

## **The Growing Impact of Telemedicine on our Approach to Vision Care**

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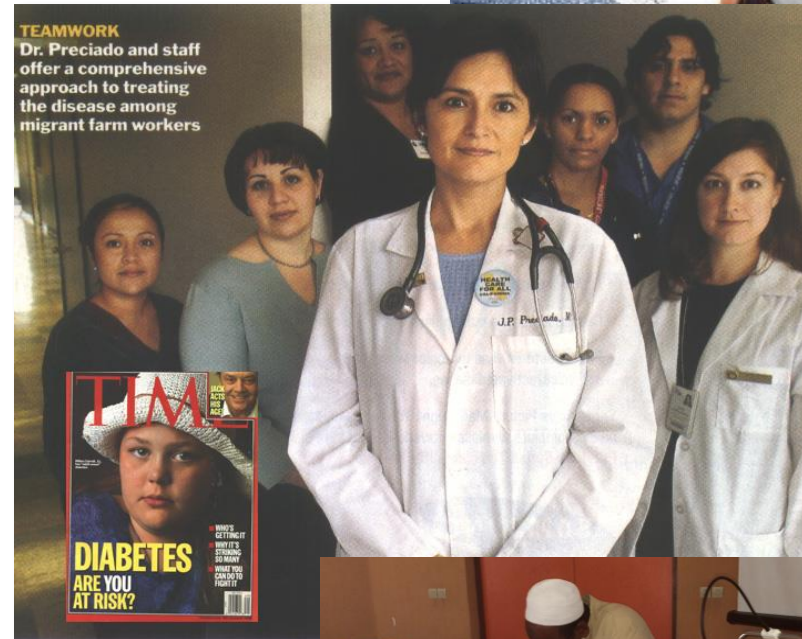
# Discussion:

- What 12 years of community based teleretinal exams has taught us
- Technology development in teleretinal care
- Adherence-based program development
- Changing the game by blurring the borders in eye care

# Telemedicine At U.C. Berkeley and EyePACS:

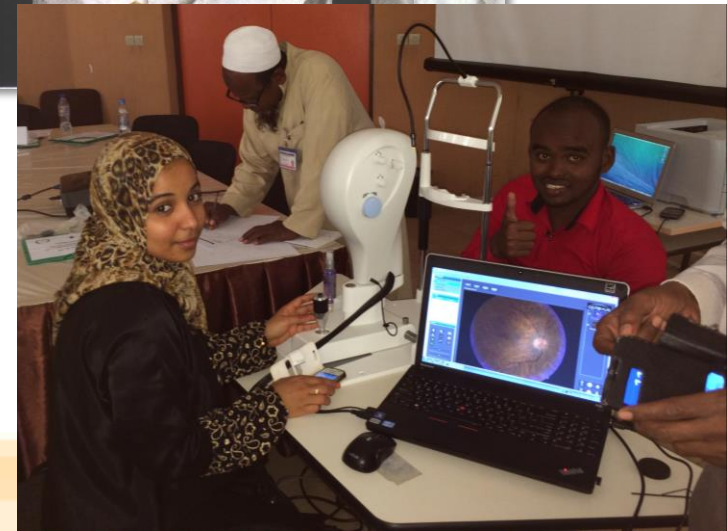
- 1994 – First telemedicine consult
- 1999 – Telemedicine Consults with China and India
- 2001 – EyePACS first version
- 2003 – Diabetic retinopathy detection
- 2005 – CHCF supports development
- 2010 – UCB and EyePACS self-sustaining program
- 2015 – Active programs in 40 states and 5 countries; 8,000 exams per month

