# AI in TRD Surgery:

## Precision, Prediction & Performance

## (" *It Can See Better Than You*")


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THE CHALLENGE

# "TRD: The Surgical Rubik's Cube"

TRD is one of the most challenging conditions we face, affecting 5-10% of patients with PDR.

It's not just a surgery; it's a high-stakes puzzle with no room for error.

1

### Surgical Complexity

Managing TRD is "Somewhere bet. defusing a bomb & untangling Christmas lights"

requiring immense skill, patience & meticulous attention to detail.

2

### Tissue Plane Identification

Distinguishing bet. delicate retinal tissue & the fibrous membranes causing traction is a constant battle.

A misstep can have devastating consequences.

3

### Hemorrhage Control

Intraope. ***BLEEDING*** can quickly obscure the surgical field, turning a challenging case into a nightmare. Rapid & effective control is paramount.

4

### Human Error & Fatigue

Our brains are not GPU clusters. We tend to forget & miss subtle signs, especially as surgeon fatigue sets in towards the end of a long list.

This affects decision-making and performance.

5

### Limited Margin of Error

Certain maneuvers, like subretinal injections, demand absolute precision. Any deviation can lead to severe complications.

The margin for error is razor-thin.

# "Will Robots Learn to Operate: DL in TRD Surgery"

AI isn't created "**Equal**"

Even John Mccarthy (1956) could not have predicted the potential

### LLM: The Communicator

enable computers to understand, interpret & generate human language.

Resident who knows kanski inside out but has limited clinical experience

"the brain that comprehends lab test, surgical reports & pt. H/O and generate D.D & ttt suggestions.

### ML: The Follower

requires us to tell the model exactly what to do.

Resident who follows exact guidelines proposed by Seniors.

excels at tasks with clear rules & defined outcomes, i.e. guidelines for Dx or basic procedural steps.

### DL: The Innovator

*more advanced model,*

inspired by the intricate neural networks of the human brain.

figures out on its own which features matter directly from raw data, esp. images, without explicit programming

requires massive amounts of data & powerful GPU processing.

The consultant who learns & adapts, identifying subtle patterns we might miss.

_Small footnote: "This presentation was co-created with LLM AI - because even consultants need help sometimes"_

