Merging Analytic Modeling With Clinical and Operations Data Research: Rotman School Presentation, March 2019

Rotman School of Management
UNIVERSITY OF TORONTO

March 4, 2019 Roundtable: Data Analytics in Healthcare

The Power of Hybrid Medical Research: Merging Analytic Modeling With Clinical and Operations Data Research

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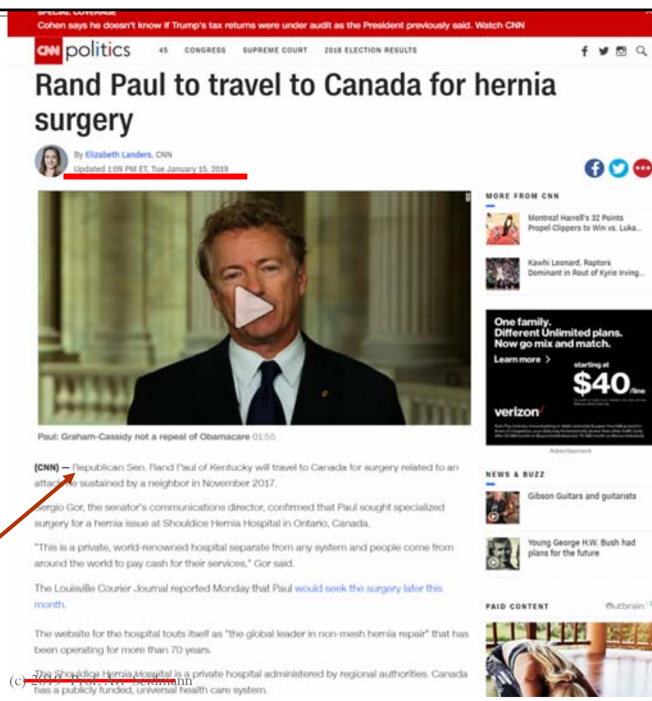
SIMON SCHOOL OF BUSINESS
UNIVERSITY of ROCHESTER

The $ Burden of Chronic Diseases

It consumes about 75% of all our Healthcare Budget



SPECIAL COVERAGE
Cohen says he doesn't know if Trump's tax returns were under audit as the President previously said. Watch CNN

CNN politics 45 CONGRESS SUPREME COURT 2018 ELECTION RESULTS

Rand Paul to travel to Canada for hernia surgery

By Elizabeth Landers, CNN
Updated 1:09 PM ET, Tue January 15, 2019

Paul: Graham-Cassidy not a repeal of Obamacare 01:55

(CNN) — Republican Sen. Rand Paul of Kentucky will travel to Canada for surgery related to an attack he sustained by a neighbor in November 2017.

Sergio Gor, the senator's communications director, confirmed that Paul sought specialized surgery for a hernia issue at Shouldice Hernia Hospital in Ontario, Canada.

"This is a private, world-renowned hospital separate from any system and people come from around the world to pay cash for their services," Gor said.

The Louisville Courier Journal reported Monday that Paul would seek the surgery later this month.

The website for the hospital touts itself as "the global leader in non-mesh hernia repair" that has been operating for more than 70 years.

The Shouldice Hernia Hospital is a private hospital administered by regional authorities. Canada has a publicly funded, universal health care system.

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Kawhi Leonard, Raptors Dominant in Rout of Kyrie Irving...

NEWS & BUZZ
Gibson Guitars and guitarists
Young George H.W. Bush had plans for the future

PAID CONTENT

The Meaning of it All….

The Role of Medical Infiormatics

Big Data and AI

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The Most Famous One

JAMA Network

JAMA Internal Medicine | Journals | Enter Search

This Issue | Views 9,194 | Citations 45 | Altmetric 282

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Original Investigation | Less Is More | FREE

November 2015

Diagnostic Accuracy of Digital Screening Mammography With and Without Computer-Aided Detection

Constance D. Lehman, MD, PhD[1]; Robert D. Wellman, MS[2]; Diana S. M. Buist, PhD[2]; et al

Author Affiliations | Article Information

JAMA Intern Med. 2015;175(11):1828-1837. doi:10.1001/jamainternmed.2015.5231

Medical Imaging

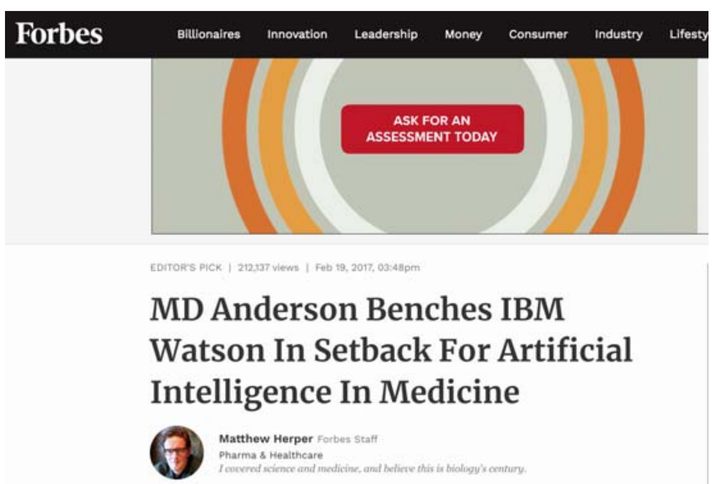
Introduction

Computer-aided detection (CAD) for mammography is intended to assist radiologists in identifying subtle cancers that might otherwise be missed. Computer-aided detection marks potential areas of concern on the mammogram, and the radiologist determines whether the area warrants further evaluation. Although CAD for mammography was approved by the US Food and Drug Administration (FDA) in 1998,[1] by 2001, less than 5% of screening mammograms were interpreted with CAD in the United States. However, in 2002, the Centers for Medicare and Medicaid Services (CMS) increased reimbursement for CAD, and by 2008, 74% of all screening mammograms in the Medicare population were interpreted with CAD.[2,3]

Medical Imaging

Conclusions and Relevance Computer-aided detection does not improve diagnostic accuracy of mammography. These results suggest that insurers pay more for CAD with no established benefit to women.

Oncology Care


Forbes | Billionaires | Innovation | Leadership | Money | Consumer | Industry | Lifesty

EDITOR'S PICK | 212,137 views | Feb 19, 2017, 03:48pm

MD Anderson Benches IBM Watson In Setback For Artificial Intelligence In Medicine

Matthew Herper Forbes Staff
Pharma & Healthcare
I covered science and medicine, and believe this is biology's century.

Rise of AI-as-a-medical-device

- **The FDA is fast-tracking approvals of artificial intelligence**

software for clinical imaging & diagnostics.

- In April 2018, the FDA approved AI software that **screens patients for diabetic retinopathy** without the need for a second opinion from an expert.
- It was given a "breakthrough device designation" to expedite the process of bringing the product to market.
- The software, IDx-DR, was able to correctly identify patients with "more than mild diabetic retinopathy" 87.4% of the time, and identify those who did not have it 89.5% of the time.

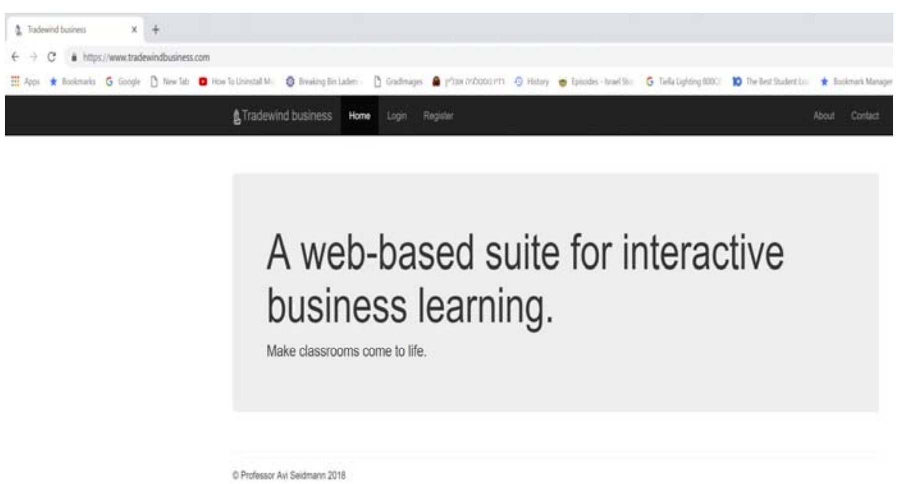
Apple disrupts clinical trials

- Since 2015, Apple has launched two open-source frameworks —**ResearchKit** and **CareKit** — to help clinical trials recruit patients and monitor their health remotely.
- The frameworks allow researchers and developers to create medical apps to monitor people's daily lives.
- In January 2018, Apple announced that iPhone users will now have **access to all their electronic health records** from participating institutions on their iPhone's Health app
- The App is Called "**Health Records**."

Our Telemedicine Research Sample

- *"Randomized, controlled trial of "virtual housecalls" for Parkinson disease"* (with Dorsey et al),
  - *JAMA Neurology (2013)*
- *"Telemedicine in leading US neurology departments"* (with George, et al)
  - *The Neurohospitalist (2012)*
- *"The competitive impact of telemedicine mode of treatment for chronic conditions" (with Rajan and Dorsey)*
  - *Journal of Management Information Systems (2013)*
- *"Telemedicine for patients suffering from Migraine"* (with Freidman and Rajan), HICSS (2019)
- *"Service Systems with Heterogeneous Customers: Investigating the Effect of Telemedicine on Chronic Care" (with Tezcan and Rajan),*
  - *Management Science (2018)*

My Research & Developments Interests



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The Physician **Crisis**

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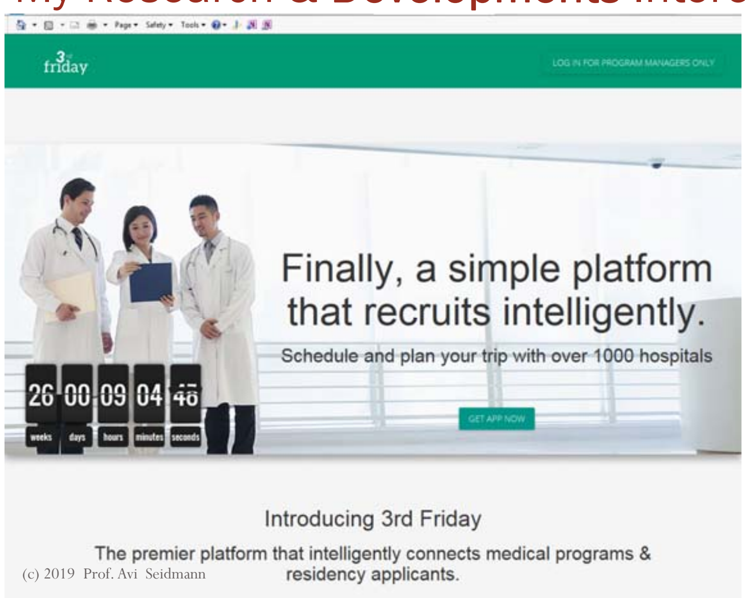
AAMC 2018 workforce research

The U.S. faces a potential shortage of 33,800 to 72,700 physicians in non-primary care specialties. This includes a potential shortfall of 20,700 to 30,500 physicians in 2030 for surgical specialties. AAMC attributed the projections to an aging population requiring more complex care as well as a stagnant supply of surgical specialists and other factors.

My Research & **Developments** Interests



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Play

A whole Cycle in 40 Seconds


THE WALL STREET JOURNAL.

