Conflicts of Interests Disclosure

- AAO Foundation – Hoskins Center for Quality and Safety
- American Board of Ophthalmology
- Centers for Disease Control and Prevention

- American Glaucoma Society
- American University Professors of Ophthalmology

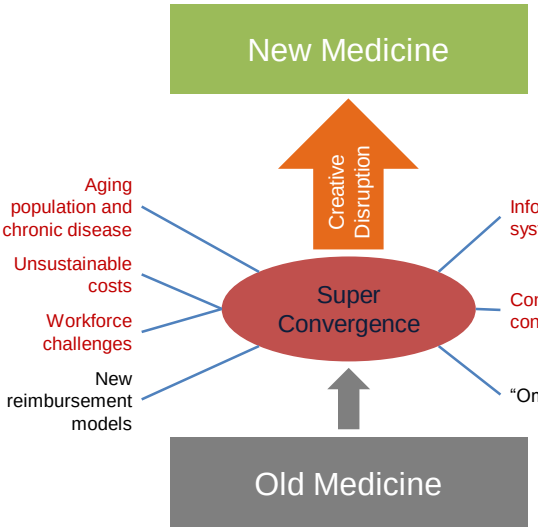
- Consultant /Research
  - Alcon Research Institute
  - Kellogg Foundation
  - National Eye Institute
- University of Michigan
- Duke University

- Intellectual property
  - Statins for glaucoma
  - EMR decision support and data entry

Framing "Tele-ophthalmology" or "E-Eye Health"

- Rationale
- Current general usage
- Meeting presentations
- Additional considerations
- Future implications

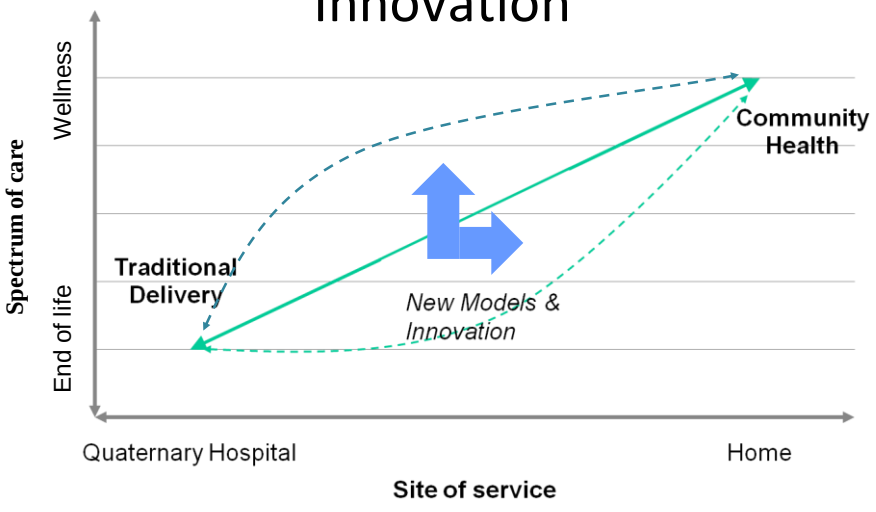
The Creative Disruption of Medicine



Adapted from "The Creative Destruction of Medicine" by Eric Topol

Care at Home

Population Health & Health Innovation



Source: Paul Lee

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E-Health / Tele-health

Kaiser-Permanante - AAPC, 2017

- 52 percent of the more than 100 million patient encounters at Kaiser take place remotely.
- 95 percent of its nearly 12 million members are covered on a capitated basis.
- invests about 25 percent of it annual capital spending on IT

Additional Kaiser Programs

- “House calls” for e-health visits
- Secure e-mail usage increases HEDIS scores
- E-health saves $ for Kaiser due to capitated state