# Turning Data Chaos into Predictive Precision

## The DL Crises (Challenges)

Too Many Images

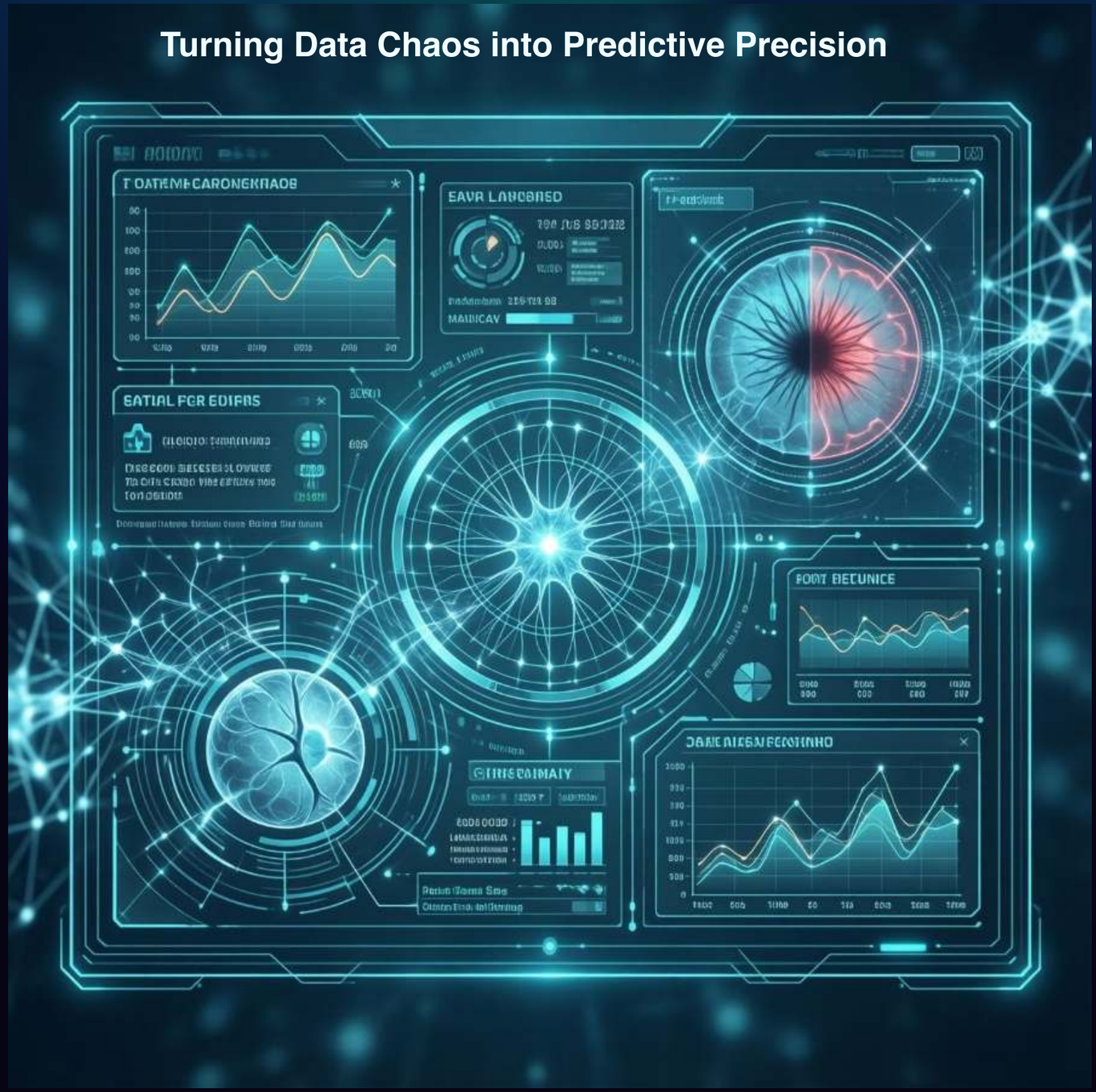
Too Much Noise

Late TRD Referrals: too complex

Need for Advanced Models

Need for Ai enhanced images

Need for Advanced GPU



## The DL Advantage (Solutions)

Learns from Thousands of Eyes

Not Affected by Cognition

Not affected by Fatigue

Faster Learning

Self Learner

# Pioneers in Retinal AI Innovation

1

DL advanced Imaging analysis

Google DeepMind

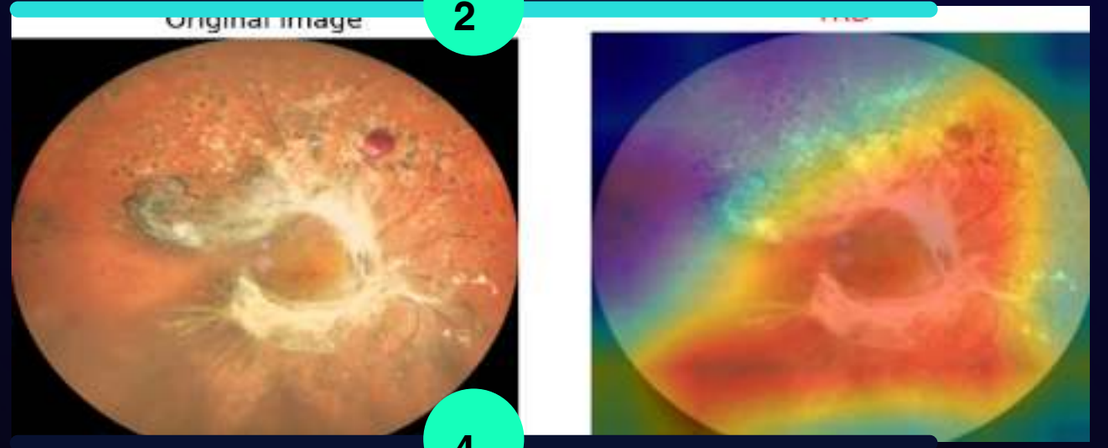
3

## Microsoft HoloLens

Achieved 92% recall in identifying traction membranes, offering augmented reality for surgical visualization.

A custom-trained CNN network specifically designed for TRD

2




4

Intraocular R

## UCLA

Intraocular Robotic Interventional and Surgical System

# Computer Vision: Giving AI the Gift of Sight (& Surgical Percision)

AI vision: Ai system that not only sees what's happening under the microscope but understands it with unprecedented precision.

## CNN (Convolutional Neural Network)

**The Tireless observer:** Experienced Eyes that Do Not Need Coffee Breaks

Mimics Human Brain

Analyzes thousands of images: OCT, UWF, $ videos

During $, the CNN identifies specific surgical tools, discerning their type, orientation, & even their fine movements within the complex ocular environment.

## STN (Spatial Transformer Network)

The STN takes vision a step further.

understand and track geometric changes in the tools, compensating for shifts in perspective, rotation, & tilt that inevitably occur during $.