UNPREPARED

The Loneliest Generation: Americans, More Than Ever, Are Aging Alone

Loneliness undermines health and is linked to early mortality—and baby boomers are especially feeling the effects

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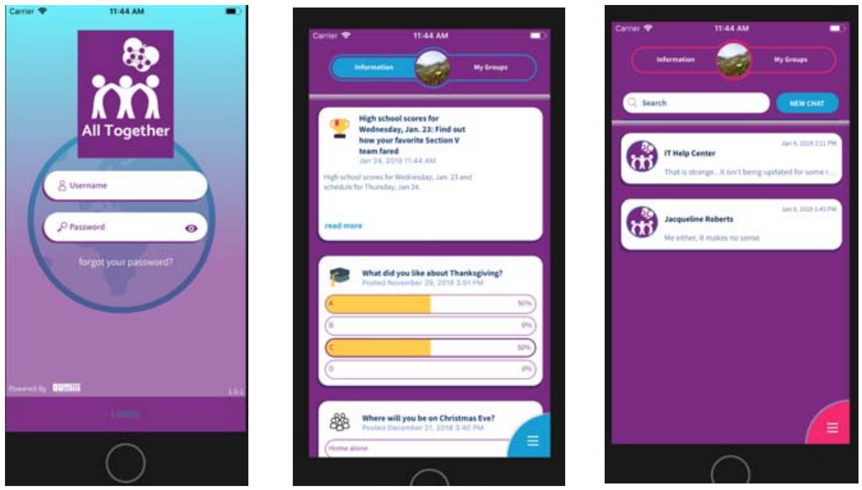
The AllTogether System



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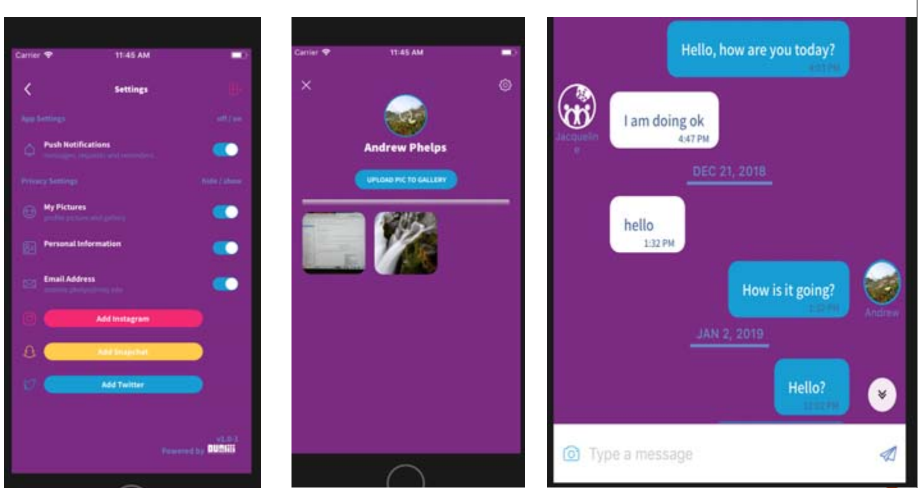
The AllTogether System II



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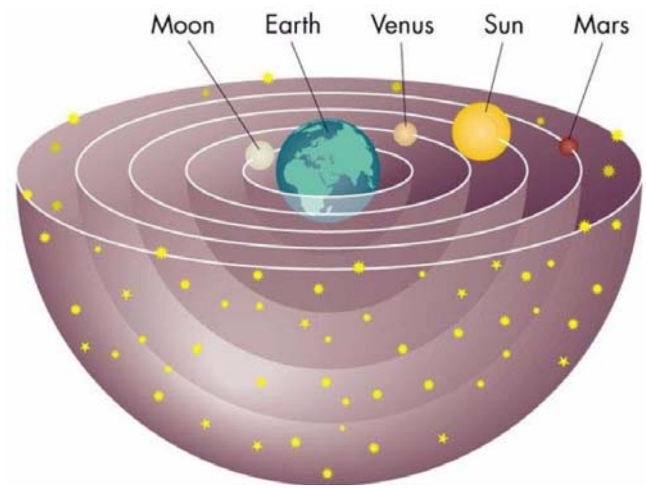
Our Talk Today

- **Lessons from Galileo Galilei**
  - Observations can be misleading…
- **1. Information *Hang-overs* in Healthcare Service Systems**
  - The value of systematic (end to end) process flow analytics
- **2. Does Technology Substitute for Nurses?**
  - The data and economics of process flow automation
- **3. The Operational Effects of Telemedicine on Chronic Care**
  - MDs and Patients as players in complex Non-Atomic Games
- **Overall Data & Analytics Insights from it all**
  - Why Medical Schools start teaching Medical Informatics

- **What you know about, You See**

Goethe (1851)

PTOLEMY GEOCENTRIC THEORY



Galilei displaying his telescope in Venice

The moons of Jupiter
“Medicean Stars”

Four Quick Lessons to Recall

1. Galileo Galilei, like Kepler, was a mathematician. He combined his newly Observed Data with Math Modelling.
2. Galileo complained to Kepler that some of the philosophers who opposed his discoveries had **refused even to look through his telescope**.

3. When the truth contradicts what WE believe, WE tend to abandon the truth.
4. WE tend to refuse to consider <u>evidence</u>—if what they might discover contradicts what WE believe.

Three Studies to Make a Point…

Analyzing the Differential Impact of Radiology Information Systems Across Radiology Modalities

Atanu Lahiri, MS, Abraham Seidmann, PhD

Purpose: The aim of this study was to assess the impact of redesigning a medical imaging workflow using a commercial radiology information system (RIS), particularly the impact of implementing a disciplined collection of background clinical information all along the clinical service chain.

Materials and Methods: The impact of the RIS on the total report turnaround time and on its various components, such as the radiologist interpretation, transcription, and radiologist review turnaround times, was empirically investigated. Advanced statistical tools were used, including lognormal survival functions and *t*-tests, to compare and analyze the pre-RIS and post-RIS operational performance of a regional network of outpatient clinics.

Results: The RIS installation did not produce uniform benefits for all modalities. There was no statistically significant impact on report turnaround times for magnetic resonance imaging. On the other hand, turnaround times for mammographic studies declined significantly.

Conclusion: Although the additional time needed to navigate through the RIS screens might have (unexpectedly) increased the radiologists' interpretation cycle times, the overall benefits of the RIS outweighed this negative effect in this study. Before the RIS installation some clinical background information was not available to the radiologists at the time of interpretation. As a part of the RIS implementation the radiology practice introduced several disciplined data collection procedures to make such information readily available downstream. These procedures significantly reduced the percentage of mammographic studies that had to be put on hold, increasing radiologists' overall performance and income. The effectiveness of any RIS solution, therefore, significantly depends on systemwide analyses of all relevant performance metrics and also on the creative implementation of new clinical and administrative workflows.

Key Words: Radiology information system, economic impact, workflow redesign, report turnaround, radiologist productivity, medical information systems

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Information *Hang-overs* in Healthcare Service Systems

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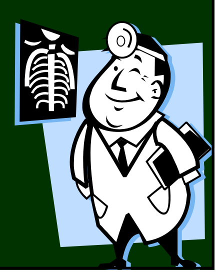
The literature on business process design has focused on issues such as bottlenecks, workflow configuration (series versus parallel), replacing an existing workflow with a shorter one, etc. One important issue that has not received adequate attention is the information-intensive nature of medical service systems. Performance of clinical workflows depends not only on how various steps are carried out but also on when certain information items are collected. We report the results of a long-term empirical study that looked at the implementation of a radiology information system (RIS) at a large regional network of radiology clinics. We find that a failure to gather necessary clinical background information in earlier steps significantly delays later steps and causes them to *hang over*, with a significant impact on the total turnaround time of diagnostic reports. We show that information systems can solve this problem by separating the task of gathering information from its usage and relocating that task upstream in the workflow. We argue that such unbundling can lead to shorter report turnaround times even if it significantly increases the utilization of the bottleneck server. These results have broader implications for the optimal design of other clinical workflows, such as the process of filling prescriptions in pharmacies or the typical surgical preanesthesia evaluation in hospitals. Finally, we explain why the impact of addressing hang-over is often nonuniform across clinical modalities, providers, and patient types.

Key words: medical information systems; clinical workflow; workflow design; hang-over; feedback queue
History: Received: March 28, 2011; accepted: December 20, 2011. Published online in *Articles in Advance* April 13, 2012.

Objective

- To investigate the **counter-intuitive** impacts of changes in the information-processing workflow on the overall performance of a clinical service organization

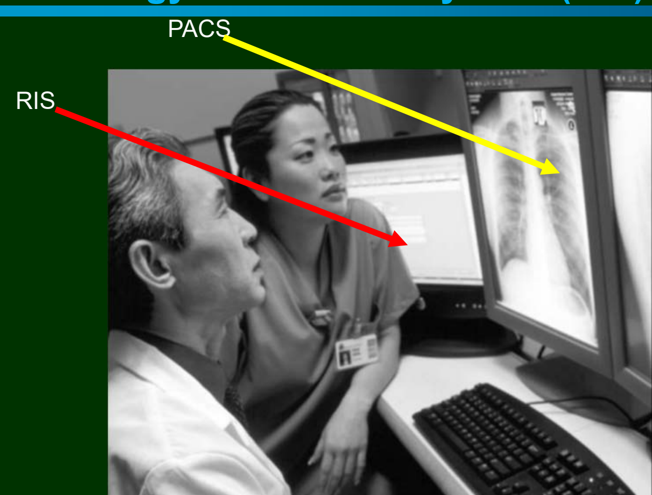


Information *Hang-overs* in Healthcare Service Systems

- At Yale, Holt et al. (2007), find that nearly 23% of 1,800 surgeries were delayed because of missing information, putting patients at severe risk!
- "*Day-of-surgery delays caused by missing information remain relatively common despite pre-anesthesia evaluation…*"

- Holt, N. F., D. G. Silverman, R. Prasad, J. Dziura, K. J. Ruskin, 2007. Pre-anesthesia clinics, information management, and operating room delays: results of a survey of practicing anesthesiologists. *Anesthesia and Analgesia* 104(3) 615-618.

Research Question: How to improve a radiology workflow using a Radiology Information System (RIS)?



