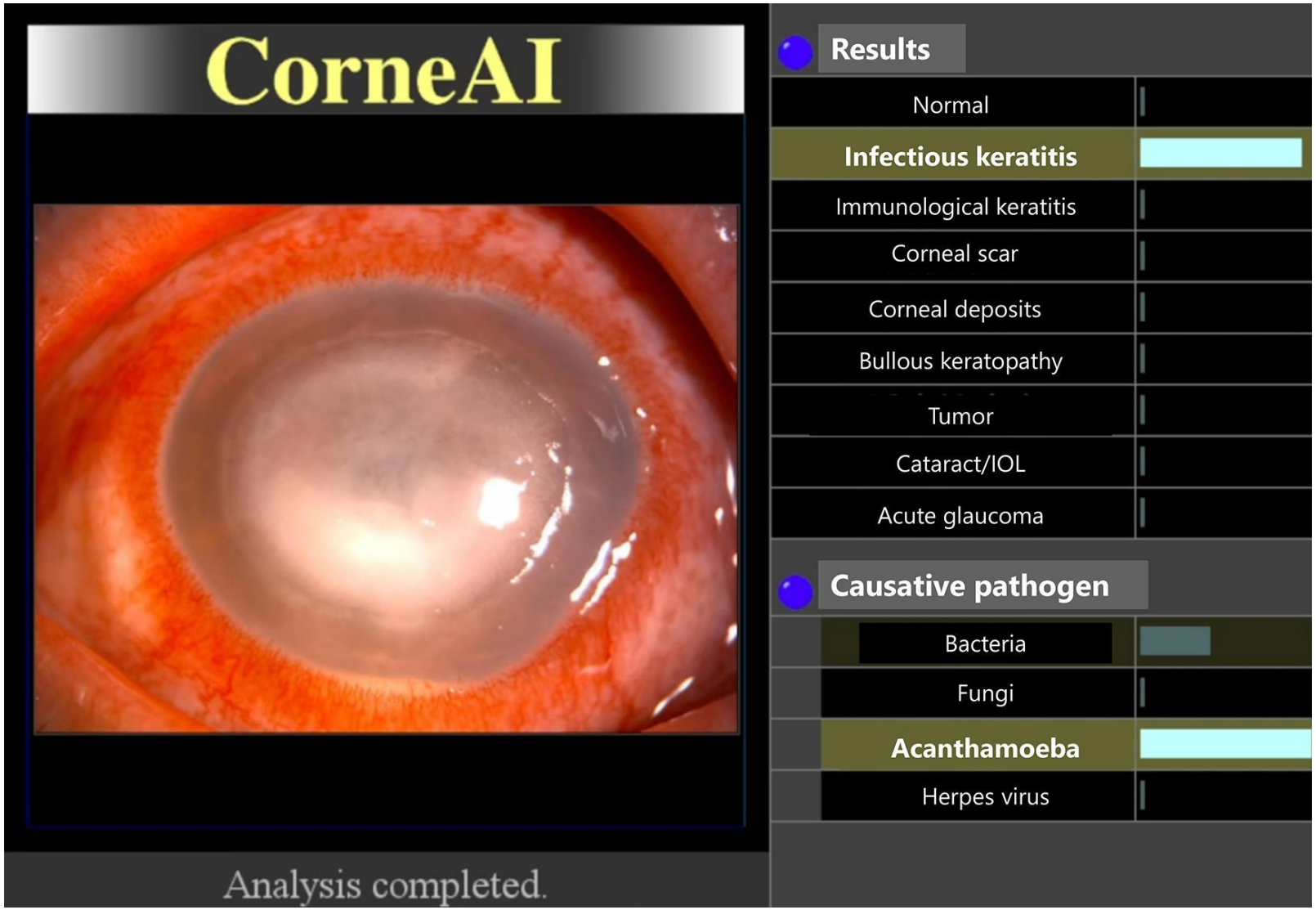
Notes

A positive result for vision-threatening diabetic retinopathy indicates a high risk for severe non-proliferative DR, proliferative DR, or clinically significant diabetic macular edema.