This ensures continuous, accurate tracking despite dynamic movements.

## Processing the 2D Video Feed

Together, the CNN and STN process the live 2D video feed from the surgical microscope, creating a real-time, intelligent understanding of the surgical field.

This allows the AI to assist with unprecedented precision.

# Real-time Tracking:
# A Surgeon's Extra Set of Eyes (& Brain)

## X & Y Tracking: The En Face View

Based on RGB video feed (en face), CNN & STN combine to track instruments & tissues across the horizontal (X) & vertical (Y) planes → immediate, visual feedback on tool position & tissue interaction.

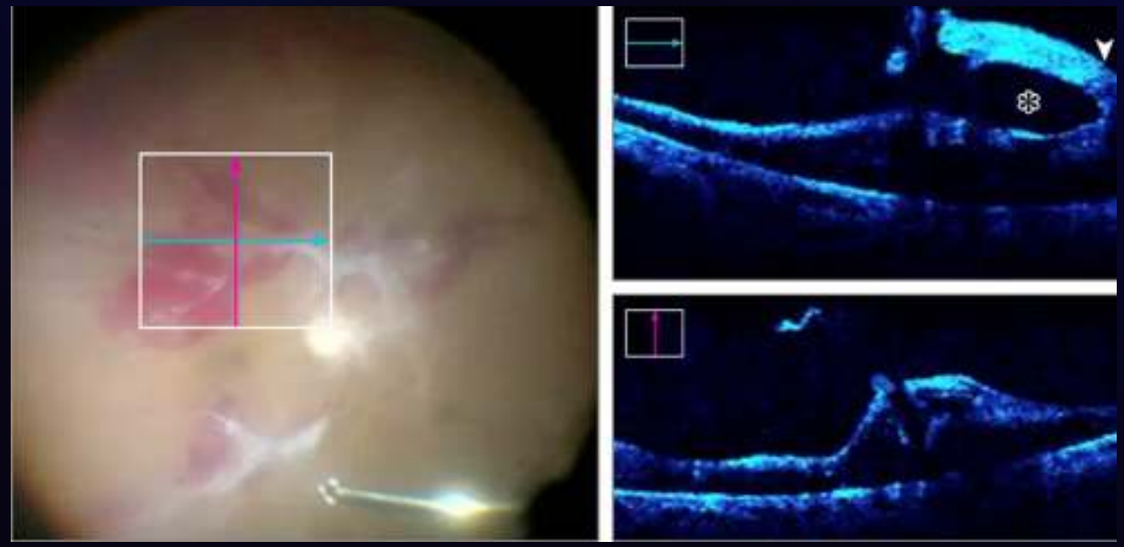
AI identifies real time $ instruments & relation 2 retina →

## Beyond the Surface: Membrane Gaps & Residual Traction

AI can identify minute membrane gaps & residual traction that might be imperceptible to the human eye. This depth-resolved understanding is critical for complete and safe membrane peeling in complex cases.