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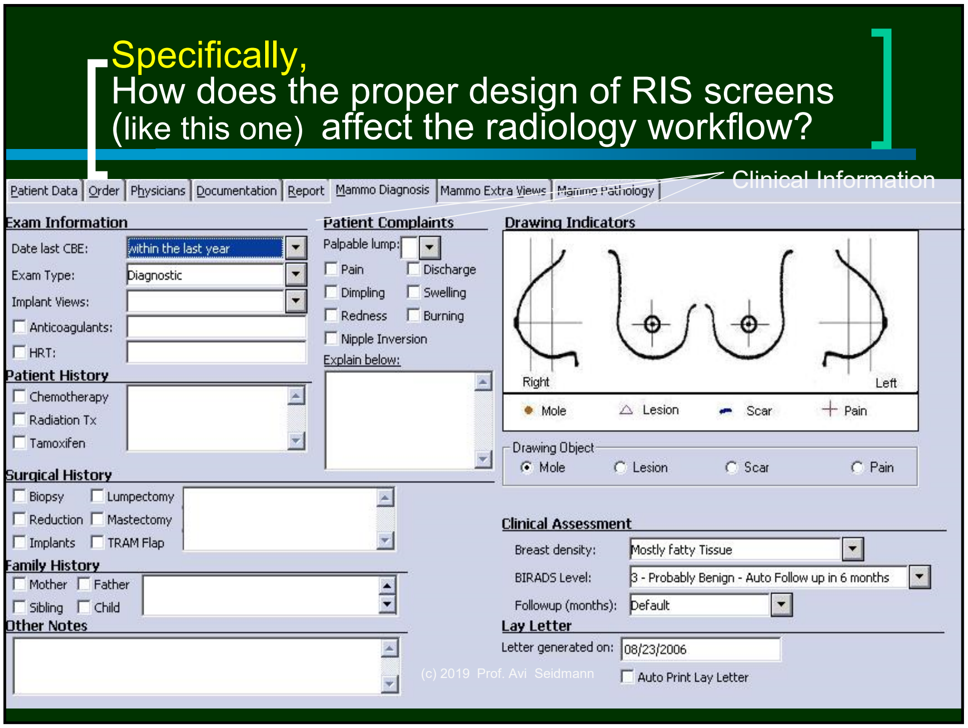
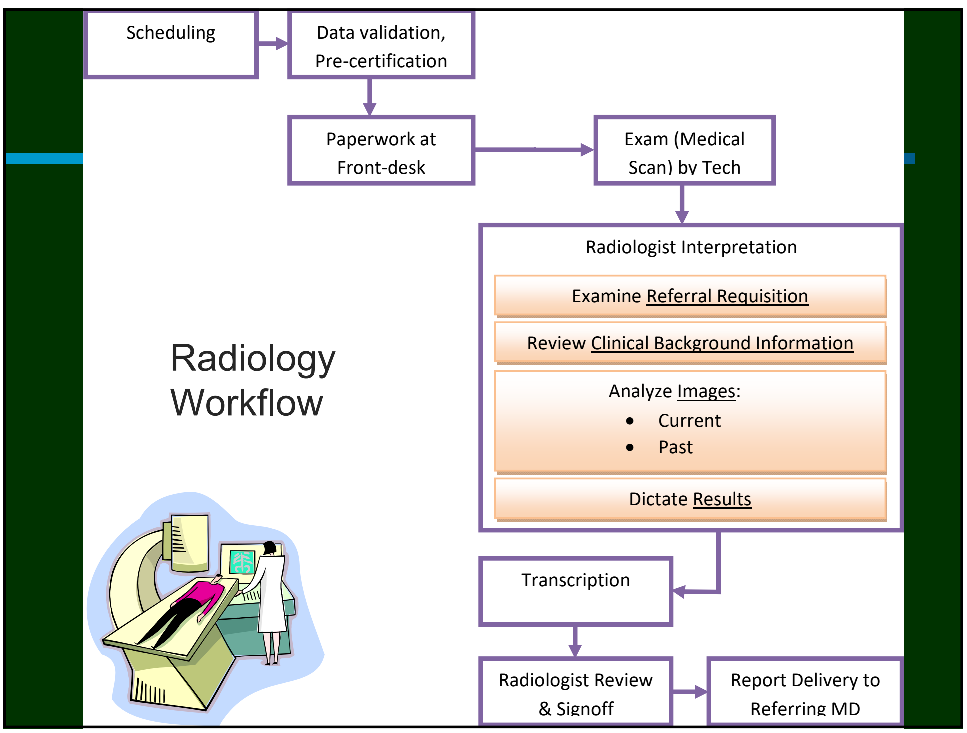
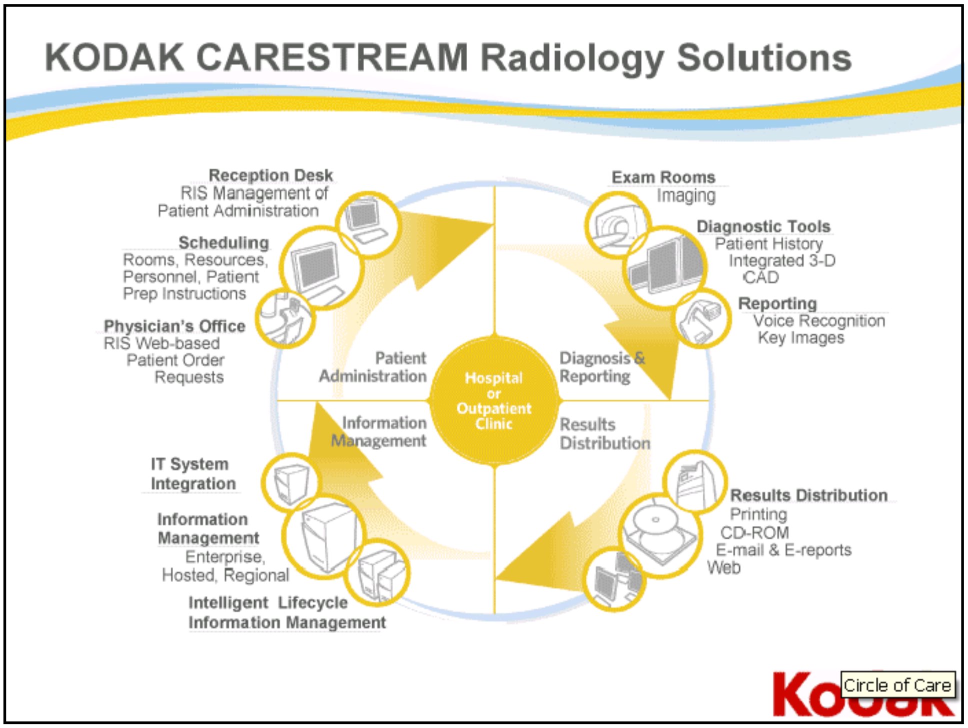
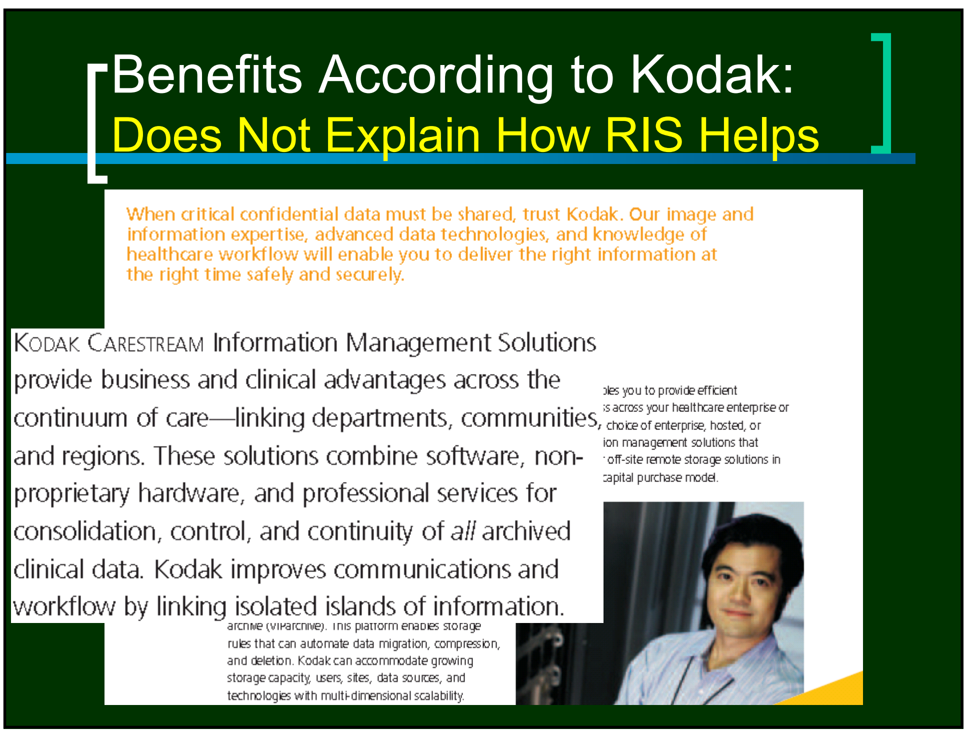
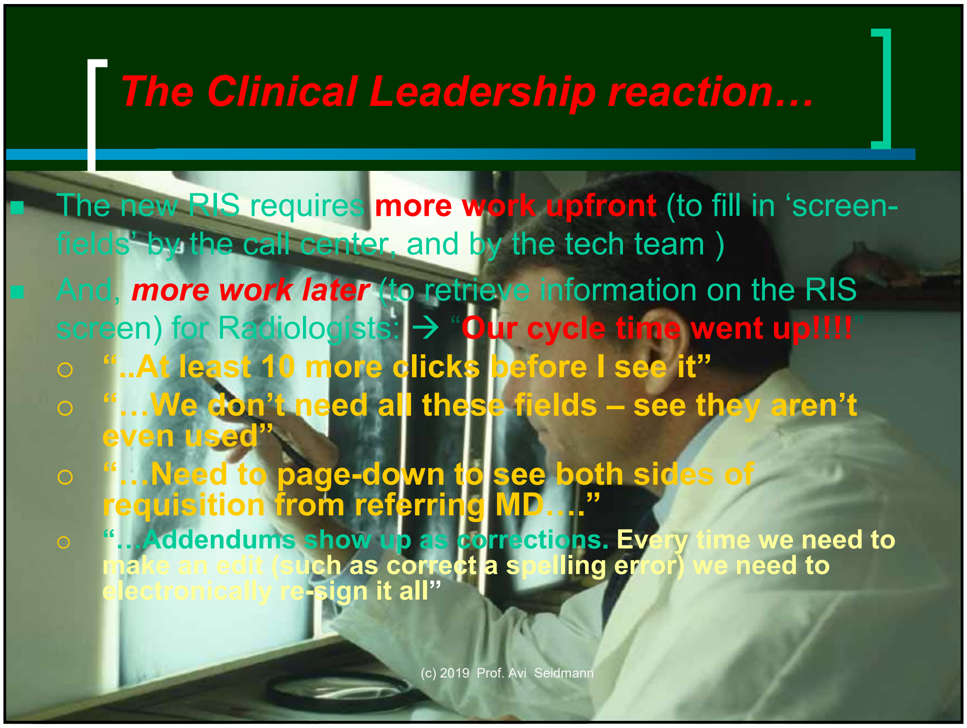