Beijing,  
1999

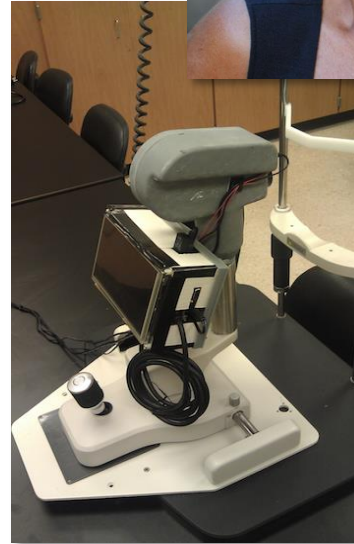


Fresno  
2003

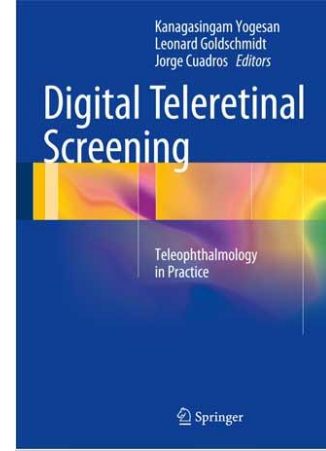
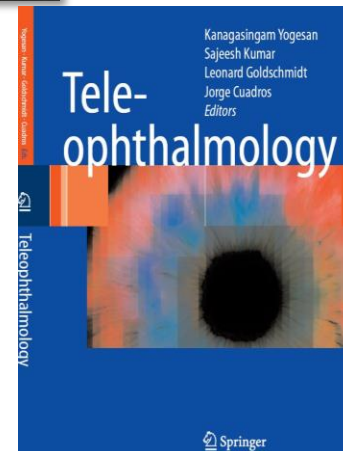
Djibouti  
2014



- Bigger – Optomap
- Smaller – PEEK, EyeGo, CellScope, EyeMitra, iExaminer, Visuscout, and more!
- Better – OCT, angiography without fluorescein, FAF, robot cameras
- Faster – SDOCT, retinal reading algorithms
- Cheaper – LKC, Asian cameras
- Will these innovations prevent blindness?



*Devices and programs discussed at UC Berkeley's 6<sup>th</sup> Translational Conference focused on innovations for the underserved*





## Lessons Learned:

- Teleretinal technology is evolving → be adaptable
  - However, success depends on organizational factors, not technology
    - Need (motivation)
    - Resources
    - Leadership
    - Mission
- 16% referred with sight-threatening conditions**  
**8.2% severe diabetic retinopathy,**  
**7.8% cataracts, glaucoma, macular degeneration, etc.**
- Minimizing barriers to access is the most essential factor for success
    - Integrated workflow and integrated support
    - Interface with EHR and data system
    - Disruptive innovation without disruption
  - Closing the loop is difficult!

# Evidence That Teleretinal Programs Prevent Blindness

- Diabetic retinopathy no longer main cause of blindness in adults age 25-70 in UK
- Veteran's Administration Program 10+ years going strong
- Teleretinal exams for diabetes now “approved” by Kaiser, “The Big 5” payers, HEDIS, ADA, AAO, AOA, CDC
- Growing number of international programs



Physician Photography Training,  
Guanajuato, Mexico

# Evidence That Teleretinal Programs Might Not Prevent Blindness

- 55% noncompliance with laser treatment in Beijing due to lack of awareness

*Hua et al, Can J Ophthalmol, 2013*

- Low compliance with screening results in poor vitrectomy outcomes

*Itoh et al, Jpn J Ophthalmol, 2012*

- “Digital retinal imaging dramatically improves screening rates, but does not improve visit compliance for treatment”

*Newman et al, Family Medicine, 2012*

- “Attendance for diabetic eye screening was inversely associated with HbA1c..”