- Across all systems n USA, projected to be 25% of outpatients visits by 2025

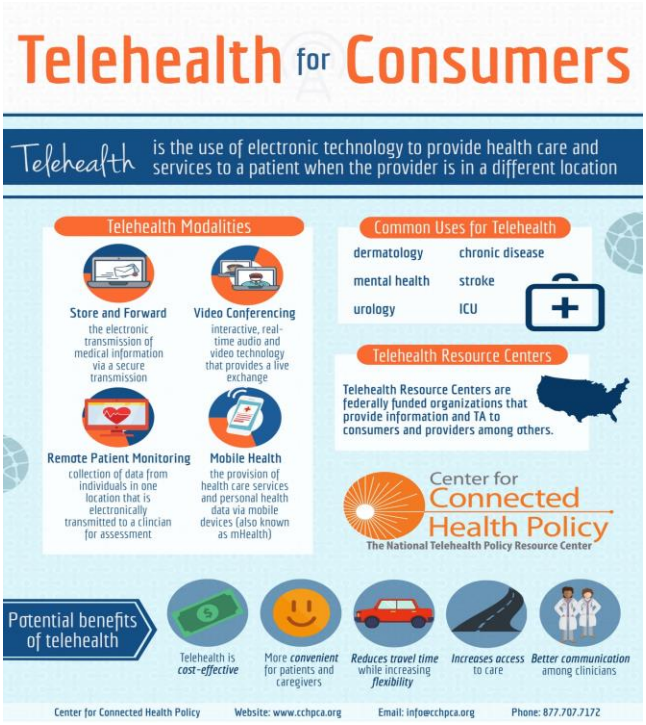
6

Drivers for Growth in Tele / Mobile Health

(ATA Survey, 2017)

- Consumer interest 48%
- Value-based care transition 26%
- Reduced cost of care 11%
- Evidence-based practice guidelines 7%

7



Tele-Ophthalmology Today

Rathi S, et al, Ophthal 2017; Woodward M et al, various

Ongoing current usage

- ROP screening AND monitoring
- Diabetic retinopathy screening and monitoring
- AMD screening and monitoring
- Glaucoma (open-angle / POAG)
- Refractive error
- Initial eye exam for screening and referral

Active exploration

- Emergency room coverage
- Corneal diseases
- Angle closure glaucoma
- Comprehensive eye exam for management
- Others

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Overview / FDA Topics

- Accelerating innovation to encourage digital health – Z Bodnar
- Regulation of digital health – B Patel
- FDA perspectives on mobile medical applications and telemedicine – R. Schuchard
- Medical device data systems – K Yeshwant

Uses in Ophthalmology

- Retinopathy of Prematurity
  - Paul Chan, MD
- Diabetic Retinopathy
  - Ingrid Zimmer-Galler, MD

- Advanced Analytics
  - Michael Chaiang, MD
- Machine Learning
  - Linda Zangwill, PhD

Key Questions

- Patient Interface with Digital Health
  - John Reites

- Digital health device as aid for diagnosis
  - D. Azar; L Bottorff; D Morrison; D Moshfeghi, M Woodward; I Zimmer-Galler // N Afshari and M Trese (moderators)
- Safety and effectiveness for use of ophthalmic device
  - M Abramoff, M Chiang, P Dugel; M Goldbaum; Q Oswald; L Zangwill // M Blumenkranz and K Nischal (moderators)
- Safeguards and methods for mitigating risks
  - L Al-Aswad; N Karandikar; D Myung; J Reites; E Sharon // M Humayun and D Sprunger (moderators)

Framing "Tele-ophthalmology" or "E-Eye Health"

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- Future implications

Additional Considerations for Use

- Technical performance
  - What is the reference standard / "gold standard"
  - Validity
    - Does it reflect or capture the "gold standard" or "truth"
    - Does it achieve the specified purpose
  - Reliability
    - Test-retest – does it provide the same result each time
    - Intra-test – is it consistent internally
    - Inter-rater – if applicable, do different "observers" get same results
- Implementation considerations
- Legal issues
- Payment coverage