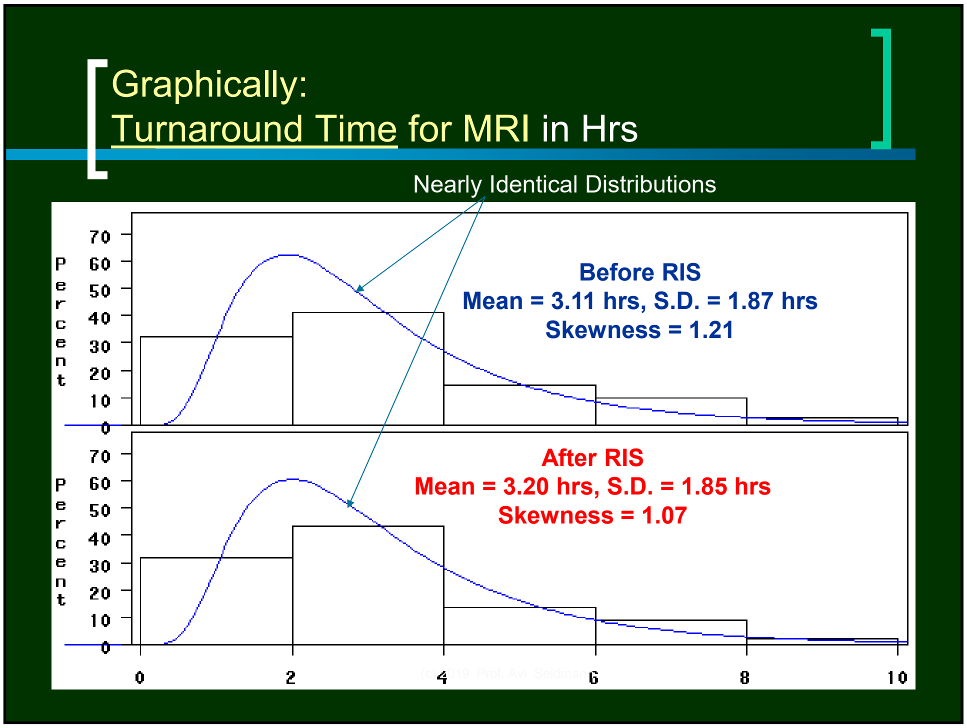

KODAK CARESTREAM Radiology Solutions
Reception Desk
RIS Management of Patient Administration
Scheduling
Rooms, Resources, Personnel, Patient Prep Instructions
Physician's Office
RIS Web-based Patient Order Requests
Exam Rooms
Imaging
Diagnostic Tools
Patient History
Integrated 3-D
CAD
Reporting
Voice Recognition
Key Images
Patient Administration
Diagnosis & Reporting
Hospital or Outpatient Clinic
Information Management
Results Distribution
IT System Integration
Information Management
Enterprise, Hosted, Regional
Intelligent Lifecycle Information Management
Results Distribution
Printing
CD-ROM
E-mail & E-reports
Web
Circle of Care

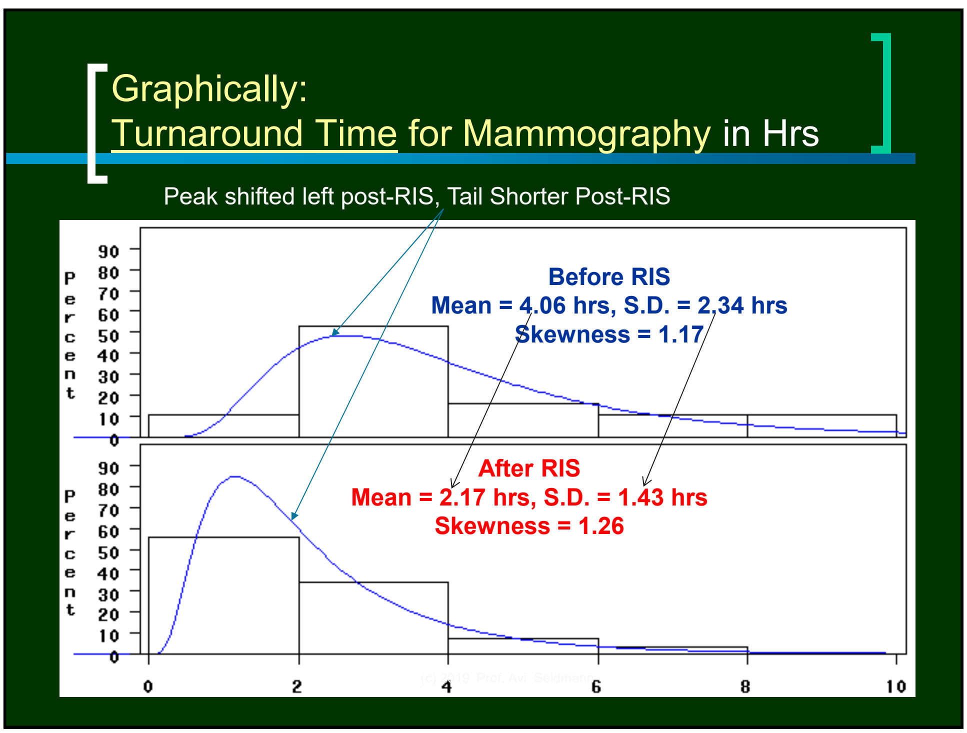

Benefits According to Kodak:
Does Not Explain How RIS Helps
When critical confidential data must be shared, trust Kodak. Our image and information expertise, advanced data technologies, and knowledge of healthcare workflow will enable you to deliver the right information at the right time safely and securely.
KODAK CARESTREAM Information Management Solutions provide business and clinical advantages across the continuum of care—linking departments, communities, and regions. These solutions combine software, non-proprietary hardware, and professional services for consolidation, control, and continuity of all archived clinical data. Kodak improves communications and workflow by linking isolated islands of information.
rules that can automate data migration, compression, and deletion. Kodak can accommodate growing storage capacity, users, sites, data sources, and technologies with multi-dimensional scalability.



Performance Measure Significant Adverse Impact on Scheduling	Pre-RIS Mean	Pre-RIS SD	Post-RIS Mean	Post-RIS SD
Scheduling-Call Length (existing patients) in Minutes	2.49	1.32	2.73*	1.23
Scheduling-Call Length (new patients) in Minutes	3.10	1.18	4.44*	1.59
Scheduling-Call Abandonment Rate	2.22%	1.23%	3.59%*	1.69%

Significant but Non-uniform Positive Impact on MDs	Pre-RIS *Mammography* Mean	Pre-RIS *Mammography* SD	Pre-RIS *MRI* Mean	Pre-RIS *MRI* SD	Post-RIS *Mammography* Mean	Post-RIS *Mammography* SD	Post-RIS *MRI* Mean	Post-RIS *MRI* SD
Interpretation TAT in Hours	1.58	1.84	1.62	1.06	0.76*	0.60	1.67	0.98
Transcription TAT in Hours	0.44	0.42	0.54	0.36	0.36	0.37	0.50	0.57
Review TAT in Hours	2.04	1.05	0.95	1.41	1.06*	1.24	1.03	1.35
RTAT (sum of the 3 TATs above) in Hours	4.06	2.34	3.11	1.87	2.17*	1.43	3.20	1.85


Graphically:
Turnaround Time for MRI in Hrs
Nearly Identical Distributions
Before RIS
Mean = 3.11 hrs, S.D. = 1.87 hrs
Skewness = 1.21
After RIS
Mean = 3.20 hrs, S.D. = 1.85 hrs
Skewness = 1.07
Percent
0 10 20 30 40 50 60 70
0 2 4 6 8 10


Graphically:
Turnaround Time for Mammography in Hrs
Peak shifted left post-RIS, Tail Shorter Post-RIS
Before RIS
Mean = 4.06 hrs, S.D. = 2.34 hrs
Skewness = 1.17
After RIS
Mean = 2.17 hrs, S.D. = 1.43 hrs
Skewness = 1.26
Percent
0 10 20 30 40 50 60 70 80 90
0 2 4 6 8 10

Lognormal Survival Function: Interpretation TAT

A: OLS
B: SUR
C: SUR with Location Dummies

Model	A	B	C
Intercept (β_0)	0.2874	0.2874	0.3489
	(<0.0001)	(<0.0001)	(<0.0001)
Mammo (β_1)	-0.3255	-0.3255	-0.3377
	(0.0349)	(0.0357)	(0.0004)
RIS (β_2)	0.0753	0.0771	0.0680
	(0.3152)	(0.3056)	(0.3689)
Mammo x RIS (β_3)	-0.5238	-0.5215	-0.5093
	(0.0013)	(0.0015)	(0.0019)
South Clinton			-0.0851
			(0.2636)
Lattimore 1.5			-0.1415
			(0.0409)
Lattimore Open			-0.0014
			(0.9864)
Ho: $\beta_2 + \beta_3 = 0$	(0.0021)	(0.0021)	(0.0022)

Mammography benefited, MRI did not

- **RIS cut Mammography turnaround by 50% despite extra information-processing work (Call center;tech;MD)**
- **But RIS did not cut MRI turnaround. Why?**

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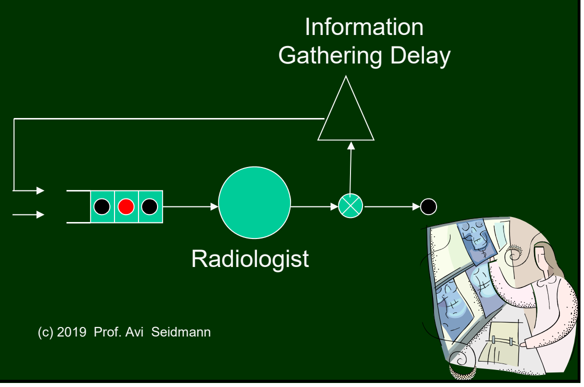
A Conceptual Model of Hang-over

- Exam for which complete background clinical and administrative Information is available
- Exam for which some information is missing



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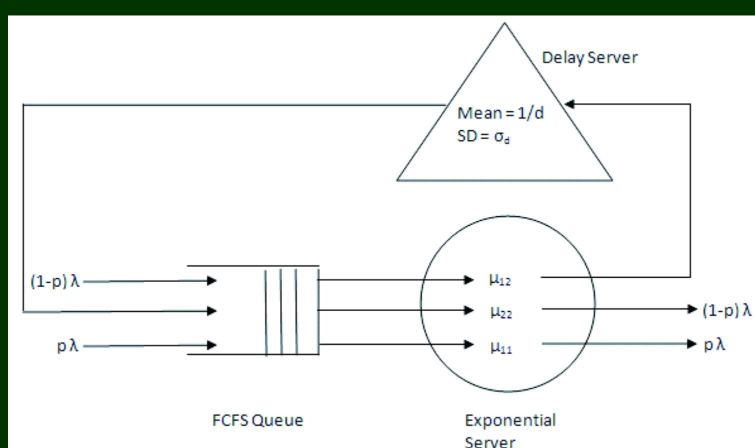
What is this '*Missing*' Data about? Radiologist-speak

- "Missing patient full name, DB error at PACS"
- "Call back diagnostic"
- "Additional views are present, need to discuss with tech why they took those additional views"
- "Missing previous study"
- "Explain surgical scars shown"
- "No referral MD notes on swelling"
- "Spoke with patient"
- "Wrong prior mammography films presented"

We develop a novel Queuing Model to investigate: The Interpretation Step



Model Characteristics

- Feedback Queue is NOT product-form:
  - Fixed (Deterministic) Feedback: 2 rounds of Service for hang-over exams, 1 round for the rest
  - Delayed Feedback: Information-gathering delay
  - Multiple Classes of Customers:
    - Some require additional info, Some don't
  - Service times of exponential server:
    - Depends on Class and the Round of Service

Theorem 1: Analytical Solution: Expected Sojourn Times

- First moments, i.e., Expected Sojourn Times, can be obtained using Operational Analysis (Denning and Buzen 1978)

$$E[S_{11}] = \frac{\frac{1}{\mu_{12}} + \rho_{11}(\frac{1}{\mu_{11}} - \frac{1}{\mu_{12}}) + \frac{\rho_{22}}{\mu_{22}}}{(1+\rho_{22})(1-\rho)} + (\frac{1}{\mu_{11}} - \frac{1}{\mu_{12}})$$

$$E[S_{12}] = \frac{\frac{1}{\mu_{12}} + \rho_{11}(\frac{1}{\mu_{11}} - \frac{1}{\mu_{12}}) + \frac{\rho_{22}}{\mu_{22}}}{(1+\rho_{22})(1-\rho)}$$

$$E[S_{22}] = \rho\frac{\frac{1}{\mu_{12}} + \rho_{11}(\frac{1}{\mu_{11}} - \frac{1}{\mu_{12}}) + \frac{\rho_{22}}{\mu_{22}}}{(1+\rho_{22})(1-\rho)} + \frac{1}{\mu_{22}}$$