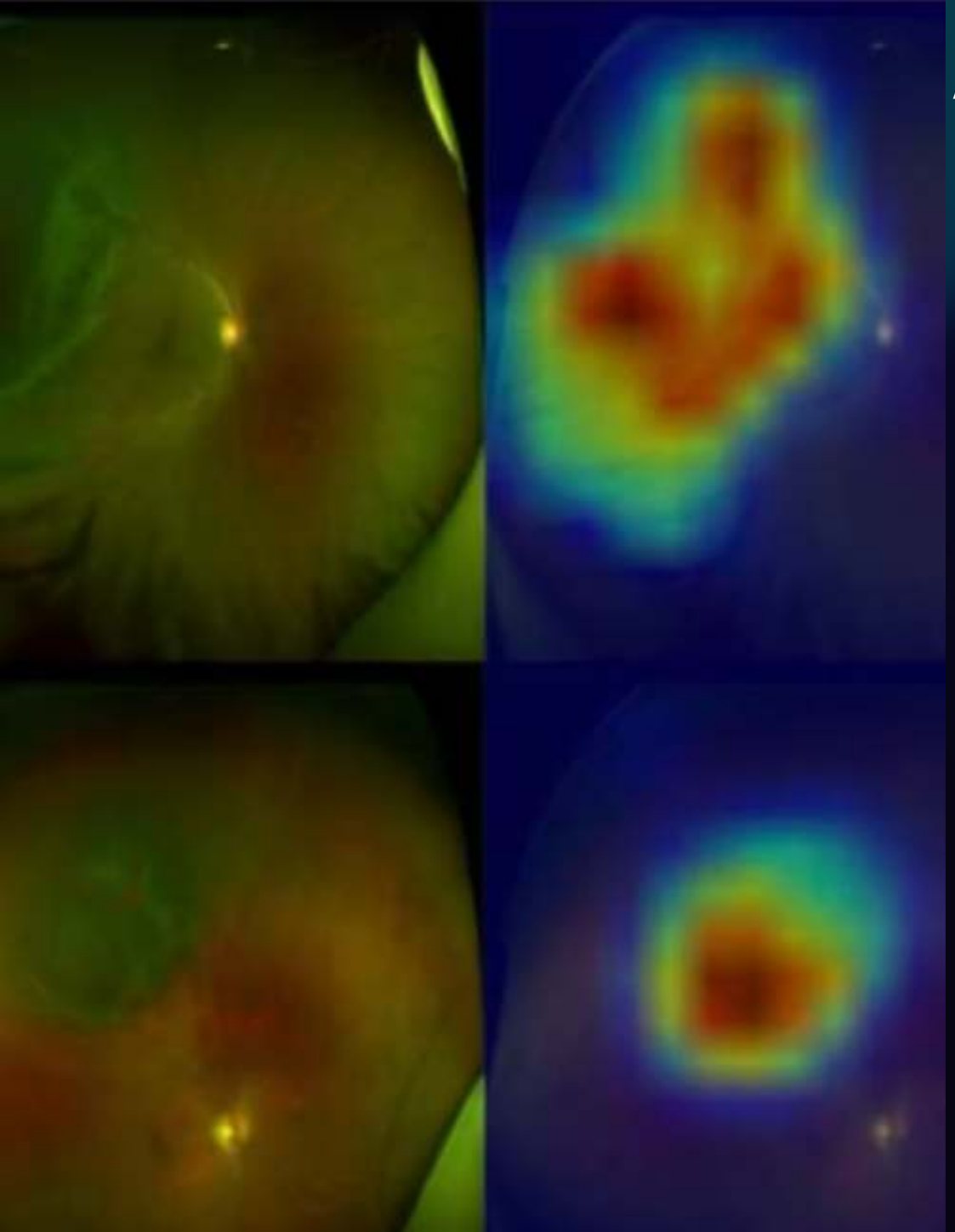
## Z (Axial) Tracking: The Depth Dimension

This is where **Intraoperative OCT (iOCT)** comes in.
Using interferometric depth data from B-scans, AI segmentation processes the intricate layers of the retina. It visualizes sub-retinal spaces, fluid pockets, perfluorocarbon liquid (PFCL), and even subtle vitreous hemorrhage (HGE).



# Current Technology

| System | Tracking | Automation |
|---|---|---|
| Zeiss Active 800 | Manual | Surgeon controlled |
| Leica EnFocus | Auto-Locate | MAnual X-Y then automated Z axis focus |
| Bionics One | Ai assisted | Digital tracking of tools to guide iOCT, overlay data |
| CNN/STN research | Autonomous tracking | Zero surgeon input, iOCT beam follows tools autonomously |



# AI Heatmap guided $ Decisions

Leveraging Gradient-weighted Class Activation Mapping (**Grad-CAM**),

AI generates heatmaps that pinpoint critical areas for retinal peeling

| Heatmap Color | AI Logic | $ Recommendation |
|---|---|---|
| RED | RED FLAG:<br>Peeling CI<br>High Stress Area | Segmentation |
| Yellow | Transitional Areas<br>Moderate tangential Stress | Delamination |
| BLUE | Peel Priority Area<br>Loose areas with high safety margin | Peeling |

# Current AI Applications in TRD Surgery

"What AI Can Do Today (Spoiler: A Lot)"

**Pre-operative Planning**

- OCT-based 3D surgical roadmaps suggest peel priority zones and predict breaks.
- Predicts $ complexity (89% accuracy) & post-operative prognosis.
- AI suggests pre-operative preparation, e.g. Anti-VEGF premedication or systemic control.

*"Like Google Maps, but for your vitrectomy."*

**Intraoperative Guidance**

- Real-time tissue differentiation using heatmaps.
- iOCT integration with overlay displays provides dynamic insights.
- Tremor filtering systems enhance surgical precision, making all surgeons steadier.

**Current Stars**

Leading the way are innovative platforms e.g

PRECEYES Surgical System (Zeiss) & Beyeonics One™ platform,

Luca (AcuSurgical robotics)

# Robotic Surgery: Advantages and Challenges

Exploring the dual nature of robotic integration in retinal surgery.