ATA Validation Standards

Diabetic Retinopathy

- Level 1 – no or minimal pathology vs worse
- Level 2 – presence or absence of sight-threatening retinopathy (severe NPDR) for screening
- Level 3 – provide clinical recommendations similar to in person exam
- Level 4 – replacement for ETDRS photos for research or clinical work

Comparison of Screening Techniques

Pugh JA, Jacobson JM, van Heuven WAJ, et al, Diab Care **1993**;16: 889-95

	Miss PDR or mod-sev	"None" when PDR or mod-severe
Ophthalmologists	50 / 73	19 / 73
PA's	43 / 51	11 / 51
One non-mydriatic	30 / 64	9 / 64
Three dilated	17 / 68	6 / 68

Uses 4 stage system in this analysis

none / mild / moderate - severe / proliferative

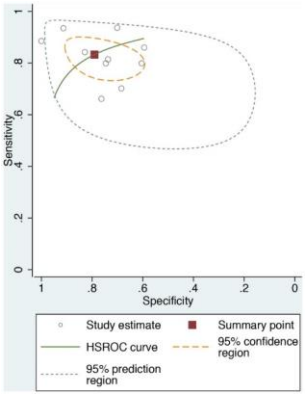
Interobserver Differences ≥ 0.2 DD

From Feuer, et al, AJO, 2002

Hitchings, et al	3 specialists	8 to 20 %
Tielsch, et al	2 specialists	17 to 19 %
Varma, et al	6 specialists	19 %
Abrams, et al	6 optometrists	29 %
	6 residents	28 %
Shuttleworth	2 ophthalmologists	3 %
Feuer, et al	Reading Center	5 to 7 %

Meta-Analysis of Comparison In-Person to Remote Care (Thomas SM et al, PLOS One, 2014)

- Pooled analysis (n=45 included studies)
  - Diagnostic accuracy (n=8) using ONH exams (remote exams)
    - Sensitivity 83%
    - Specificity 79%
  - Diagnostic accuracy (n=2) using VF for suspects (remote exams)
    - Sensitivity 82%
    - Specificity 96%
  - Diagnostic accuracy (n=3) for in-person exam
    - Sensitivity 75% (+/- 28%)
    - Specificity 89% (+/- 10%)



Additional Considerations for Use

- Technical performance
- Implementation considerations
  - Use in care continuum
  - Level of autonomy of system
  - Patient acceptance, understanding and use
  - Technical infrastructure
- Legal issues
- Payment coverage

When in Clinical Care is it Used – and what is its purpose ?

Clinical Spectrum

- General information for public
- Self-care and tracking of health
- Entry into system via screening
- Active patient care in system ("new patient")
- Continuation with care ("return patients" or "active monitoring")

Level of Autonomy

- Tool to motivate for additional evaluation
- Decision aid for detection of specific finding(s)
- Decision aid for diagnosis and / or management
- Determine diagnosis and / or management
- In lieu of specialist

Patient Willingness to Use Video Care and Other Forms of Care (Harris Poll, 2014)

- 64% willing to participate in MD video visit
  - 61% cited convenience
  - 11% aged 18 to 34 would switch to MD doing
- If they or loved one with high fever in middle of night and needed attention
  - 41% go to ER
  - 21% video visits
  - 17% call a 24 hour nurse call line
  - 5% online symptom checker

National Academy of Medicine Definition of Diagnostic Error

- "… the failure to
- (a) establish an acurate and timely explanation of the patient's health problem(s) or
- (b) communicate that explanation to the patient