When $\mu_{11} = \mu_{12} = \mu_{22}$ Converges to the product-form solution

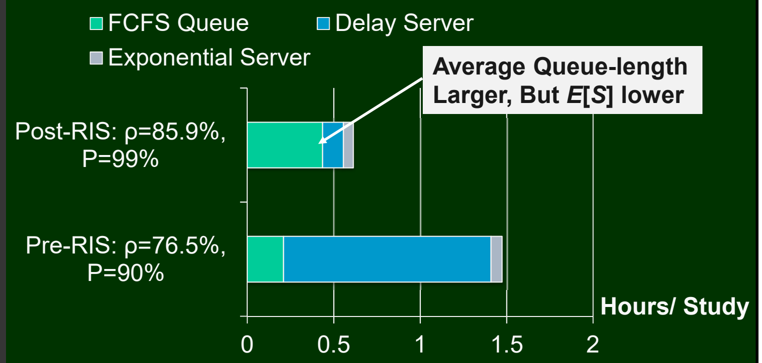
And, the mean sojourn time, $E[S]$, equals:

$$(p + (1-p)(1+\rho))\frac{\frac{1}{\mu_{12}} + \rho_{11}(\frac{1}{\mu_{11}} - \frac{1}{\mu_{12}}) + \frac{\rho_{22}}{\mu_{22}}}{(1+\rho_{22})(1-\rho)} + p(\frac{1}{\mu_{11}} - \frac{1}{\mu_{12}}) + (1-p)(\frac{1}{\mu_{22}} + \frac{1}{d})$$

Inefficient Hangover Example: Components of $E[S]=\hat{S}(\rho, P)$

Impact on the bottleneck server does not reflect the end-to-end impact on the workflow:

Lower average sojourn time despite a higher backlog at the bottleneck server



Components of $\hat{S}(\rho, p)$ in hours;
$\alpha = 1.2$, $\lambda = 12$/hr, $1/d = 12$ hrs; $\mu_{11} = \mu$ and $\mu_{12} = \mu_{22} = 2\mu/\alpha$
where μ = 16/hr pre-RIS, 14/hr post-RIS

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Theorem 2: Batching Exams with lot size (Q)

$S_Q =$ the first-pass sojourn time of a randomly selected arriving batch

$S_{Q2} =$ the first-pass sojourn time of a batch containing at least one hang-over exam

Theorem 2 *For the FCFS queue with batching as described above:*

$$E[S_{Q2}] = E[S_{12}] + \Lambda\left(\frac{1-\rho_Q}{(1+\rho_{22})(1-\rho)}\right), E[S_Q] = \frac{(1-p)p^Q Q}{1-p^Q}\left(\frac{1}{\mu_{11}} - \frac{1}{\mu_{12}}\right) + E[S_{Q2}],$$

$$E[S_{22}] = \rho E[S_{Q2}] + \frac{1}{\mu_{22}}, \text{ where } \Lambda = \frac{Q\left(\frac{p}{\mu_{11}} + \frac{1-p}{\mu_{12}}\right) - p^Q \frac{Q}{\mu_{11}}}{1-p^Q} - \frac{1}{\mu_{12}}, \text{ and } E[S_{12}] \text{ is as given by}$$

Theorem 1.

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Proof: In our MSOM 2012 paper

Lower "Interpretation Hang-over": The Impact on Radiologists' Earnings?

- We show that RIS increase...
  - the Radiologists' Earnings despite a significant increase in their <u>task time</u> per exam ....

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Does Technology Substitute for Nurses? Staffing Decisions in Nursing Homes

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Abstract. Over the past 10 years, many healthcare organizations have made significant investments in automating their clinical operations, mostly through the introduction of advanced information systems. Yet the impact of these investments on staffing is still not well understood. In this paper, we study the effect of information technology (IT)-enabled automation on staffing decisions in healthcare facilities. Using unique nursing home IT data from 2006 to 2012, we find that the licensed nurse staffing level decreases by 5.8% in high-end nursing homes but increases by 7.6% in low-end homes after the adoption of automation technology. Our research explains this by analyzing the interplay of two competing effects of automation: the substitution of technology for labor and the leveraging of complementarity between technology and labor. We also find that increased automation improves the ratings on clinical quality by 6.9% and decreases admissions of less profitable residents by 14.7% on average. These observations are consistent with the predictions of an analytical staffing model that incorporates technology adoption and vertical differentiation. Overall, these findings suggest that the impact of automation technology on staffing decisions depends crucially on a facility's vertical position in the local marketplace.

History: Accepted by Chris Forman, information systems.
Supplemental Material: The online appendix is available at https://doi.org/10.1287/mnsc.2016.2695.

Keywords: staffing • labor • technology • vertical differentiation • nursing homes

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Merging Analytic Modeling With Clinical and Operations Data Research: Rotman School Presentation, March 2019

Harvard Business Review

COSTS

IT Doesn't Matter

by Nicholas G. Carr

FROM THE MAY 2003 ISSUE

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In 1968, a young Intel engineer named Ted Hoff found a way to put the circuits necessary for computer processing onto a tiny piece of silicon. His invention of the microprocessor spurred a series of technological breakthroughs–desktop computers, local and wide area networks, enterprise software, and the Internet–that have transformed the business world. Today, no one would dispute that information technology has become the backbone of commerce. It underpins the operations of individual companies, ties together far-flung supply chains, and, increasingly, links businesses to the customers they serve. Hardly a dollar or a euro changes hands anymore without the aid of computer systems.

As IT's power and presence have expanded, companies have come to view it as a resource ever more critical to their success, a fact clearly reflected in their spending habits. In 1965, according to a study by the U.S. Department of Commerce's Bureau of Economic Analysis, less than 5% of the capital expenditures of American companies went to information technology. After the introduction of the personal computer in the early 1980s, that percentage rose to 15%. By the early 1990s, it had reached more than 30%, and by the end of the decade it had hit nearly 50%. Even with the recent sluggishness in technology spending, businesses around the world continue to spend well over $2 trillion a year on IT.

But the veneration of IT goes much deeper than dollars. It is evident as well in the shifting attitudes of top managers. Twenty years ago, most executives looked down on computers as proletarian tools–glorified typewriters and calculators–best relegated to low level employees like secretaries, analysts, and technicians. It was the rare executive who would let his fingers touch a keyboard, much less incorporate information technology into his strategic thinking. Today, that has changed completely. Chief executives now routinely talk about the strategic value of information technology, about how they can use IT to gain a competitive edge, about the "digitization" of their business models. Most have appointed chief information officers to their senior management teams, and many have hired strategy consulting firms to provide fresh ideas on how to leverage their IT investments for differentiation and advantage.

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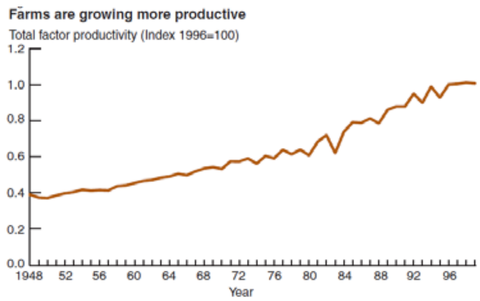
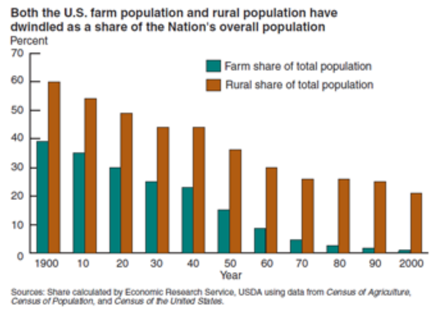
Automation through Mechanization





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Motivation

Advances in IT are changing healthcare delivery by bring digitization and automation into the industry.

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Research Question

How will IT-enabled automation affect
healthcare employment?

Nursing Homes in the United States

- A nursing home is a place for people who do not need to be in a hospital but can no longer be cared for at home.
- Due to the aging of the baby boomer generation, approximately $ 111 billion was spent on nursing home care in the United States in 2011.
- Unique features compared to hospitals:
  - Relatively simple structure of labor provision
  - Relatively homogeneous services: chronic care

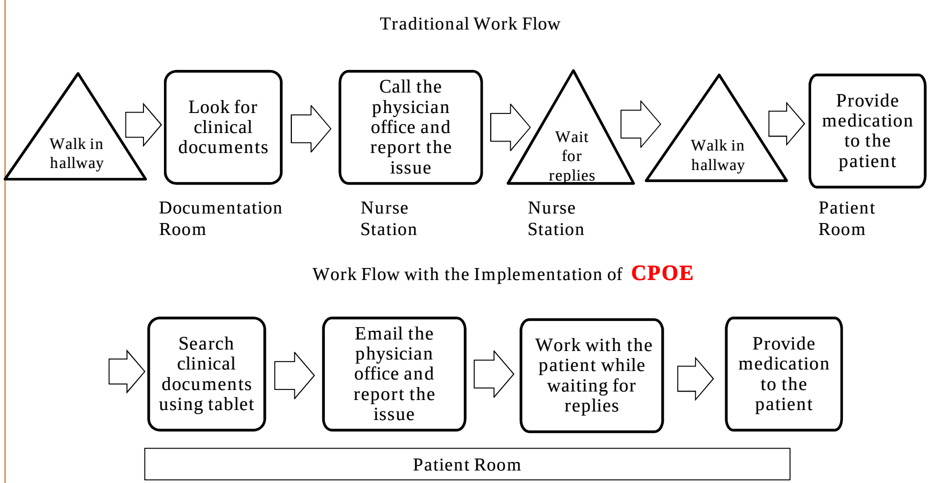
Quality Mix

- Patient types
  - Short-term care patients (post-acute care)
  - Long-term care patients (chronic care)
- Payer Types: Quality Mix
  - About 60% of patients are Medicaid (daily rate $140)
  - 20% are Medicare patients for post-acute care (daily rate $500)
  - 20% are private-paying patients (daily rate $300-400)
  - The whole industry chases lucrative patients as a new trend.

Vertical Differentiation

- The entire nursing home industry is competitive.
- The quality of care in a nursing home is mainly determined by the nurses on a daily basis.
  - Five star ratings
    - Manor Care
    - Kindred
  - Staffing (positively associated with star ratings)
    - The dispersion of staffing-to-resident ratio is between 1 percentile and 99 percentile is 4.59 HPRD.
    - The state minimum staffing standards provide an exogenous lower bound for the staffing level in each individual market.

Process Flow Chart: Medication Management



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Research Question

- Research Question:
  - Is technology "eating" nurses?
- We came across surprisingly few studies that have examined the causal effect of IT-enabled automation adoption on staffing decision in individual healthcare facilities.

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Model Setup

- A nursing home's staffing problem:

Vertical Position

Wages ($)

$$\max_{s} \mathrm{V}(s) = \mathrm{R}(q, \theta) - w * s$$

Staffing Level

Revenue ($)/Pt

Quality Level

- Parameterization:

Care Quality

$$Q(r,k) = rk, \qquad R(q,\theta) = 1 - \theta e^{-A\theta q}. \quad \{\partial R/\partial q > 0,\ \partial^2 R/\partial q^2 < 0\}$$

Staff-to-patient ratio

Technology Level

$$0 < \underline{\theta} < \overline{\theta} < \sqrt{\frac{we^2}{Ak}}.$$

Model Analysis

Lemma:

The optimal staffing level s^*, the optimal quality level q^*, and the resulting average revenue per patient for a nursing home with vertical position θ are given below:

$$s^* = \frac{1}{Ak\theta}\ln\frac{Ak\theta^2}{w}, \qquad q^* = \frac{1}{A\theta}\ln\frac{Ak\theta^2}{w}, \qquad R(q^*,\theta) = 1 - \frac{w}{Ak\theta}.$$

Proposition 1:

The optimal staffing level s^*, the optimal quality level q^*, and the average revenue per patient $R(q^*,\theta)$ are increasing in θ.