AI for Diagnosis of Corneal Diseases

- **Distinguishes Infectious vs. Noninfectious**: Guides Antibiotics vs. steroids.
- **Identifies Pathogens**: Estimates causative organisms from slit-lamp images
- **Rapid Diagnosis**: Prevents complications-perforation, scarring, vision loss.
- **Detects Multiple Conditions**: Differentiates keratitis, pterygium, dry eye, and other anterior segment diseases.

AI for Diagnosis of Corneal Diseases



AI for Diagnosis of Other Eye Diseases

- **AMD**: Detects early signs, predicts progression, guides prevention
- **ROP**: Accurately stages from retinal images, often surpassing humas
- **Glaucoma**: Identifies optic nerve damage early using fundus and OCT
- **Keratoconus**: Diagnoses clinical and subclinical forms, supporting personalized management.

AI for Diagnosis of Other Eye Diseases

- **Pediatric Ophthalmology:**
  - Strabismus Detection
  - Refractive Error Screening
  - Reading Disability Risk
  - Amblyopia Detection:

AI for Ophthalmic Surgery

- **Robotic Surgery**: Improves precision and tremor control for delicate procedures like subretinal delivery.
- **Cataract Surgery**: Offers real-time visual feedback during phacoemulsification.
- **Preoperative Safety**: Verifies identity, laterality, and lens parameters using AI tools.
- **Intraoperative Guidance**: Uses OCT-based AI to guide tool placement and enhance surgical accuracy.