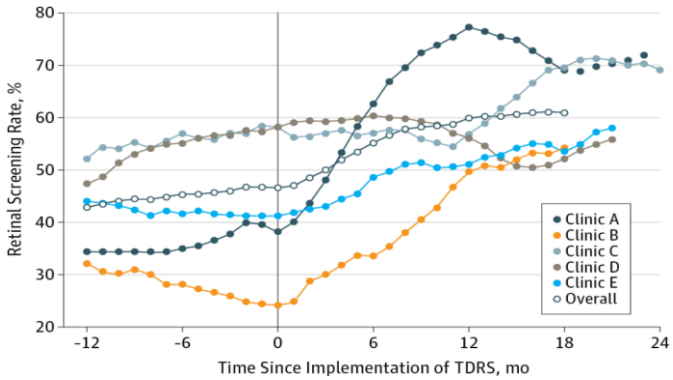


Figure Legend:

Comparison of Unadjusted Screening Rates Over Time at 5 Safety Net Clinics Before and After Initiation of Teleretinal Diabetic Retinopathy Screening (TDRS)Time of initiation of TDRS represented as time 0 for all clinics (vertical line), although clinics implemented the intervention on a rolling basis, with actual start dates varying across a 10-month period.

Patient Follow-up of DR Screening

Jani PD, Forbes L, Choudhury A, et al. JAMA Ophthalmology, 2017

- 5 primary care clinics in rural and underserved populations – 1661 patients
- Impact on DR assessments
  - Pre-implementation 26%
  - After implementations 40%
- Follow-up care
  - 60% completed referral visit

Additional Considerations for Use

- Technical performance
- Implementation considerations
- Legal issues
  - State licensure laws
    - Patient location as "site" of practice
    - "Consultation" exception in many states
  - Corporate practice of medicine restrictions
  - HIPAA issues (e.g., business associate agreement with vendor(s))
  - Legal liability
- Payment coverage

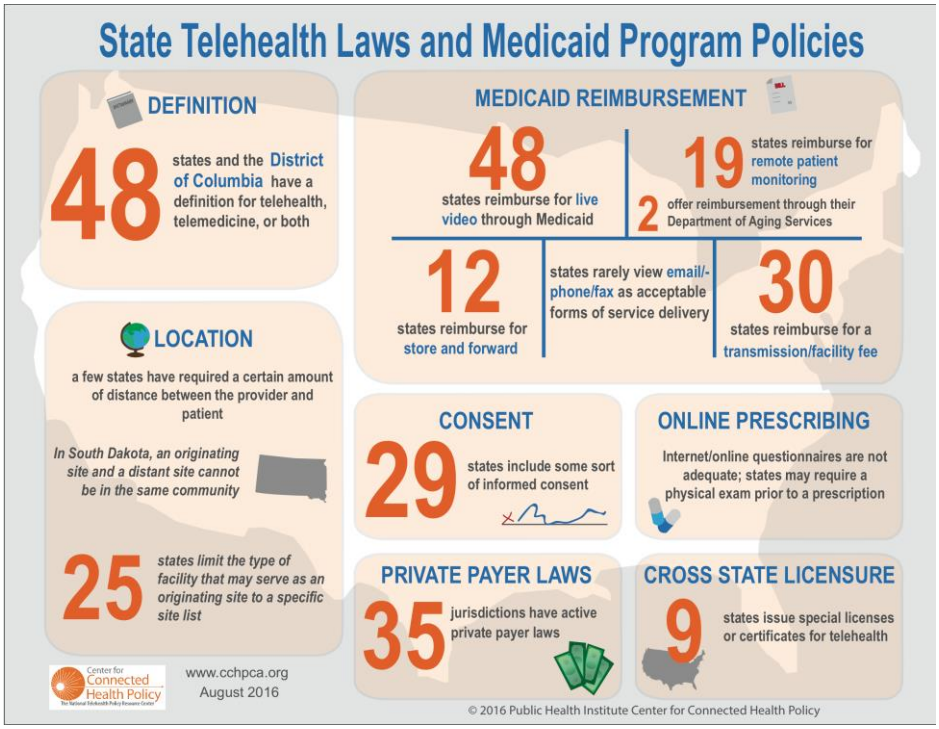
Legal Liability Issues to Review

Questions pertaining to physician

- Is telehealth service covered by insurance policy ?
- Is it covered if service is provided to patient in another state ?
- Is it within at least a "respectable minority" standard of care ?
- Is it consistent with federal and state rules ?