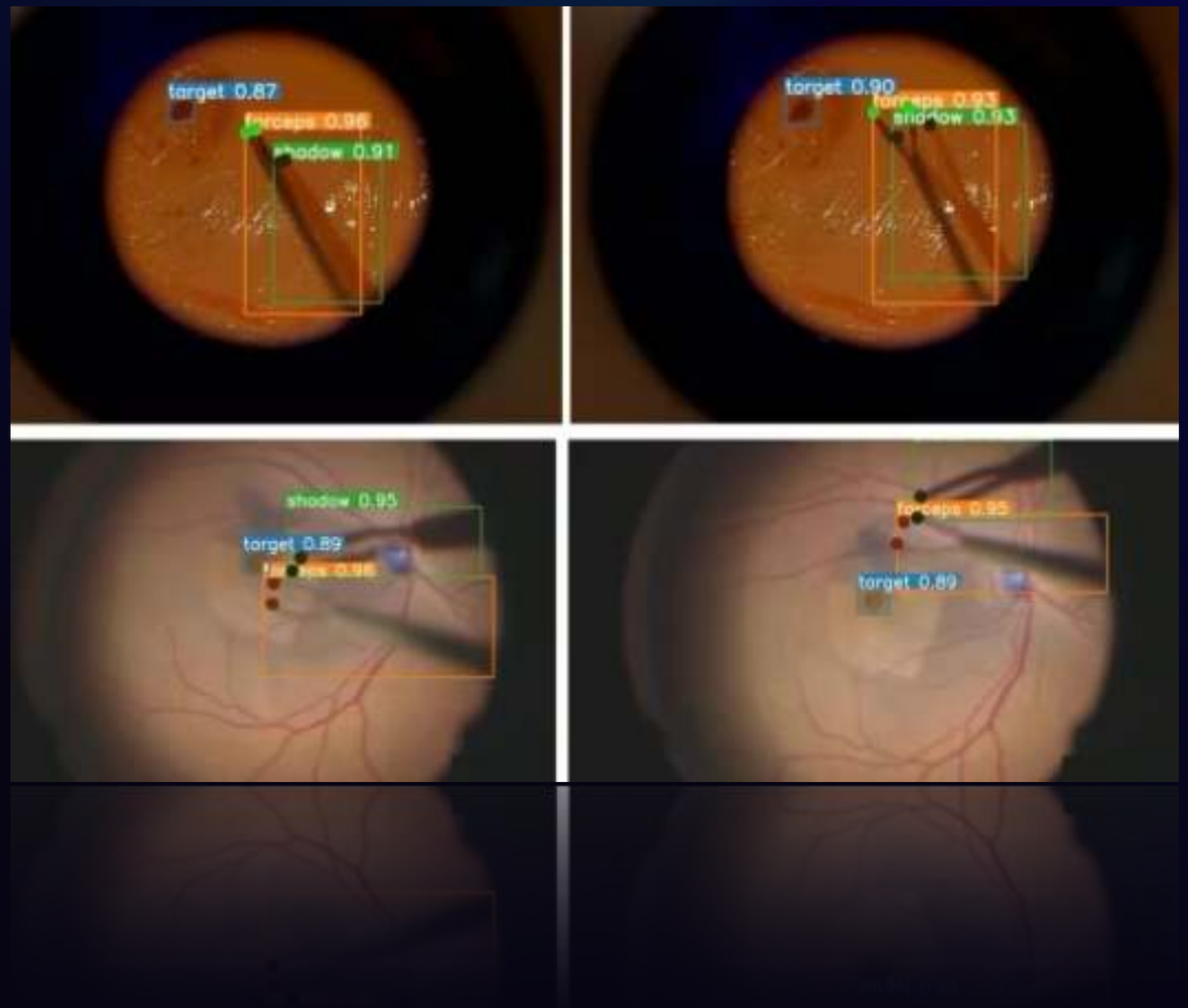
## 1 Advantages

- Removes tremor, enhancing PRECISION.
- Autonomous control of specific tasks - - fatigue & optimizes pt safety & surgeon ergonomics
  ++ PERFOMANCE

## 2 Challenges

- Visual input issues, particularly with shadows.
- Variable position of robotic system not being fixed.

- Need for light pipe motion automation.
- DL must learn the distance bet. instruments based on shadows despite changes in forceps length and shape.