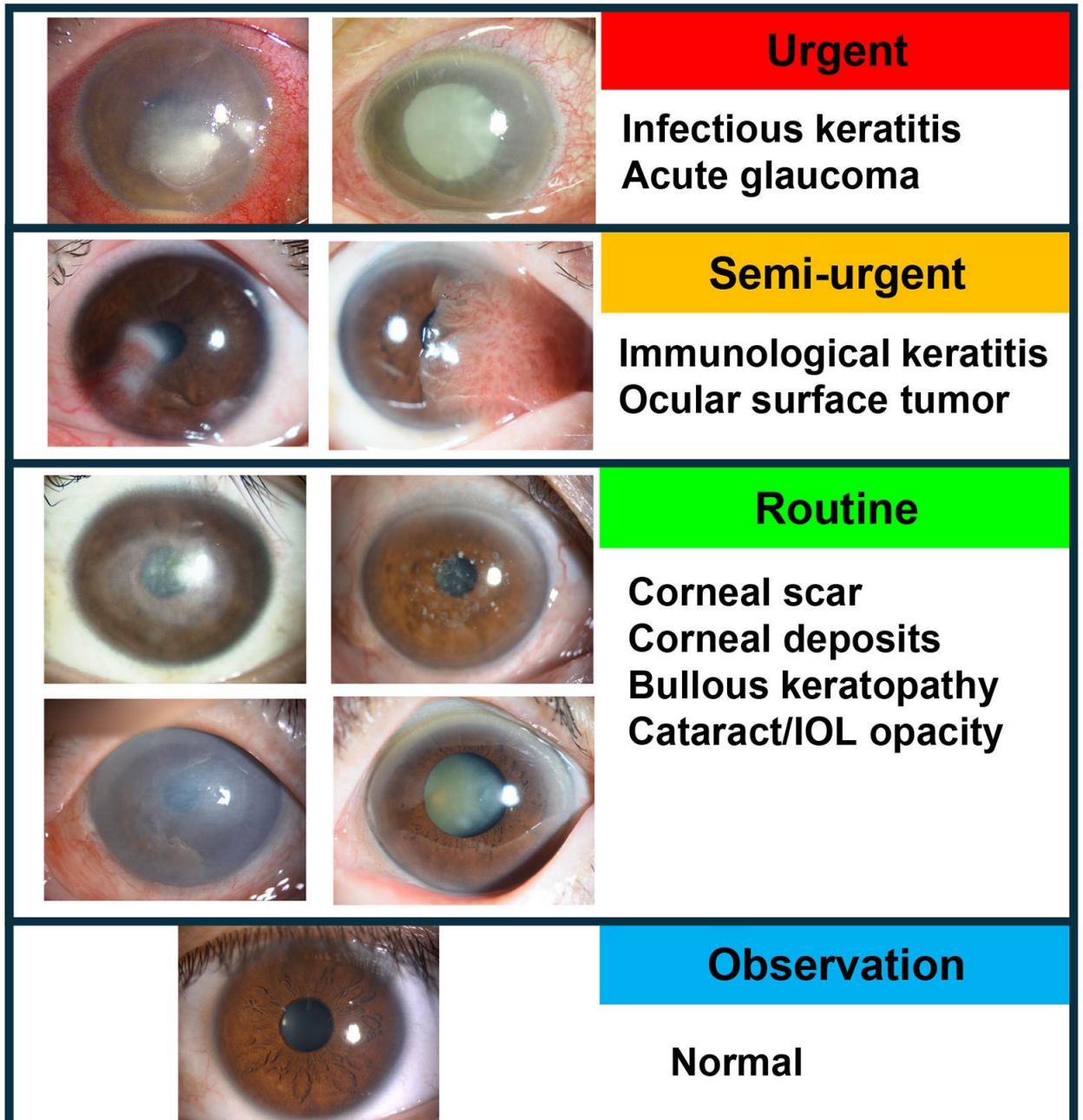
AI for Ophthalmic Surgery

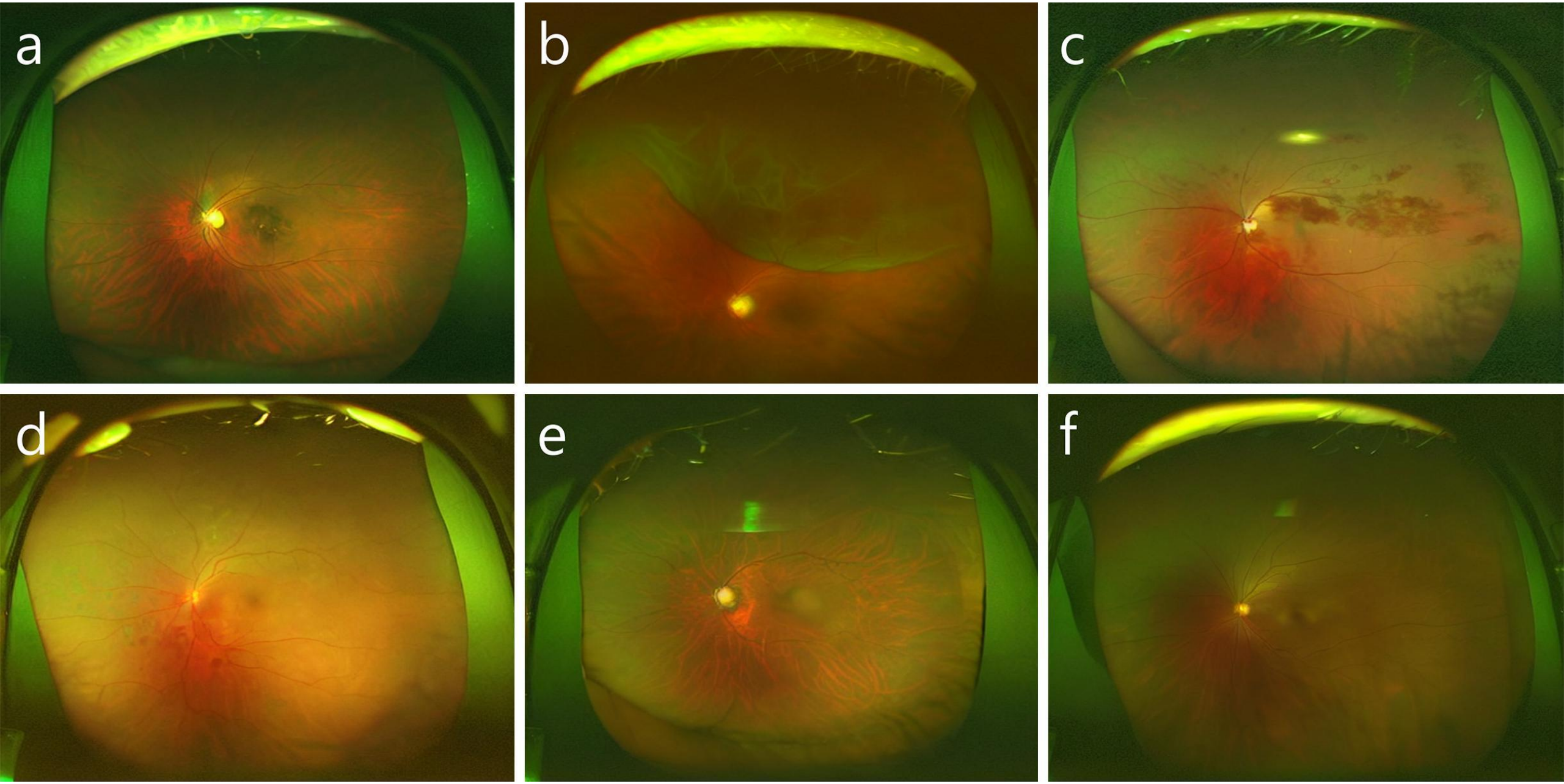
•Mobile camera is used to capture the image to recognize the parameters shown on the packages of planned, reserved, and backup lenses. The AI system verifies the accuracy of these parameters before surgery