Systems issues in e-health

- Is misdiagnosis / mismanagement the responsibility of the system or the physician ?
  - Level of autonomy of system
  - Systemic flaw or bias
- What is role, if any, of systems maintenance of technical infrastructure (e.g., display and lighting standards)



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Relationship with Patient Interactions and Health System Design

- Establish relationship

- Acquire data
- Interpret data
- Accurate diagnosis
- Appropriate therapy

- Patient use of care

- Follow-up Care
- Communities / Networks

- Personal to patient and physician
- Instruments
- Algorithms
- Data integration / Analysis
- Point of care support / decision systems
- Leverage technology

- Relationships

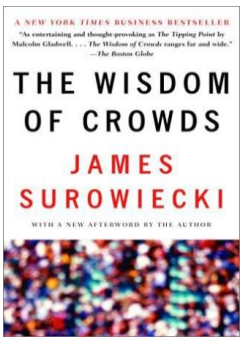
New Market Entrants

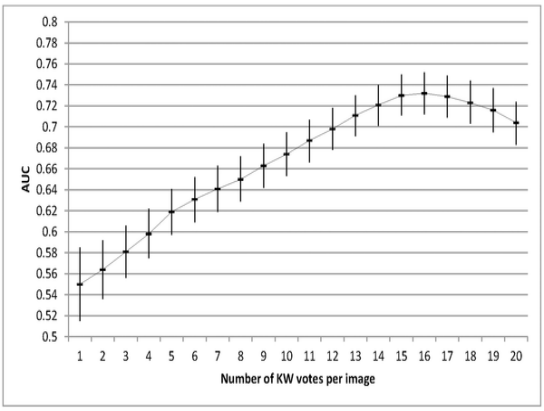
Private Equity

Google

Value of Diversity in Groups for Complex Tasks

Scott Page, Center for the Study of Complex Systems, Univ. of Michigan





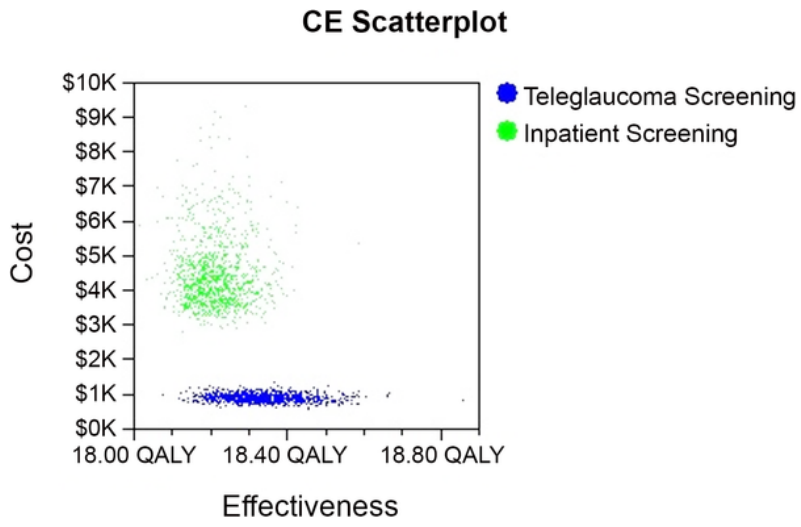
Mitry D, Peto T, Hayat S, Morgan JE, Khaw KT, et al. (2013) **Crowdsourcing as a Novel Technique for Retinal Fundus Photography Classification:** Analysis of Images in the EPIC Norfolk Cohort on Behalf of the UKBiobank Eye and Vision Consortium. PLoS ONE 8(8): e71154. doi:10.1371/journal.pone.0071154 http://journals.plos.org/plosone/article?id=info:doi/10.1371/journal.pone.0071154

Diabetic Retinopathy Analysis Using Maching Learning (DREAM)