*Scanlon et al, Diabetic Medicine, 2013*

# Closing The Loop: Report on Referral Outcomes

Study: 288 patients from 4 clinics referred through EyePACS in 2008 for specialist care of sight-threatening retinopathy

By the end of December 2009:

- 85% received notification of referral – median 46 days after EyePACS screening
- 70% received appointment – Average 65 days
- 48% of appointments were kept (96 out of 184)
- **Only 22.5% of referred patients received treatment or entered monitoring with specialist.**
- 10 patients were treated for retinopathy (10 out of 288)

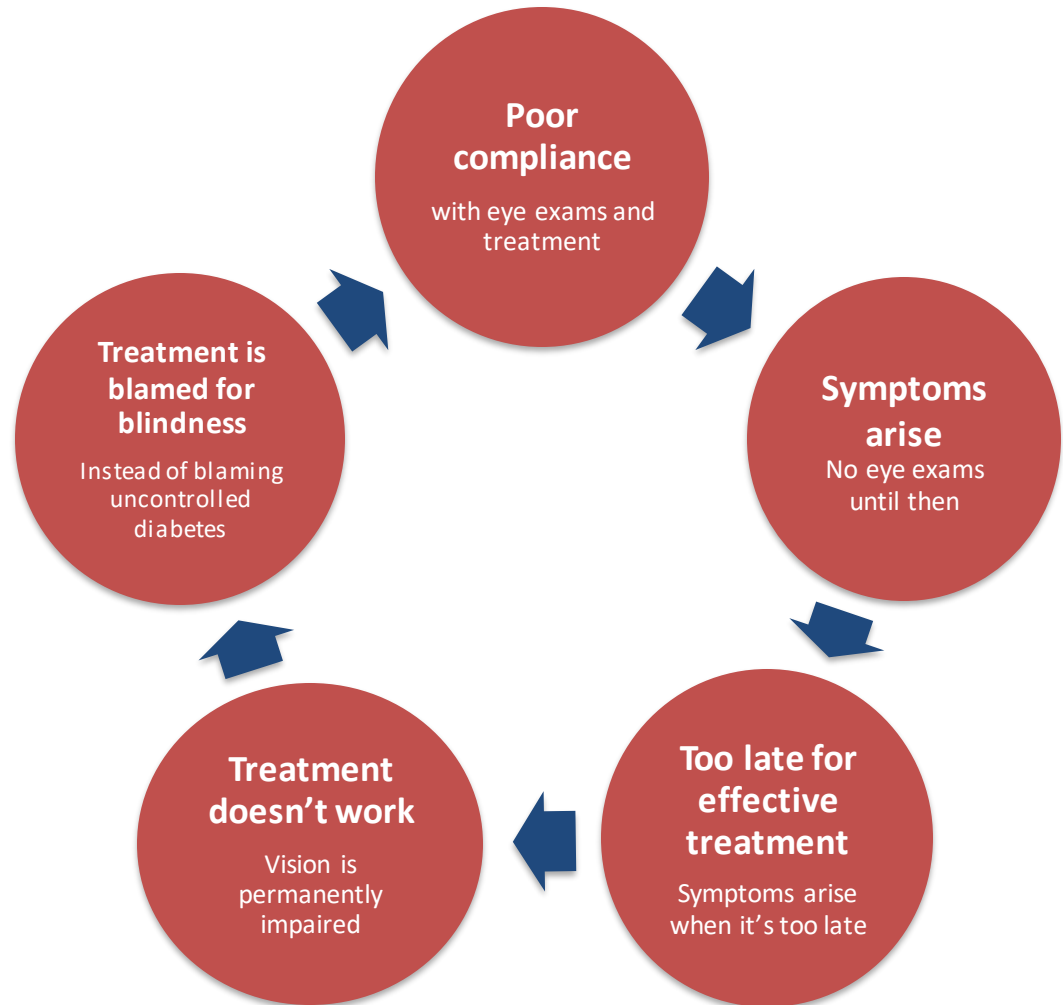


# Closing The Loop: County Retinopathy Treatment Study

- Summer 2009: Contacted 56 patients who missed ophthalmology referral appt. for retinopathy:
  - 21 failed due to logistics (didn't get appt, couldn't leave work, no child care, etc.)
  - 17 failed due to lack of money, eligibility, or insurance
  - 18 failed due to belief that treatment would not help (I see fine so I don't need tx, my friend went blind from laser, etc.)
- 2014: 254 referred patients from county health system with SNPDR, PDR, or probable CSME from January, 2011 to December 2013 with no prior visit to ophthalmology clinic
  - Only 34 attended visit to ophthalmology
  - Only 12 were treated