Smartphone Imaging and AI

- **Improves Access**: Enables remote diagnosis in underserved areas.
- **High-Quality Imaging**: Captures detailed views of the cornea, conjunctiva, and eyelid.
- **Fast & Accurate**: Delivers quick, reliable results for timely treatment.
- **Effective Triage**: Highlights high-risk conditions to guide clinical decisions

Smartphone Imaging and AI




a
b
c
d
e
f

AI/ML Tech used in Ophthalmology:

1. **CNNs & Transformers/NLP** – Image classification, segmentation, and detection.
2. **GANs & Diffusion Models** – Image synthesis, augmentation, super-resolution.
3. **Transfer & Self-Supervised Learning** – Improve performance with limited labels.
4. **Multimodal Fusion** – Combining fundus, OCT, visual fields, and EHR data.
5. **Explainable AI (XAI)** –Grad-CAM, SHAP, and saliency maps for transparency.
6. **Classical ML (SVM, XGBoost)** – For structured data and risk prediction.
7. **Edge AI & Surgical Support** – On-device diagnosis and robotic guidance.

Limitations of AI:

1. Data Privacy
2. Black-Box Phenomenon
3. Quality of images/ Heterogeneity of Images
4. Accessibility due to cost
5. Lack of comprehensive Regulations and Guidelines
6. Generalizability of Results/ External Validity
7. Job Loss to Humans?