Model Analysis

Proposition 2:

The optimal quality level q^* and the average revenue per patient $R(q^*, \theta)$ are increasing in the automation level k.

Proposition 3:

An increase in automation level leads to **an increase** of a nursing home's staffing level (S) if the vertical position: $\theta < \sqrt{\frac{we}{Ak}}$, but it leads to **a decrease** of a nursing home's staffing level (S) if the vertical position: $\theta > \sqrt{\frac{we}{Ak}}$.

Hypotheses

- **Hypothesis 1**: An increase in automation level leads to an *increase* in the quality level of a nursing home.
- **Hypothesis 2**: An increase in automation level leads to a *decrease* in staff-to-patient ratio for a nursing home with a high vertical position.
- **Hypothesis 3**: An increase in automation level leads to an *increase* in staff-to-patient ratio for a nursing home with a low vertical position.

Hunting for Reliable Data

- Data Sources
  - The Online Survey Certificate and Reporting Database (**OSCAR**) from 2006 to 2012
  - The Health Information Systems Society (**HIMSS**) from 2005 to 2011
- Key Variables:
  - Process Quality: the number of patient complaints
  - Staff-to-Patient Ratio: staff hours per patient day (HPRD) for licensed nurses (LNs)
  - Vertical Position

Econometric Models

- Average Effect:

$$S_{it} = \alpha_0 + \alpha_1 IT_{i,t-1} * Post_{t-1} + \alpha_2 X_{it} + \alpha_3 Z_{ct} + \alpha_4 State_s * Year_t + \alpha_i + \alpha_t + \varepsilon_{it} \quad (1)$$

- Heterogeneous Effect:

$$S_{it} = \beta_0 + \beta_1 IT_{i,t-1} * Post_{t-1} + \beta_2 IT_{i,t-1} * Post_{t-1} * Position_i + \beta_3 X_{it} + \beta_4 Z_{ct} + \beta_5 State_s * Year_t + \beta_i + \beta_t + \varepsilon_{it} \quad (2)$$

- Endogeneity Issues
  - The adoption of CPOE is not randomly assigned.

Instrumental Variable (IV)

- We construct an instrumental variable, *hospital_CPOE*, describing the yearly hospital CPOE adoption rates in the local market where we define a county as a market.
  - Exclusion criteria
  - Inclusion criteria
    - First stage: 0.552 (p-value <0.001)
    - Weak IV problem:
      - The Kleibergen-Paap rk Wald F statistics is 622.17, allowing us to easily reject the null hypothesis.
- Alternative IV
  - We divided the number of non-affiliated hospitals that adopted CPOE by the total number of non-affiliated hospitals in the local market in a given year.

Average Effect on Staffing

Dependent Variable: Consumer Complaints on Process Quality	Baseline Total Complaints OLS (1)	First Stage (2)	2SLS (3)
CPOE	0.000		$\boxed{0.012}$
	(0.014)		$\boxed{(0.027)}$
IV: Hospital_CPOE		0.552***	
		(0.022)	
Nursing Home Dummies	Y	Y	Y
Year Dummies	Y	Y	Y
Individual State Linear Trends	Y	Y	Y
Weak Identification Test	Kleibergen-Paap rk Wald F statistic: 622.17***		
Observations	12313	12313	12250
Within R-squared	0.06	0.272	0.06
Number of provider	2119	2119	2056

Robust standard errors in parentheses clustered by nursing home
*** p<0.01, ** p<0.05, * p<0.1

The adoption of CPOE has no effect on staffing on average.

Heterogeneous Effect by Vertical Position

Dependent Variable: Hours per patient Day	Licensed Nurses			Registered Nurses	
	Minimum LNs			Minimum RNs	
	OLS	2SLS	2SLS	2SLS	2SLS
	(1)	(2)	(3)	(4)	(5)
CPOE	0.106***	0.282***	0.145***	0.154***	0.073**
	(0.036)	(0.062)	(0.046)	(0.040)	(0.029)
CPOE * Position	-0.065**	-0.172***		-0.145***	
	(0.029)	(0.042)		(0.044)	
CPOE * High End			-0.255***		-0.109**
			(0.071)		(0.047)
Nursing Home Dummies	Y	Y	Y	Y	Y
Year Dummies	Y	Y	Y	Y	Y
State Linear Trends	Y	Y	Y	Y	Y
F test: CPOE+CPOE* High End			-0.110**		-0.036*
Observations	12,313	12,250	12,250	12,250	12,250
Within R-squared	0.046	0.040	0.041	0.057	0.058
Number of provider	2,119	2,056	2,056	2,056	2,056

Robust standard errors in parentheses clustered by nursing home
*** p<0.01, ** p<0.05, * p<0.1

The adoption of CPOE has opposite effects on staffing decisions.

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Effects on Patient Composition

Dependent Variable: Log of Daily Admissions	Patient Types			
	Total Admission		Medicaid Admission	
	(1)	(2)	(3)	(4)
CPOE	0.006	0.138	-0.147**	-0.201*
	(0.086)	(0.147)	(0.072)	(0.112)
CPOE * Position		-0.079		0.038
		(0.057)		(0.052)
Nursing Home Dummies	Y	Y	Y	Y
Year Dummies	Y	Y	Y	Y
State Linear Trends	Y	Y	Y	Y
Observations	11,017	11,017	9,548	9,548
Centered R-squared	0.282	0.282	0.055	0.054
Number of provider	1,880	1,880	1,630	1,630

Robust standard errors in parentheses clustered by nursing home
*** p<0.01, ** p<0.05, * p<0.1

The adoption of CPOE decreases the admissions of Medicaid patients by 14.7%.

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Conclusions

- IT does ~~not~~ matter!
- IT has a significant impact in healthcare which is still very labor intensive

Key Findings

IT-enabled automation: CPOE

- **No effect** on staffing on the industry average, BUT....
- Data Analytics supports the Economic Model's Predictions:

➔ **CPOE Implementaion**

  - **reduces** staffing by 5.8% in high-end nursing homes, (**Substitute**) but
  - **increases** staffing by 7.6% in low-end nursing homes (**Complement**).

- Results in a 14.7% significant **decrease** in the admissions of Medicaid patients, the least profitable type patients.

CLINICAL TRIALS

SECTION EDITOR: IRA SHOULSON, MD

ONLINE FIRST

Randomized Controlled Clinical Trial of "Virtual House Calls" for Parkinson Disease

E. Ray Dorsey, MD, MBA; Vinayak Venkataraman, BS; Matthew J. Grana, BA; Michael T. Bull, BS; Benjamin P. George, MPH; Cynthia M. Boyd, MD, MPH; Christopher A. Beck, PhD; Balaraman Rajan, MBA, MS; Abraham Seidmann, PhD; Kevin M. Biglan, MD, MPH

Importance: The burden of neurological disorders is increasing, but access to care is limited. Providing specialty care to patients via telemedicine could help alleviate this growing problem.

Objective: To evaluate the feasibility, effectiveness, and economic benefits of using web-based videoconferencing (telemedicine) to provide specialty care to patients with Parkinson disease in their homes.

Design: A 7-month, 2-center, randomized controlled clinical trial.

Setting: Patients' homes and outpatient clinics at 2 academic medical centers.

Participants: Twenty patients with Parkinson disease with Internet access at home.

Intervention: Care from a specialist delivered remotely at home or in person in the clinic.

Main Outcome Measures: The primary outcome variable was feasibility, as measured by the percentage of telemedicine visits completed as scheduled. Secondary outcome measures included clinical benefit, as measured by the 39-item Parkinson Disease Questionnaire, and economic value, as measured by time and travel.

Results: Twenty participants enrolled in the study and were randomly assigned to telemedicine (n=9) or in-person care (n=11). Of the 27 scheduled telemedicine visits, 25 (93%) were completed, and of the 33 scheduled in-person visits, 30 (91%) were completed (*P*=.99). In this small study, the change in quality of life did not differ for those randomly assigned to telemedicine compared with those randomly assigned to in-person care (4.0-point improvement vs 6.4-point improvement; *P*=.61). Compared with in-person visits, each telemedicine visit saved participants, on average, 100 miles of travel and 3 hours of time.

Conclusion and Relevance: Using web-based videoconferencing to provide specialty care at home is feasible, provides value to patients, and may offer similar clinical benefit to that of in-person care. Larger studies are needed to determine whether the clinical benefits are indeed comparable to those of in-person care and whether the results observed are generalizable.

Trial Registration: clinicaltrials.gov Identifier: NCT01476306

JAMA Neurol. Published online March 11, 2013. doi:10.1001/jamaneurol.2013.123

informs.
http://pubsonline.informs.org/journal/mnsc/

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Service Systems with Heterogeneous Customers: Investigating the Effect of Telemedicine on Chronic Care

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Abstract. Medical specialists treating chronic conditions typically face a heterogeneous set of patients. Such heterogeneity arises because of differences in medical conditions as well as the travel burden each patient faces to visit the clinic periodically. Given this heterogeneity, we compare the strategic behavior of revenue-maximizing and welfare-maximizing specialists and prove that the former will serve a smaller patient population, spend more time with the patients, and have shorter waiting times. We also analyze the impact of telemedicine technology on patient utility and the specialists' operating decisions. We consider both the case when specialists can freely set their own fee for service and the case when fees are set exogenously by a third-party payer. We prove that with the introduction of telemedicine, the specialists become more productive and the overall social welfare increases, although some patients, unexpectedly, will be worse off. Our analytical results lead to some important policy implications for facilitating the further deployment of telemedicine in the care of chronically ill patients.

History: Accepted by Serguei Netessine, operations management.

Keywords: healthcare • treatment • enabling technologies • information technology policy and management • economics of information systems • service operations • telemedicine

TYPICAL MEDICATION REGIMEN FOR PATIENTS WITH MULTIPLE SYSTEM SYMPTOMS OF PARKINSON'S DISEASE

Symptom	Medication
Movement	Carbidopa-levodopa (Sinemet®)
	Carbidopa-levodopa
	Amantadine (Symmetrel®)
	Entacapone (Comtan®)
	Pramipexole (Mirapex®)

Comments from the patients (Pro TM)

- "I spend more time in the car than with the Dr."
- "I would hope that telemedicine would provide more access to a doctor for those who were unable to see their doctor in person. I would like more access to best health care."
- "No travel to downtown, no toll fees, and no long walk from the parking garage to the office."
- "little interruption to normal schedule"
- "I don't have to take off the entire day, drive 120 miles, fight the traffic, the horrible parking situation, eating out expensive."

On the other hand (Negative)...

- "I would not like to put any communication barriers between myself and my doctor, including a camera or distance."
- "I do not get a real patient visit where the doctor reviews all my systems to see if I am getting better, the worse, or the same. Trying to provide good patient care over the Internet is superficial,"
- "I think the doctor listens more carefully when I have an office visit, and I feel like I am able to better communicate my personal medical issues to the doctor."
- "It may seem less personal."
- "I would miss shaking hands with my doctor."