# Mind-Blowing Current Capabilities: Sci-Fi No More

## Autonomous Surgical Steps

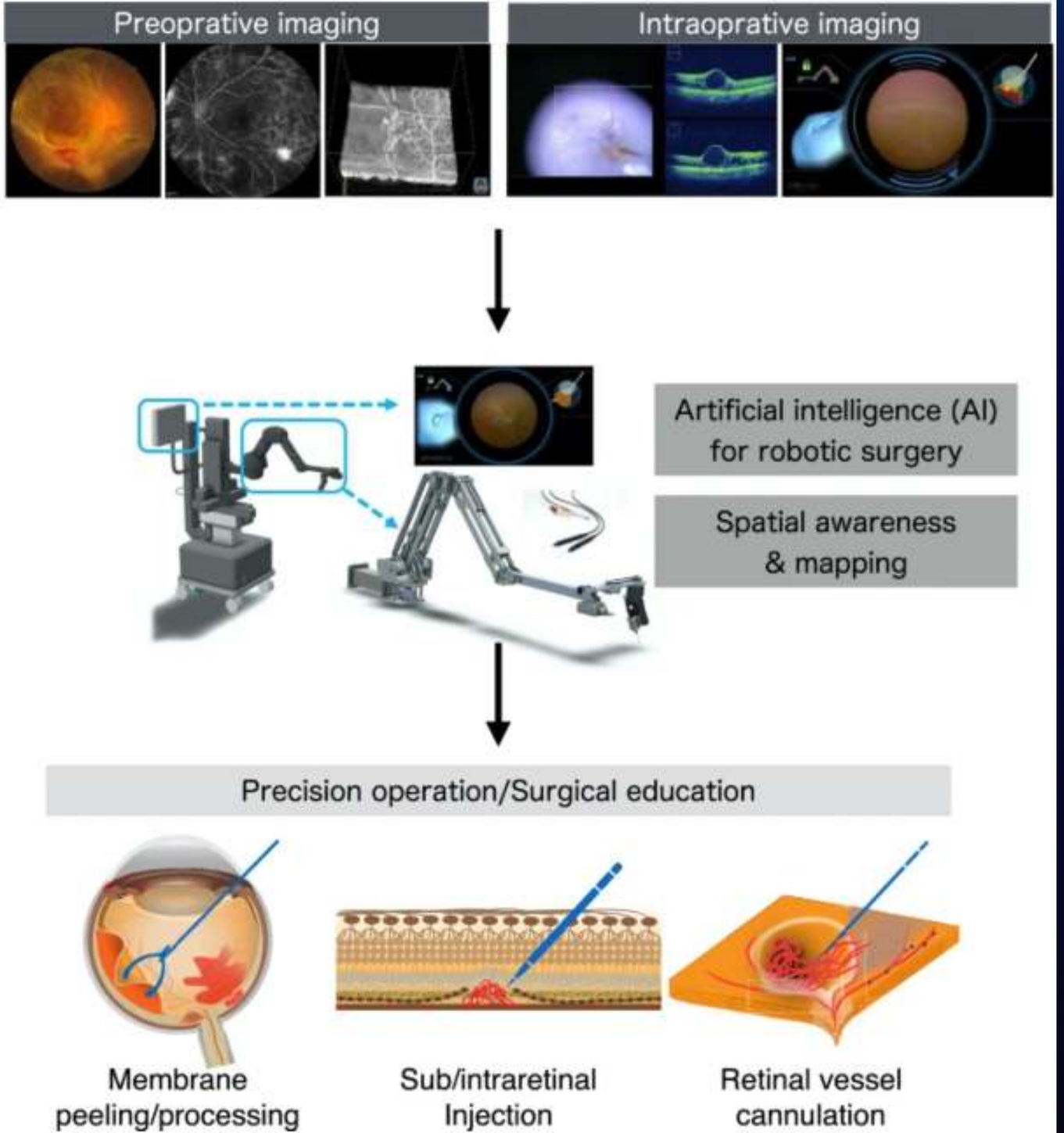
Robot-assisted cannulation of retinal veins (precision down to 10μm)
AI-guided laser photocoagulation patterns.