References

1. Oshika T. Artificial Intelligence Applications in Ophthalmology. JMA J. 2025;8(1):66-75.
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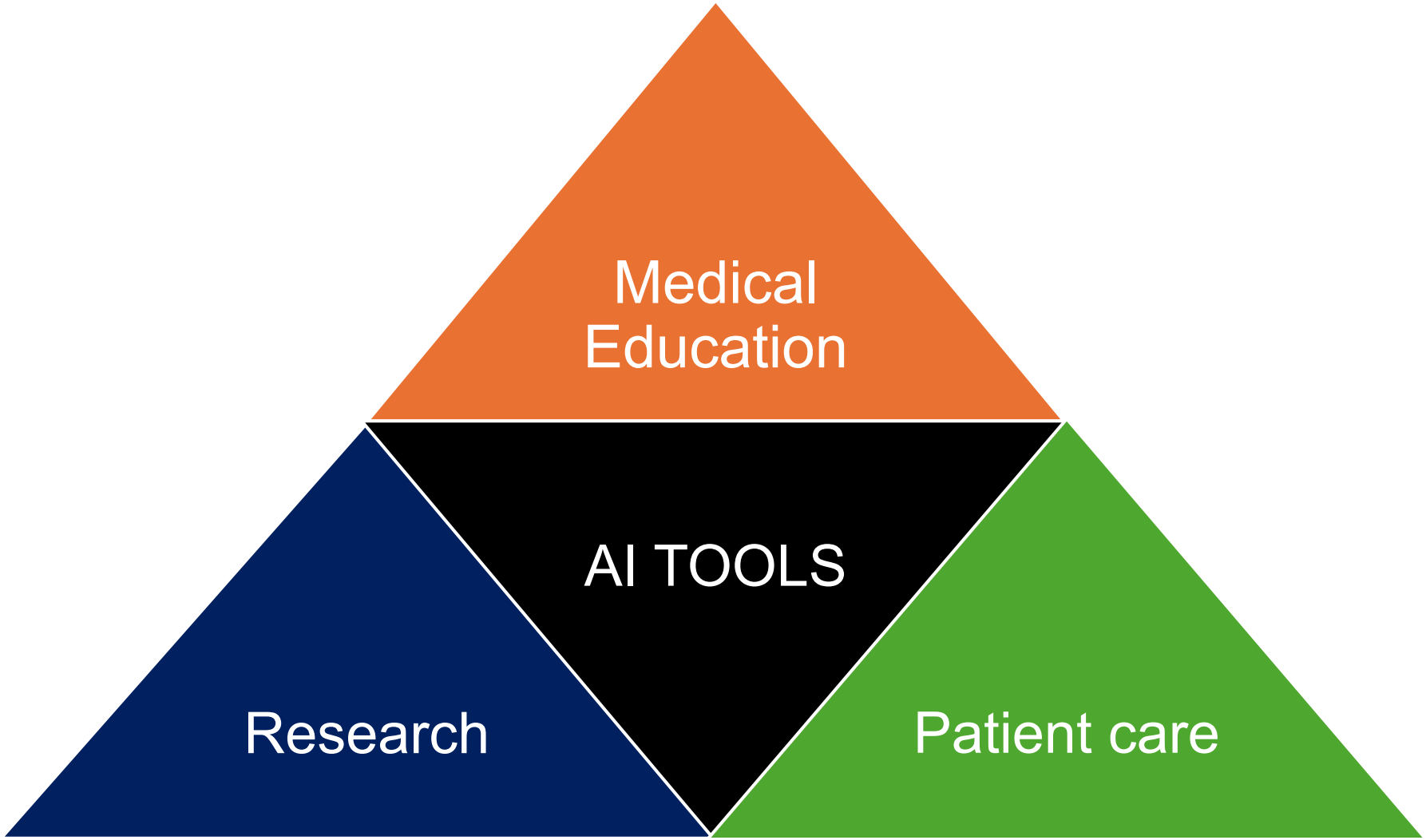
5. https://pmc.ncbi.nlm.nih.gov/articles/PMC10793375/
6. https://www.eyenuk.com/en/
7. https://www.altris.ai/article/top-mobile-optometry-ophthalmology-apps-for-eye-care-specialists/
8. https://pmc.ncbi.nlm.nih.gov/articles/PMC11703125/
9. https://pmc.ncbi.nlm.nih.gov/articles/PMC12044197/