Telemedicine Trade-offs

Costs/Risks

- Limited physical exam and reduced clinical information
- Private secure place needed for patients
- Potential overuse by patients
- No free medication (samples)
- Limited Personal Contact
- Technology dependent
- No labs nearby

Benefits

- Reduced cancellations and No shows
- Greater geographic reach
- Reduced Travel

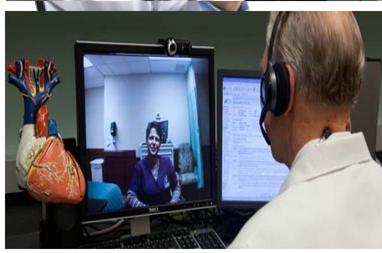
Problem Accessing Care

$$\text{Visit cost} = f(.,d)$$

What is Telemedicine?

Pt to MD

Small Hospital to Larger Hospital



Nurse to MD

MD to MD

Pilot telemedicine program for ophthalmology helps to increase interventions for preventing vision loss

Telemedicine-based diabetic retinopathy detection at URMC

Rajeev Ramchandran, MD
URMC Ophthalmologist

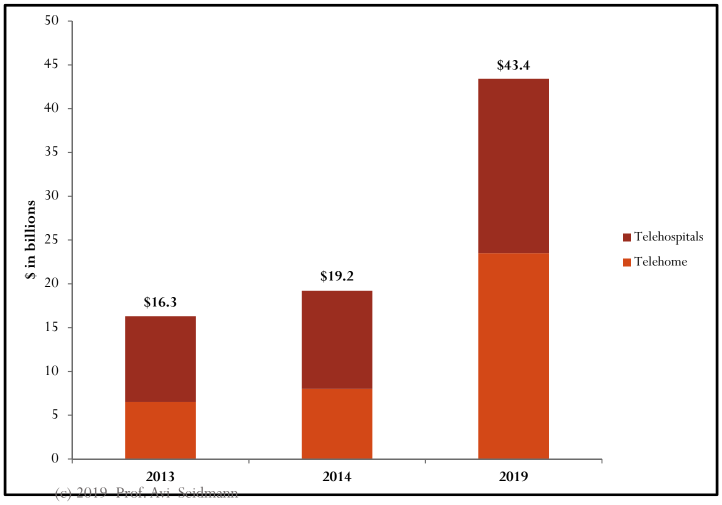
- In 2013, Flaum Eye Institute received a $600,000 grant from the Greater Rochester Health Foundation in support of Rochester Area Tele-I-Care

- Tele-I-Care program links the Flaum Eye Institute, RGHS Department of Ophthalmology, and primary care physicians to identify people with diabetes who are at risk of vision loss

Source: Rajan B, Seidmann A, Ramchandran R. Teleophthalmology for Diabetic Patients: Saving Vision through IT. hicss, 4239-43. 2014 47th Hawaii International Conference on System Sciences.

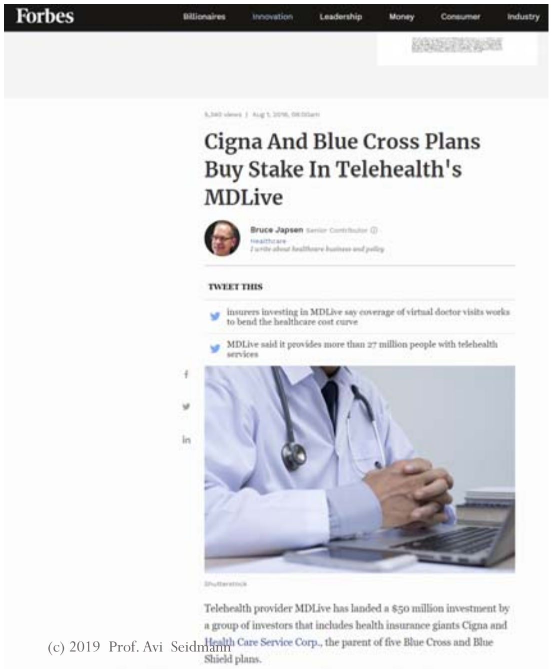
Telemedicine is a rapidly growing market that can improve access to care

Projected growth in telemedicine market



Source: BCC Research; http://www.bccresearch.com/market-research/healthcare/telemedicine-technologies-report-hlc014g.html

A $350 Million TM Deal (July 2018)


Forbes | Billionaires | Innovation | Leadership | Money | Consumer | Industry

Cigna And Blue Cross Plans Buy Stake In Telehealth's MDLive

Bruce Japsen

TWEET THIS

insurers investing in MDLive say coverage of virtual doctor visits works to bend the healthcare cost curve

MDLive said it provides more than 27 million people with telehealth services

Telehealth provider MDLive has landed a $50 million investment by a group of investors that includes health insurance giants Cigna and Health Care Service Corp., the parent of five Blue Cross and Blue Shield plans.

It is expected to be a boon to MDLive and rivals like American Well and Teladoc Health as well as an array of startups getting into the business of offering access to physicians and patients via smart phone, tablet or computer.

Forbes (August, 1, 2018)

Clearly, convenience is driving changes in health care and other service industries

People-powered apps

Source: Wall Street Journal, 5/6/15

Many TM Initiatives take Place Now

amwell

GeriCare
Care closer to you

(c) 2019 Prof. Avi Seidmann

Telehealth allows care to be provided where it is most needed ...

Year of first randomized controlled trial	1993	1998	1999	2011
Number of randomized controlled trials	596	316	206	40
Analogy to banking	ATM at a bank	ATM at a shopping mall	Banking at home	Mobile banking

Source: PubMed searches of telehealth and care delivery in various locations, filtered for randomized controlled trials and excluding home monitoring, on 9/15/2017

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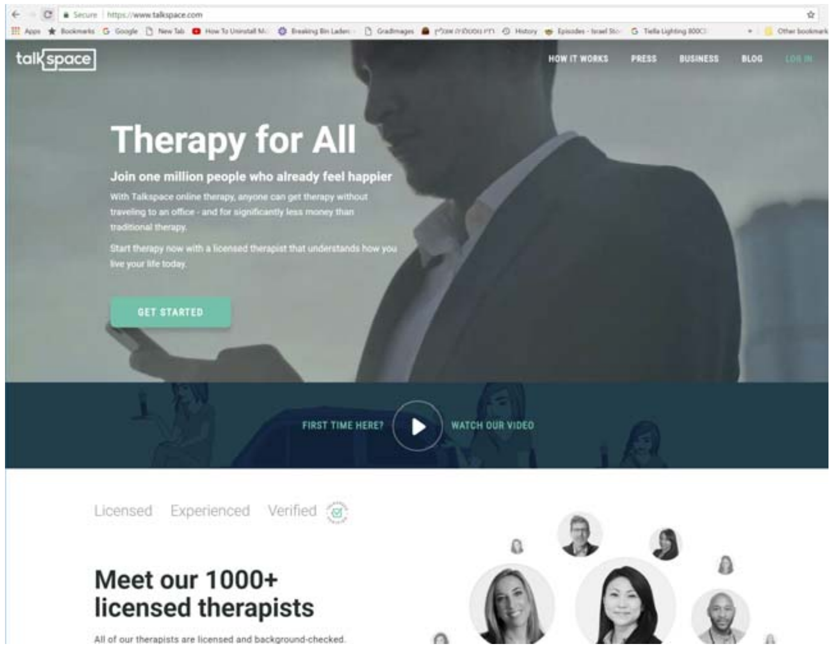
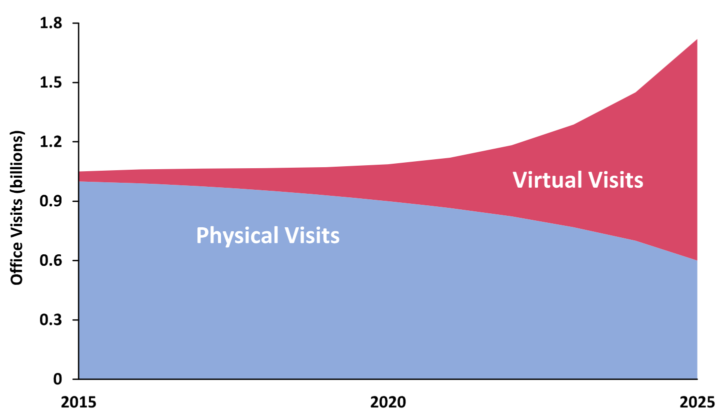


Telemedicine is poised for exponential growth, … and we may see even more in the future

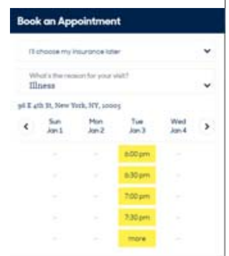
Projected number of office visits in the U.S., 2015 – 2025

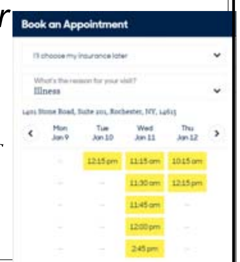


Source: Dorsey ER, Topol EJ. Here's what your future doctor visits could look like. Fortune. May 2, 2017. Available at: http://fortune.com/2017/05/02/brainstorm-health-2017/

Patients tend to ‘Prefer’ **Longer** Visits, Over Shorter….. (Zocdoc Study)

- *“…The displayed appointment book might give consumers a signal of in-clinic service time, with a shorter duration decreasing consumer demand…”*
- *“.. consumers in Manhattan care more about **waiting time**, whereas consumers in the other boroughs care more about **service time**...”*

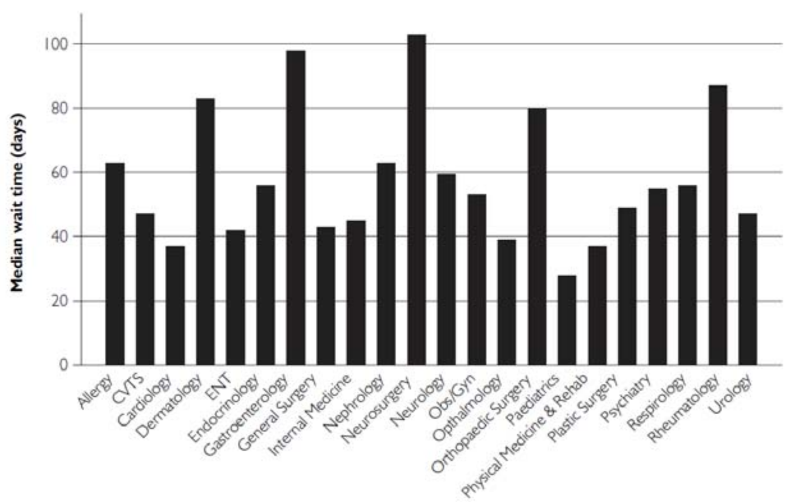




“*The Effect of Online Reviews on Physician Demand: A Structural Model of Patient Choice*” *by* Yuqian Xu, Mor Armony, and Anindya Ghose (Working Paper, Stern School of Business, New York University, 2016)

What Are Wait Times to See a Specialist?