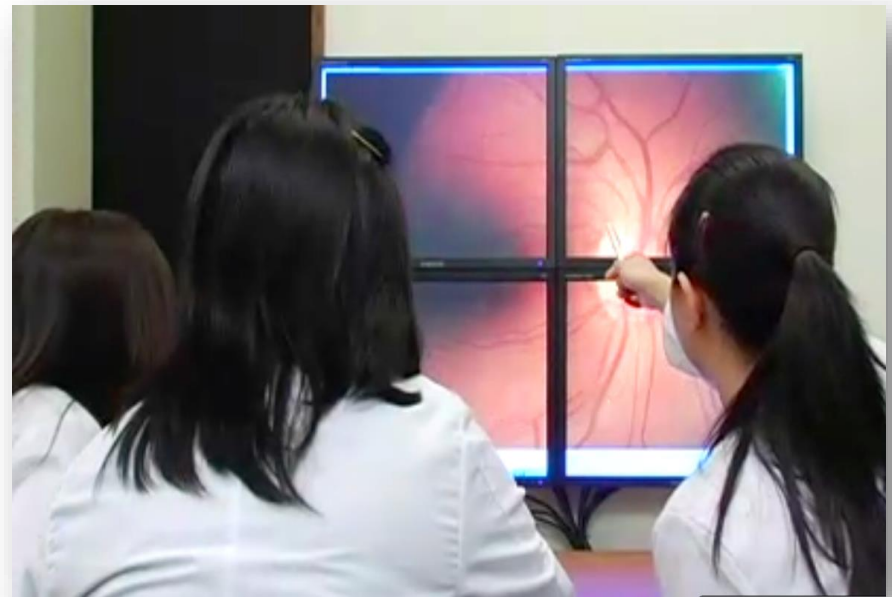
# The Vicious Cycle of Blindness

- Expressed by majority of ophthalmologists that I have encountered
- The greatest cause of permanent blindness from diabetes?
- Often not addressed by common “James Bond” –based project development



# Primary Care Providers Review Diabetic Retinal Images In Real Time, Supported By Remote Experts

- Primary Care Providers and staff are in the best position to:
  - Give immediate consultation to patients
  - Prompt referral of patients needing sight-saving tx.
- Communicate with patients about sight-threatening complications is enhanced by:
  - Established relationship
  - Reviewing actual findings with patients (seeing is believing)
- Can Primary Care Providers effectively interpret retinal images?



# Can Primary Care Providers Effectively Interpret Retinal Images For Triage of DR?

- Presented at ATTD 2013: Three clinicians (2 family MDs and a med tech) were trained and certified remotely through EyePACS Reviewer Credentialing Program.
  - Lake County, IL
  - Ventura County, CA
  - San Diego County, CA
- Each clinician graded about 85 cases each (255 total cases)
- Cases were then compared to expert grader (1 optometrist and 1 retinal specialist)



# Retinal Grading System






George Bresnick MD MPA,  
Former ETDRS Group Member

- Lesion grading (pattern recognition task to detect presence and severity of lesions) instead of full diagnosis
- Based on ETDRS, International Retinopathy Grading System, AAO Preferred Practice Patterns