AI for Eye Docs: Tools You Can’t Ignore

AI Tools

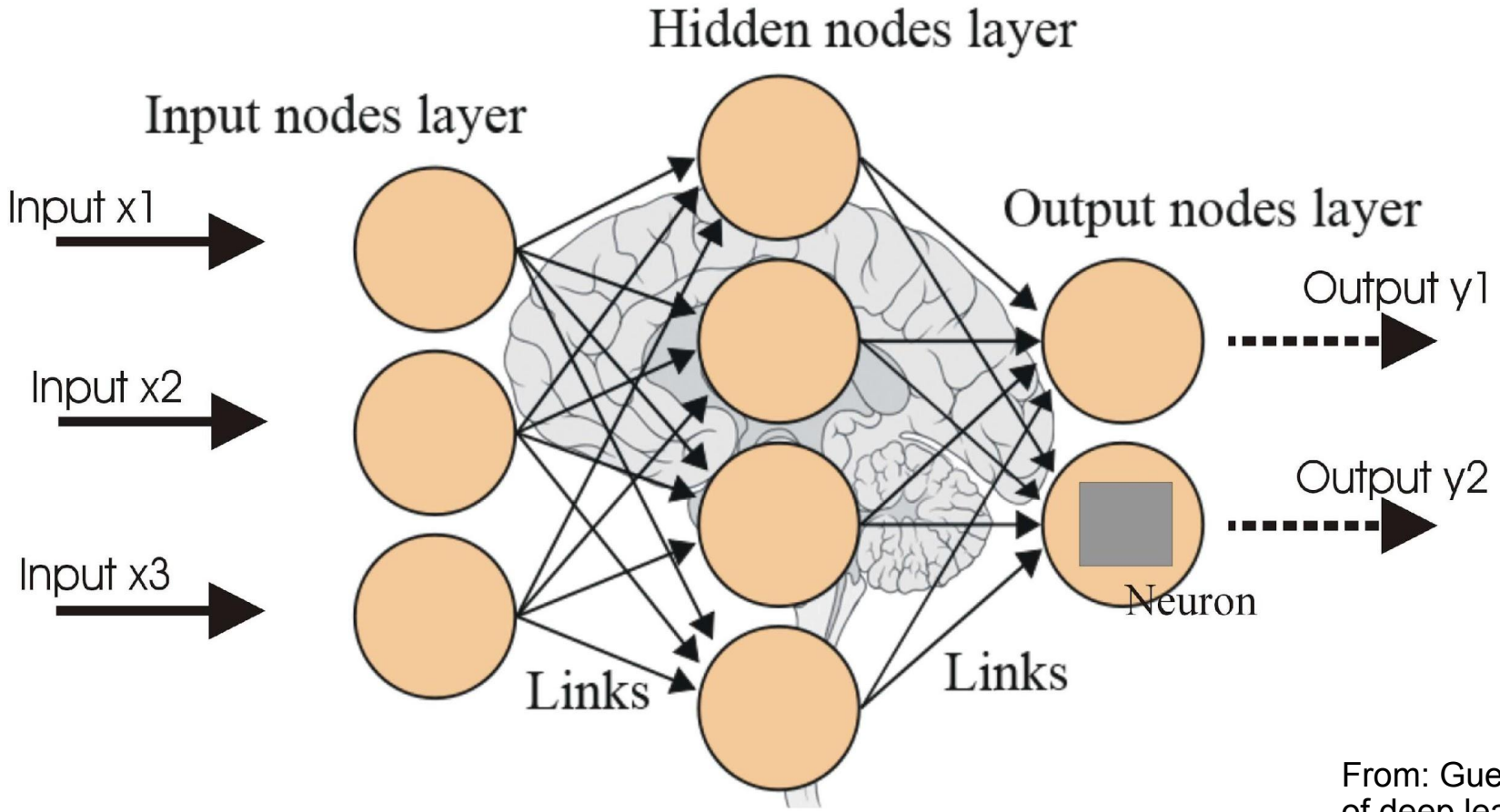


LARGE LANGUAGE MODELS

LARGE LANGUAGE MODELS

- **Language model** is built to process and understand a text input (prompt) and then generate a text output (response) accordingly.
- **Large:** Minimum of **10 billion parameters used**.
- **What are the LLMs you know?**

Neural Networks



From: Guest Blog. The evolution and core concepts of deep learning & neural networks [Internet]. Analytics Vidhya. 2020.