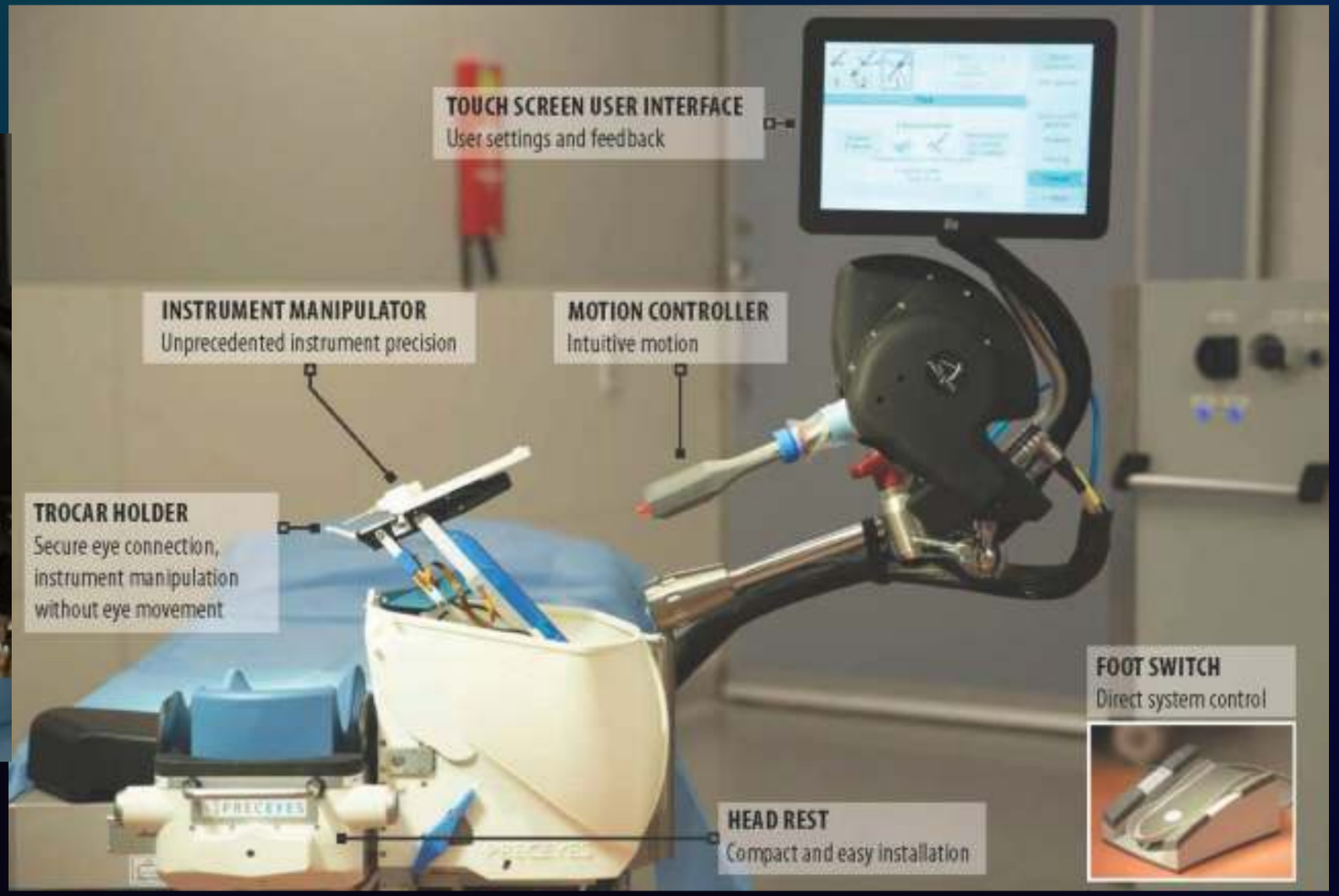
## Predictive Analytics

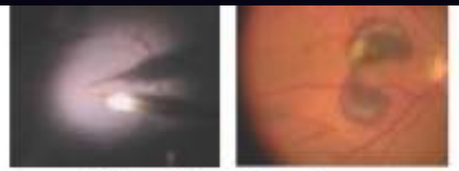
ML models predict post-operative visual outcomes with an $R^2$ of 0.84, offering risk stratification superior to even the most experienced colleagues.

## The "Wow" Factor

- AI detects microbreaks invisible to the human eye.
- Real-time blood flow analysis during $ provides
- immediate feedback.





**Subretinal injections**
[Nature Biomed Eng, 2018; 2:649-656]

**Staining and ERM Peeling**
[Floretina Congr; 2019]

**Vein cannulation**
[Br J Opth, 2016; 100:1742-1746]

# Using Pixels for Prognosis: HUD Integrated AR Beyeonics Vision

The future of visualization is here with fully digital exoscopes and AI processing every pixel for enhanced surgical precision.

- Better stereopsis and extended depth of focus.

**Next Generation Visualization**

- Advanced color manipulation for clearer views.

**AI Tracking & Overlay**

- Seamless overlay of vitrectomy settings and OCT scans.
- Maintains precise registration even with eye movement.

# The Evidence:
# Numbers That Make Administrators Happy

**94%**

**Accuracy in Referral Decisions**

A groundbreaking collaboration between Moorfields and DeepMind showcased AI's diagnostic prowess.