# Grading Template

## Grading Template

EyePACS GRADING GUIDELINES	Right Eye			Left Eye		
	NO	Yes	Cannot Grade	NO	Yes	Cannot Grade
No apparent diabetic retinopathy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Microaneurysms ONLY (MA)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cotton wool spots (CW)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Hemorrhages with or without MA (HMA) 2a= 	<input type="checkbox"/>	<2a <input type="checkbox"/> <input checked="" type="checkbox"/> >2a	<input type="checkbox"/>	<input type="checkbox"/>	<2a <input checked="" type="checkbox"/> <input type="checkbox"/> >2a	<input type="checkbox"/>
Definite Venous Beading 6a= 	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Intraretinal microvascular abnormalities (IRMA) 8a= 	<input type="checkbox"/>	<8a <input type="checkbox"/> <input checked="" type="checkbox"/> >8a	<input type="checkbox"/>	<input type="checkbox"/>	<8a <input type="checkbox"/> <input checked="" type="checkbox"/> >8a	<input type="checkbox"/>
New vessels (NV) or Fibrous Proliferation (FP)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Preretinal (PRH) or vitreous (VH) hemorrhage	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Panretinal laser scars present (PRP)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Focal laser scars present	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
He present; distance to the center of macula (HE)	<input type="checkbox"/>	>2DD <input type="checkbox"/> <2DD <input type="checkbox"/> <1DD <input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	>2DD <input type="checkbox"/> <2DD <input checked="" type="checkbox"/> <1DD <input type="checkbox"/>	<input type="checkbox"/>

Other referable conditions in either eye:

Cataract

Glaucoma

Occlusion

Maculopathy

Other

### Image Observation Comments:

Moderate bilateral cortical cataracts. Right superior pigmented lesion approximately 1500 microns in diameter with irregular borders and uneven pigmentation.

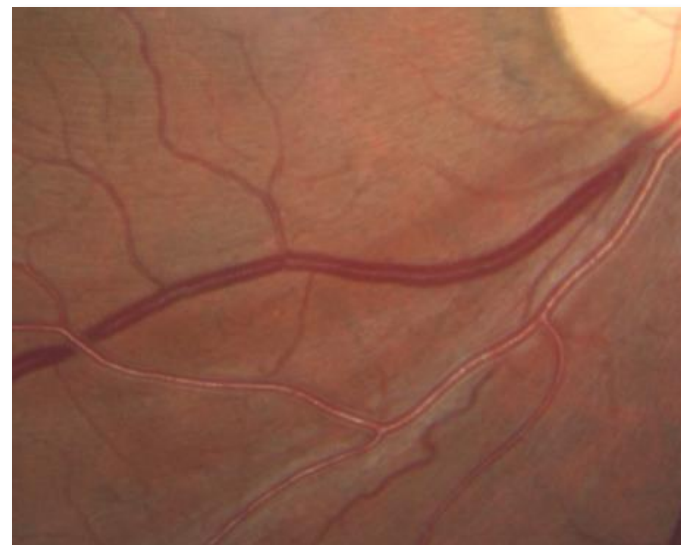
# Primary Care Providers Can Effectively Interpret Retinal Images For Triage of DR

- Primary Care Providers exceeded British Diabetic Association criteria for diabetic retinopathy screening
  - BDA criteria: > 80% Sensitivity; > 95% Specificity
  - PCPs: 81% Sensitivity; 98% Specificity when referring at level of retinopathy “greater than moderate”
- For more risk averse settings (i.e. greater emphasis on minimizing false negatives), lowering threshold of referral to “greater than mild” gives:
  - Sensitivity is 93%
  - Specificity is 82%

# Using Retinal Images For Medical Care

## – Microvascular Report Card

- Retinal biomarkers are effective independent risk factors for cardiovascular disease. Some examples:
  - Retinopathy, focal narrowing, and AV nicking
    - 4X greater risk of Uncontrolled hypertension (treated and untreated)
  - Increased venule (but not arteriole) diameter
    - 1.5 X greater risk of proteinuria and renal insufficiency in type 1 diabetics
  - Generalized narrowing of arterioles
    - 2 times greater likelihood of lower extremity amputation.
  - Arteriolar narrowing in normotensives
    - 3 X greater risk of developing hypertension over 10 years
- More research needed to validate guides
- Automated algorithms may help



- Electronic health record integration with retinal images is essential for easy access to images



# Current Work

- Integrating retinal image reading into primary care curricula
- Clinical trials through our Internet-based research environment
- Broader blindness prevention through evaluation of change over time
- Image processing algorithm trials on “real world” images

# Integrating retinal image reading into primary care

- Three US county primary care and midlevel training programs adopting retinal grading certification
- Factors determining compliance with treatment recommendations among diabetic patients in Guanajuato, Mexico
- Integrating chronic disease detection in urgent care clinics in Djibouti