Roychowdhury S, et al, IEEE J Biomed Halth Informatics, 2014; 18: 1717-28

Method	SEN (%)	SPEC (%)	AUC
MESSIDOR Data			
Sanchez et.al.[27]	92.2	50	0.876
Agurto et.al.[8]	92	54	0.84
Antal et.al.[33]	96	51	0.875
Esnaashari et.al.[32] ($\leq$ 300 images)	95	89.29	-
Barriga et.al.[34](400 images)	98	67	0.86
DREAM	100	53.16	0.904
Local Data			
Agurto et.al.[35](2247 images)	92	51	0.89
Acharya et.al.[36](300 images)	82	88	-
Acharya et.al.[37](331 images)	82	86	-
Usher et.al.[38](1273 images)	94.8	52.8	-

Fig 4. Cost-Effectiveness Scatterplot.



Thomas S, Hodge W, Malvankar-Mehta M (2015) The Cost-Effectiveness Analysis of Teleglaucoma Screening Device. PLOS ONE 10(9): e0137913. https://doi.org/10.1371/journal.pone.0137913
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0137913

PLOS ONE | TENTH ANNIVERSARY

Telemedicine - Glaucoma

- PubMed – 73 papers on 7/5/15; 85 papers on 8/7/16; 97 papers on 10//11/17
- First paper (English) in 1998
  - Yogeson K, Constable IJ, Eikelboom RH, van Saarloos PP. Tele-ophthalmic screening using digital imaging device. Aust NZJ Ophthal 1998.
- Use of teleconsultation enables remote management of 69% of glaucoma and suspects by optometrists, 48% requiring repeat teleconsult
  - Vernon S, Arora S, Kassam F, Edwards MC, Damji KF. Northern Alberta Remote Teleglaucoma program Can J Ophthal 2014

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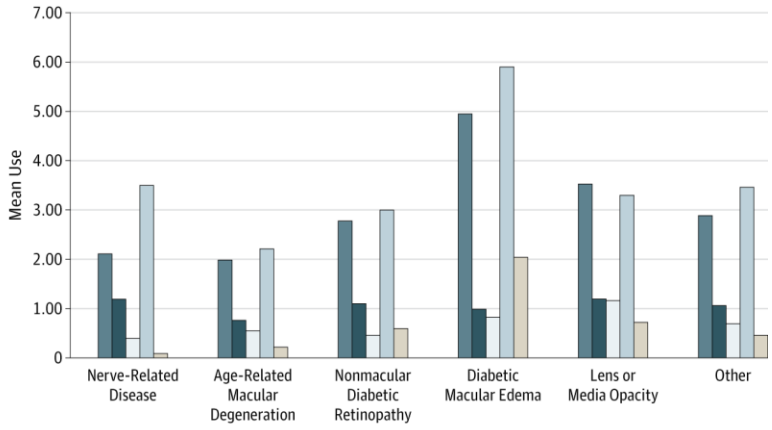
One non-mydriatic	30 / 64	9 / 64	(10)
Three dilated	17 / 68	6 / 68	(3)

Uses 4 stage system in this analysis

none / mild / moderate - severe / proliferative

Eye Care Use for 260 Patients Seen in Clinic for 2 Years after Teleretinal Screening by Disease

(Chasan JE, et al, JAMA Ophthal 2014)



	Nerve-Related Disease	Age-Related Macular Degeneration	Nonmacular Diabetic Retinopathy	Diabetic Macular Edema	Lens or Media Opacity	Other
Cumulative No. of visits	2.11	2.03	2.79	4.96	3.52	2.89
Total No. of spectacles	1.20	0.78	1.10	0.96	1.22	1.07
Total No. of prescriptions	0.39	0.57	0.46	0.84	1.18	0.69
Total No. of diagnostic procedures	3.50	2.22	3.01	5.88	3.29	3.46
Total No. of surgical procedures	0.11	0.24	0.59	2.04	0.74	0.47