**40%**

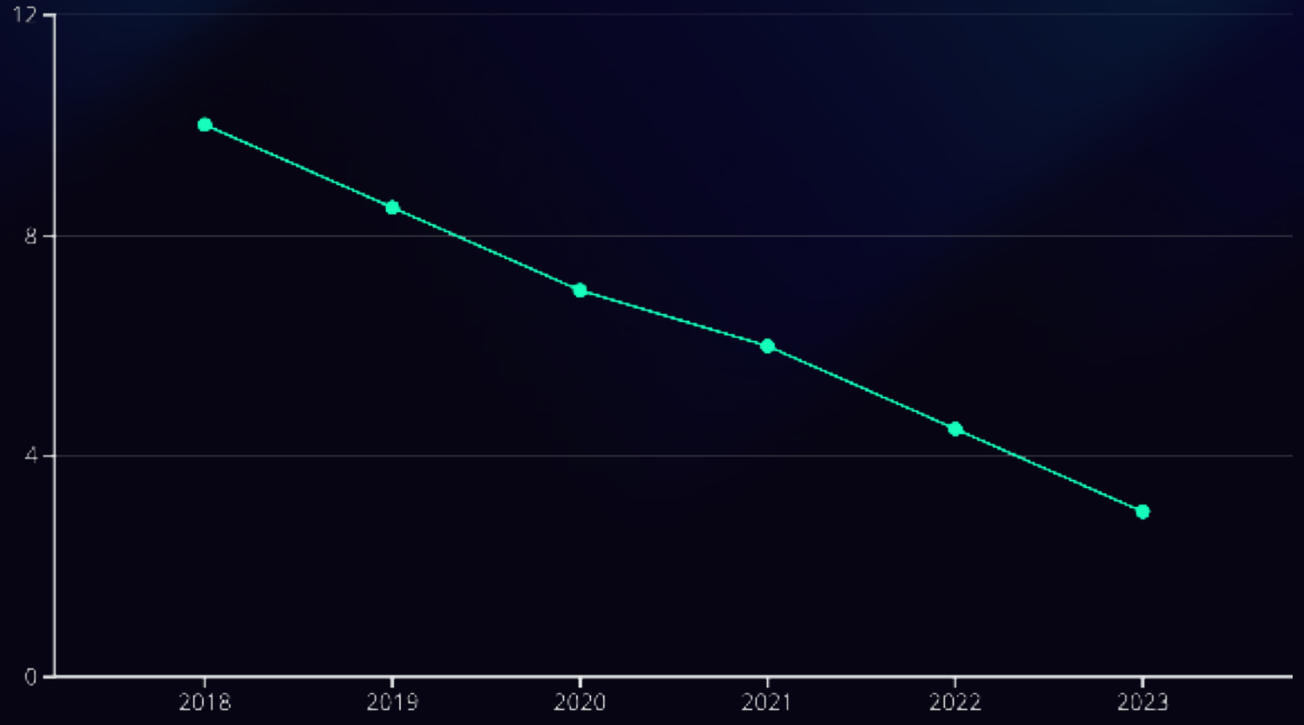
**Reduction in Surgical Time**

A 2023 Duke University Study demonstrated significant efficiency gains with AI guidance.

**26%**

**Fewer Iatrogenic Breaks**

Johns Hopkins research highlighted the safety benefits of AI-assisted membrane peeling.




"Even robots make us better humans." This graph illustrates the declining complication rates with the integration of AI in surgical procedures.

# Future Trends: The Next Years in Retinal Surgery

01

### Fully Autonomous Surgical Steps

Trials for AI performing ILM peeling are set to begin in 2025, alongside smart instruments that "refuse" dangerous movements.

02

### Augmented Reality Integration

Expect holographic surgical planning and real-time complication probability overlays.

*"Like Iron Man's helmet, but for your eyes."*

03

### Personalized Surgical AI

AI models will be trained on YOUR specific techniques, learning from every case globally to enhance collective intelligence.

04

### Predictive Maintenance

AI will predict when YOU need a break,

acting as *"Your Fitbit, but for surgical performance."*

# AI as $ Co-PILOT not PILOT

AI assistance is Here:  Ai is already available & improves on Daily Basis

It makes good Surgeons better, Not Obsolete
Patient are set to gain the benefits of Ai -Surgeon Collaboration
Don’t Worry: You will still Have a Job in 10 Years… OR ???

AI limitations: Medico-Legal, Human compassion, AI supervision, …
COST, Training, Data Privacy issues, Integration with old school equipment

Acknolwedgements
Our Silicone based co-workers: LLMs e.g Perplexity, Gemini, Nvidia nemotron,…
Web based aI Tools E.G Gamma

They learn faster than some residents and require No coffee breaks

Questions ?  Or should I Ask Ai ??


THANK YOU
AI RETINAL
SURGERY UNIT