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
Technology Development

- 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 6th 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

• 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!

16% referred with sight-threatening conditions
8.2% severe diabetic retinopathy,
7.8% cataracts, glaucoma, macular degeneration, etc.
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

• 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

George Bresnick MD MPA, Former ETDRS Group Member
### Grading Template

<table>
<thead>
<tr>
<th>EyePACS Grading Guidelines</th>
<th>Right Eye</th>
<th></th>
<th></th>
<th>Left Eye</th>
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</tr>
</thead>
<tbody>
<tr>
<td>No apparent diabetic retinopathy</td>
<td></td>
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<tr>
<td>Microaneurysms ONLY (MA)</td>
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<tr>
<td>Cotton wool spots (CW)</td>
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<tr>
<td>Hemorrhages with or without MA (HMA) 2a=</td>
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<tr>
<td>Definite Venous Beading 6a=</td>
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<tr>
<td>Intraretinal microvascular abnormalities (IRMA) 8a=</td>
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<tr>
<td>New vessels (NV) or Fibrous Proliferation (FP)</td>
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<tr>
<td>Preretinal (PRH) or vitreous (VH) hemorrhage</td>
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<tr>
<td>Panretinal laser scars present(PR)</td>
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<td></td>
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<tr>
<td>Focal laser scars present</td>
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</tr>
<tr>
<td>He present; distance to the center of macula(HE)</td>
<td>&gt;2DD</td>
<td>&lt;2DD</td>
<td>&lt;1DD</td>
<td>&gt;2DD</td>
<td>&lt;2DD</td>
<td>&lt;1DD</td>
</tr>
</tbody>
</table>

#### Other referrable conditions in either eye:

**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%
Retinal biomarkers are effective independent risk factors for cardiovascular disease. Some examples:

- Retinopathy, focal narrowing, and AV nicking
  \(\rightarrow\) 4X greater risk of Uncontrolled hypertension
  (treated and untreated)
- Increased venule (but not arteriole) diameter
  \(\rightarrow\) 1.5 X greater risk of proteinuria and renal insufficiency in type 1 diabetics
- Generalized narrowing of arterioles
  \(\rightarrow\) 2 times greater likelihood of lower extremity amputation.
- Arteriolar narrowing in normotensives
  \(\rightarrow\) 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 overlayed 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
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
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?

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

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