Training Libyan physicians in Istanbul - 2014

# Clinical Trials Through An Internet-Based Research Environment

- Validation studies
  - retinal cameras
  - laser scanning ophthalmoscopes
  - Electrodiagnostic device trial for preliminary screening of diabetic retinopathy
- Validation of hard exudates as a surrogate for retinal thickening
- Development of SDOCT normative database for diabetic patients
- Complex pathologies in underserved populations
  - Comorbidities
  - Accumulated lack of treatment
  - Mobility issues
- Ethical considerations:
  - Align patient needs with study needs
  - Cultural sensitivity
- Longitudinal studies difficult
  - patients don't return
  - Information systems not accurate for matching visits

# Broader Blindness Prevention Through Evaluation Of Change Over Time

- No single test or combination of tests can adequately screen for glaucoma
  - *Cochrane Collaboration*
- Rate of progression greatly affects many conditions, such as pigmented lesions and maculopathy
- Patients are more likely to return to PCMH than to same eye care provider
- Expand retinal imaging to more at-risk patients by primary care photodocumentation for future disease detection.

# Looking For Change Over Time

- 61 year old Middle Eastern female with no prior eye disease diagnosis
- Date of encounter: 2/7/2012
- Diabetes for 1 year
- HbA1c = 6.0
- Indicators for glaucoma:
  - Enlarged optic nerve cupping



# Comparison Shows Significant Change

**June, 2010**



**February, 2012**



Comparison of images over 20 months showed significant change in optic nerve appearance. Sequential images shows us how fast glaucoma is progressing.

# Looking For Change Over Time

- Preliminary study:
- 87 returning diabetic patients with no suspected diagnosis of glaucoma, but with risk factors:
  - Over 70 or
  - Hispanic over 60 or
  - Black over 50 or
  - Family history and over 50
- 5 were found to have some glaucomatous optic nerve changes
- Alternating overlaid images did not perform better than side-by-side images
- Will follow up with clinics to confirm diagnosis of glaucoma

# More Than Screening, But Less Than An Exam

Is there a place in our health  
system for this type of encounter?