GPT

- **Gen AI**: Ability to generate text, images, videos etc that is creative and original & can generate human-like responses.
- **Pre-trained:** Trained on an extensive corpus of unlabeled text, to learn general linguistic patterns & acquire a wide knowledge base.
- **Transformer:** Neural Network Architecture, consists of an encoder and decoder part. They improve NLP by hardware acceleration & speeding-up AI computations.

Source: https://www.borealisai.com/research-blogs/a-high-level-overview-of-large-language-models/

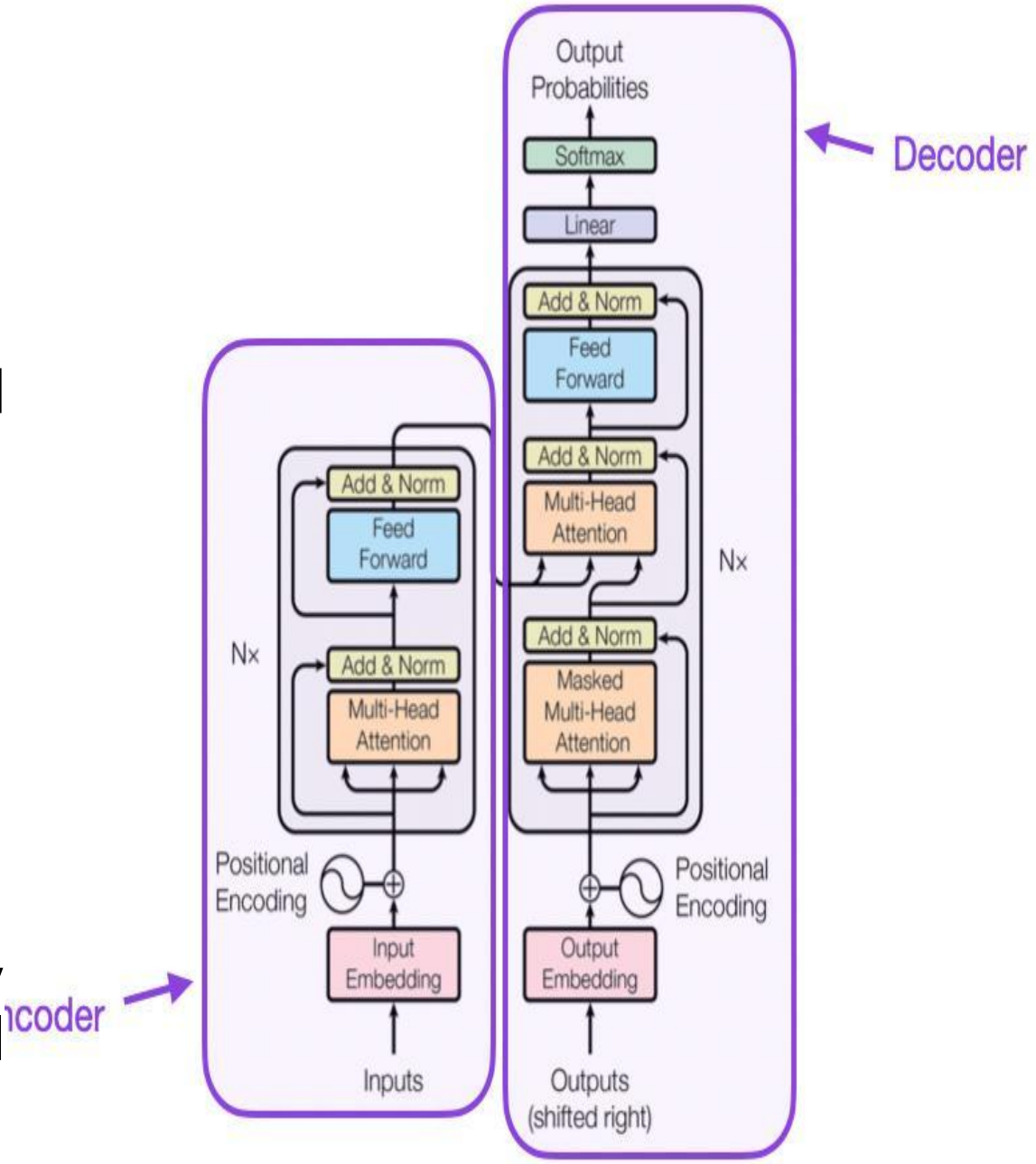
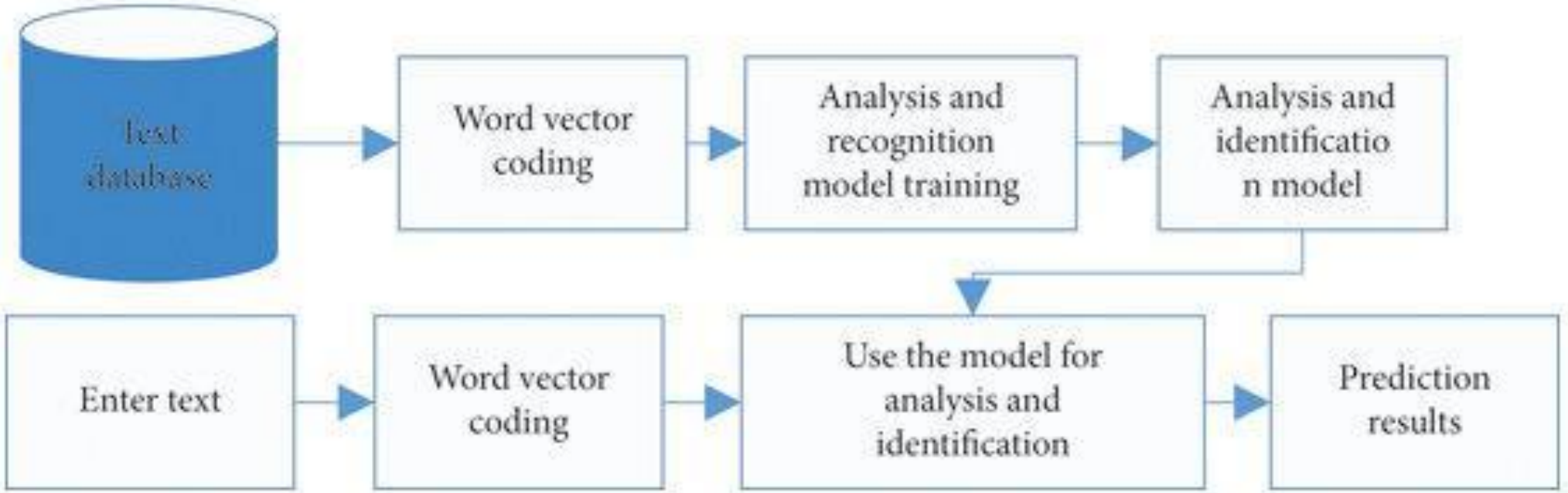


Figure 1: The Transformer - model architecture.

How do LLMs work?



AI in Research Ideation & Proposal Writing

AI in Research Ideation & Proposal Writing

LLMs for Research

- ChatGPT
- Gemini
- Perplexity
- Claude
- DeepSeek
- Qwen
- Grok
- Mistral

Stand-alone AI tools

- Elicit
- Consensus
- Research Rabbit
- SciSpace
- PaperPal
- Rdiscovery

AI tools for Education

- Custom chatbots
- Tutors
- LearnLM
- NotebookLM

AI is an effective supplement for Doctors, Not a substitute…

THANK YOU…

"English as the primary language for programming"

-Nvidia CEO Jensen Huang