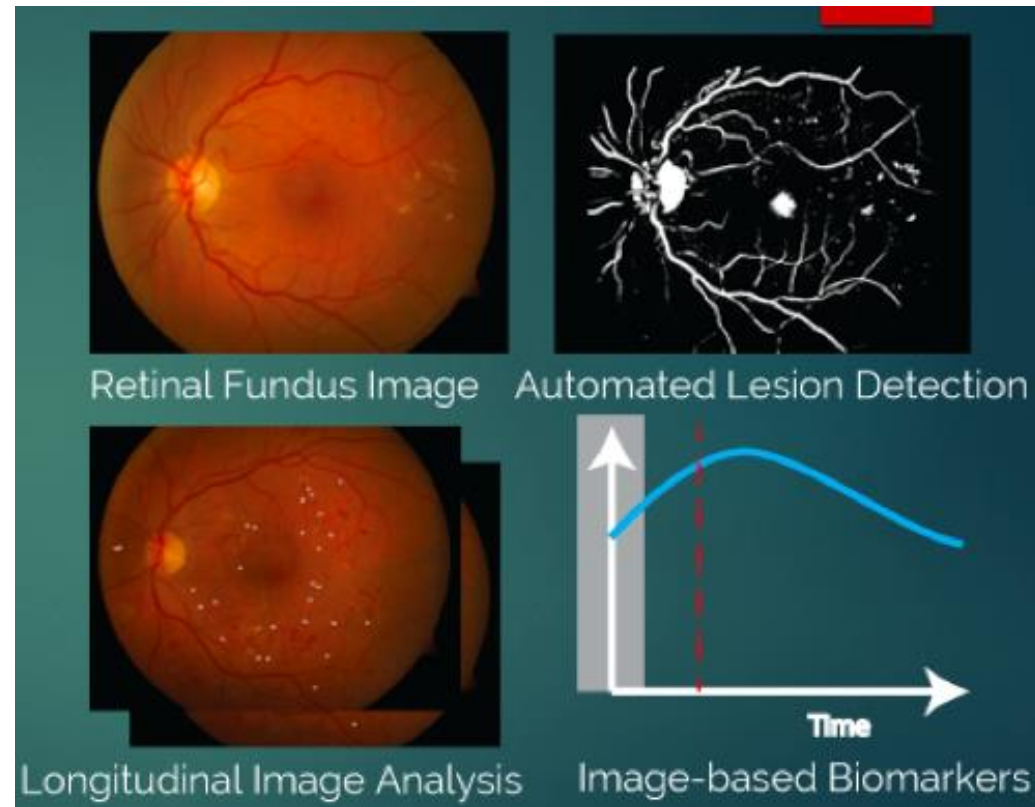


# Retinal Image Processing Algorithms On “Real World” Images

- Can artificial intelligence help us prevent blindness from diabetes?
  - Hundreds of researchers working on this problem for nearly twenty years
  - Test image sets, such as STARE and MESSIDOR (may not represent images that are actually taken in the primary care settings without pupil dilation)
  - Labs reporting up to 99% sensitivity with specificity >80%
  - Many in late stage FDA trials

# Retinal Image Processing Algorithms On “Real World” Images

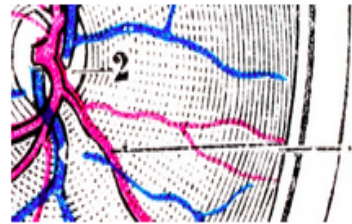
- 53,824 images processed on first run
- 90% Sensitivity/61% specificity, however, these included typical images from EyePACS network
- Newer algorithms are performing better



# Kaggle Competition Grand Challenge

- Launched with 100,000 typical screening images in February, 2015
- Ends on July 27, 2015
- 268 teams and 302 players so far
- 1705 entries so far
- Best score is .77 so far
- Prize is \$100,000
- Most entries are open source, therefore, will be made freely available to users

kaggle



\$100,000 • 268 teams

**Diabetic Retinopathy Detection**

Tue 17 Feb 2015



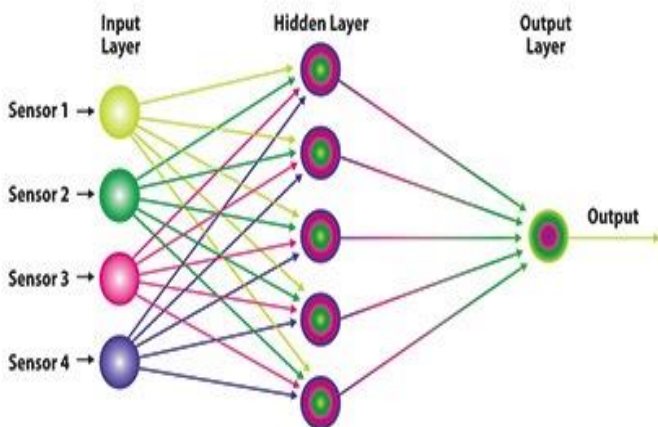
**CALIFORNIA HEALTHCARE FOUNDATION**

SUPPORTING IDEAS & INNOVATIONS TO IMPROVE HEALTH CARE FOR ALL CALIFORNIANS

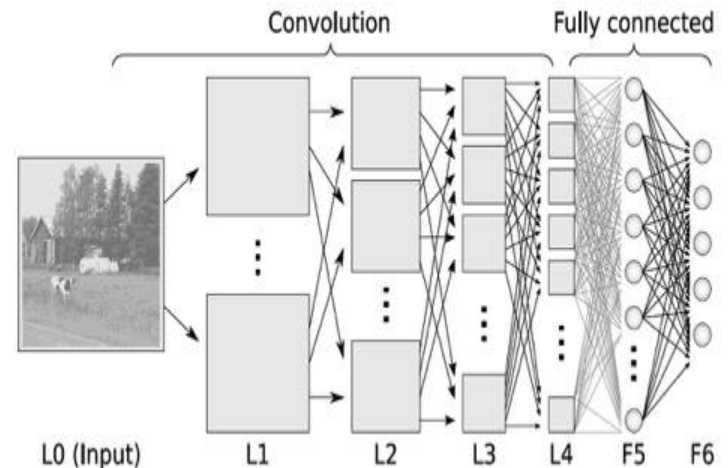
# Google Deep Learning Lab To Analyze 1,000,000 Images

- **Recent success with many huge data sets**
  - Search, maps, image recognition
- Approximating complexity of animal brain

- **Training the algorithm uses a major portion of the lab's computing resources**
- **Once trained, algorithm runs instantly on smartphone**



Complexity!



# Will AI Replace Humans or Enhance Them?

- Humans are great abstractors; computers, not so much.. yet
- Communication vs. Computation
  - What becomes the role of humans in a computationally rich environment?
  - What does it mean to have a 7 % chance of blindness
- Structural coupling
  - With many innovations, people change over time
  - How will we change?

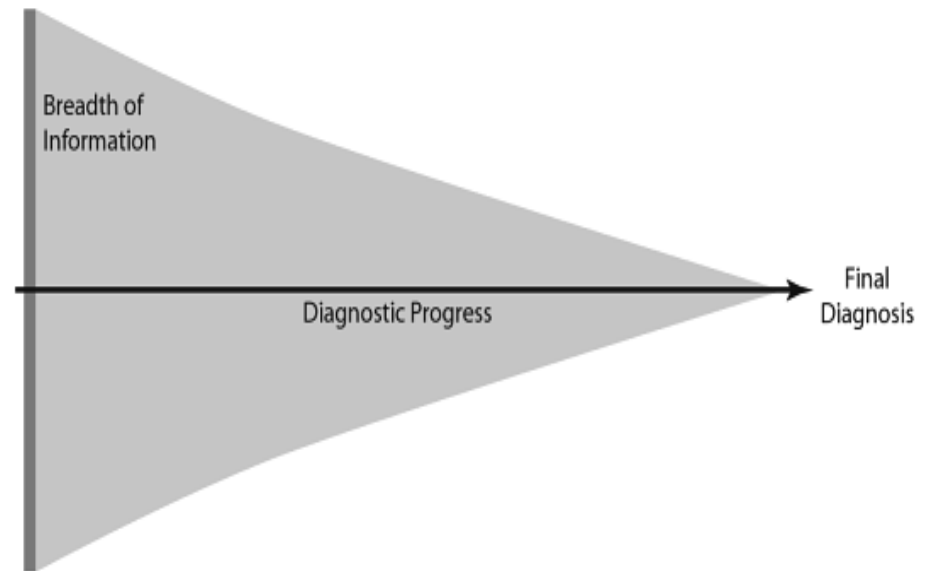


Figure 4.1. The Cognitive Span Required during Diagnosis. Source: Blois 1980, p.

Marsden Blois, MD,  
PhD,  
University of  
California,  
San Francisco 1988



# Conclusion: General Program Development Guidelines

- Increasing patient and provider adherence to treatment:
  - Target the right people
  - Address sociocultural, logistical, and resource barriers to treatment
  - Engage patients, families, and their communities
- Strategies:
  - Opportunistic exams - catch patients where they are likely to be
  - “Propinquity” – immediate feedback improves adherence
  - Couple exam with primary provider and support staff visits
  - Minimize false positives
  - Easily accessible data via integration with information systems
  - Follow up on referrals
  - Develop analysis tools

# Adherence-Based Technology And Program Development

- We screen to prevent blindness. The greatest cause of blindness is lack of communication, understanding, empathy, and trust
- When developing new technology tools and programs, keep in mind the question: “will this help to help patients actually do what they need to do to help themselves?”



*Natalie B. at CHC Connecticut receives a hug from patient as robotic camera looks on...*

# *Thank You!*



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