An Analysis of 26,942 Referrals in Southwestern Ontario (2012)



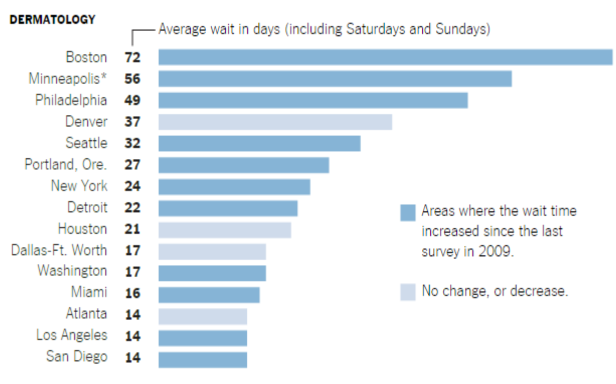
The Health Care Waiting Game

Long Waits for Doctors' Appointments Have Become the Norm

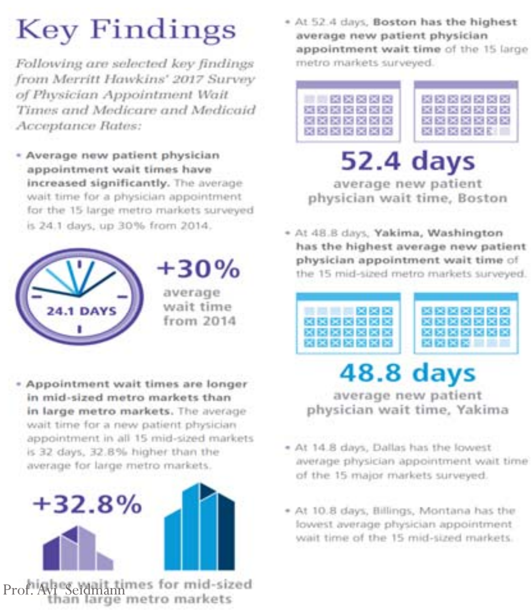
New York Times, July 5, 2014

Waiting … and Waiting …

Average time to get five kinds of appointments for new patients in 2013, from a survey of 15 metropolitan areas. JULY 5, 2014



What has Changed from 2014 to 2017?



What has Changed from 2014 to 2017?

FAMILY MEDICINE

City	Total Responses	Shortest Time to Appt.	Longest Time to Appt.	Average Time to Appt.	Accept Medicaid? YES (%)
Boston, 2017	18	3 days	365 days	109 days	78
Boston, 2014	20	12 days	152 days	66 days	65
Boston, 2009	17	6 days	365 days	63 days	53
Los Angeles, 2017	20	1 day	365 days	42 days	45
Los Angeles, 2014	19	1 day	126 days	20 days	53
Los Angeles, 2009	20	1 day	365 days	59 days	30
Portland, 2017	20	1 day	240 days	39 days	55
Portland, 2014	20	3 days	45 days	13 days	60
Portland, 2009	19	3 days	16 days	8 days	79
Miami, 2017	20	3 days	180 days	28 days	40
Miami, 2014	16	1 day	56 days	12 days	56
Miami, 2009	15	1 day	25 days	7 days	40
Atlanta, 2017	20	1 day	169 days	27 days	35
Atlanta, 2014	20	1 day	112 days	24 days	40
Atlanta, 2009	18	3 days	21 days	9 days	67

Motivation

- **Patients** have some expectations when they come to see the specialist.
  - Expect to spend **"quality" time** with the specialist.
  - All patients are **"different"** (Distance, morbidity condition…)
  - Perceive **more time with the specialist** as providing higher quality
  - Expect to get an appointment within **minimal waiting time.**
- **Specialists (MDs)** have a finite capacity for treating patients.
  - Expects to be paid **a fair fee** per office visit
  - Address the broad spectrum of **heterogeneous** population
  - Need to **balance** long-term patient expectations with short-term revenue generation.
- Each patient walking into the clinic generates **a negative externality** for the other patients.

Our Research Questions today

- How to identify and measure the operational impacts of telemedicine?
- Why should a "busy" specialist offer telemedicine?
- What is the impact of patients heterogeneity on the optimal operation policy of the specialist?
- Who wins and who loses from using telemedicine technology for Chronic Care Delivery?
  - Medical Outcomes
  - Economics
  - Operations

The Utility Function for Patients

$$\psi(\lambda, p, \mu, x) =$$

Clinical Utility

$$m - t(x) - Q(\mu) - \mathbb{E}\, W(\lambda, \mu) - \beta p \geq 0 \qquad \forall\, x \leq X_m.$$

Co-insurance

Heterogeneous Pt's Utility

Delay/Opportunity cost of Time

Disutility of Faster Service

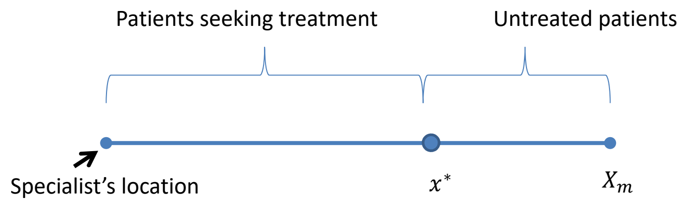
Equilibrium Arrival Rate

$$\lambda(p, \mu) = \Lambda \int_0^{X_m} g_x(i)\, f(x) dx$$

Density function

1 if chooses to seek treatment

Equilibrium for patients



$$x^* = \inf\{x \geq 0 \colon \psi(\Lambda F(x), p, \mu, x) \leq 0 \text{ and } \Lambda F(x) \leq \mu\} \wedge X_m$$

$$\lambda = \Lambda \int_0^{x^*} f(x)\,\mathrm{d}x = \Lambda F(x^*).$$

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The Physician Optimization Objective

Revenue Maximization Objective:

$$R(p,\mu) = \begin{cases} p\,\lambda(p,\mu), & if\ p \geq 0\ and\ \mu > \lambda(p,\mu) \\ 0, & otherwise. \end{cases}$$

$$R^* = \max_{p,\mu \geq 0} R(p,\mu).$$

Social Welfare Maximization objective:

$$V(\lambda) = \Lambda \int_0^{X_m} m - t(x)\, g_x(i)\, f(x) dx\,.$$

$$U(\lambda,\mu) = \begin{cases} V(\lambda) + \lambda(-Q(\mu) - \mathbb{E}\, W(\lambda,\mu)), & if\ \mu > \lambda, \\ 0, & otherwise. \end{cases}$$

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$$U^* = \max_{\lambda \geq 0, \mu \geq 0} U(\lambda,\mu).$$

Solution to Revenue Maximization: Proof approach

Theorem: Equivalent Specialist Revenue function

$$\tilde{R}(\lambda,\mu) = \begin{cases} p(\lambda,\mu)\,\lambda, & if\,\lambda \in [0,\Lambda]\ and\ \mu > \lambda \\ 0, & otherwise. \end{cases}$$

$$\max_{p,\mu\geq 0} R(p,\mu) = \max_{\lambda,\mu\geq 0} \tilde{R}(\lambda,\mu).$$

Solving the Optimization Problem

The Specialist's Revenue Maximization Objective

Problem 1$= R(p,\mu) =$

$$\begin{cases} p\,\lambda(p,\mu), & if\ p \geq 0\ and\ \mu > \lambda(p,\mu) \\ 0, & otherwise. \end{cases}$$

$$R^* = \max_{p,\mu\geq 0} R(p,\mu).$$

Problem 2 $=$

$$\tilde{R}(\lambda,\mu) = \begin{cases} p(\lambda,\mu)\,\lambda, & if\,\lambda \in [0,\Lambda]\ and\ \mu > \lambda \\ 0, & otherwise. \end{cases}$$

$$\boldsymbol{\max_{p,\mu\geq 0} R(p,\mu) = \max_{\lambda,\mu\geq 0} \tilde{R}(\lambda,\mu).}$$

Established Bounds on the Service Rate

Let $\kappa = \Lambda F\left(t^{-1}\left(m - Q\left(\frac{c}{M_v}\right)\right)\right)$

Lemma 2: If $\mu \geq Q^{-1}(M_v)$ or if $\mu \leq \lambda + \frac{c}{M_v}$, then $\tilde{R}(\lambda, \mu) = 0$ for any $\mu \geq 0$ and $\lambda \in [0, \Lambda]$. Also if $\lambda \geq \kappa$, then $\tilde{R}(\lambda, \mu) = 0$ for any $\mu \geq 0$.

$$R^* = \sup_{\lambda \geq 0,\, \lambda + \frac{c}{M_v} \leq \mu \leq Q^{-1}(M_v)} \tilde{R}(\lambda, \mu).$$

Results: Optimal Service Rate

Let $\gamma(\lambda)$ be given by $\left\{\mu : Q'(\mu) - \frac{c}{(\mu-\lambda)^2} = 0 \text{ and } \mu > \lambda\right\}$.

i. **Lemma 4**: If there exists μ such that $p(\lambda, \mu) > 0$, then

$$\max_{\mu \geq 0} \tilde{R}(p(\lambda, \mu), \mu) = \tilde{R}\left(p(\lambda, \gamma(\lambda)), \gamma(\lambda)\right)$$

$$\max_{\mu \geq 0} U(\lambda, \mu) = U\left(\lambda, \gamma(\lambda)\right)$$

ii. **Lemma 5**: $\gamma(\lambda)$ is a well-defined continuous function for any finite constant:

$M > 0$ and $0 < \gamma'(\lambda) = \frac{2c}{2c + (\gamma(\lambda) - \lambda)^3 Q''(\gamma(\lambda))} \leq 1.$

Optimal Arrival Rate (Patients Load)

$$V'(\lambda) + \lambda V''(\lambda) - Q\left(\gamma(\lambda)\right) - \frac{c}{\gamma(\lambda) - \lambda} - \frac{c\lambda}{(\gamma(\lambda) - \lambda)^2} = 0$$

Proposition 1. Consider two travel burden functions t_1 and t_2 such that $t_1(x) = a$ and $t_2(x) = t(x) + a$ for some constant $a \geq 0$, for all $x \geq 0$. The following results hold:

(i) $\lambda_1{}^* \geq \lambda_2{}^*$,

(ii) If in addition $\lambda_1{}^* > 0$ and $\lambda_2{}^* > 0$, then $\mu_1{}^* \geq \mu_2{}^*$.

As the "***distance***" cost per mile <u>increases</u> the optimal service rate of the specialist <u>decreases</u>:

- Specialists will treat fewer patients , as per (i)
- Specialists will tend to compensate for the traveling burden by spending more time with the patient, as per (ii)

Analytical Results

I. Given an arrival rate, the **optimal service rate** (for the specialist) will be <u>non-decreasing with the arrival rate</u>, $0 < \gamma'(\lambda) \leq 1$.

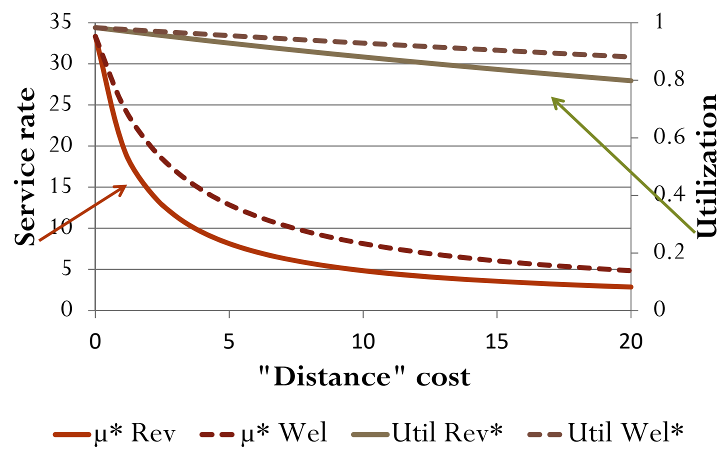
II. **Proposition 2:** A specialist trying to **maximize revenue** generation rate will **operate slower and see fewer patients** as compared to a specialist trying to **maximize social welfare**.

$$\mu_R{}^* < \mu_S{}^* \quad \text{and} \quad \lambda_R{}^* < \lambda_S{}^*$$

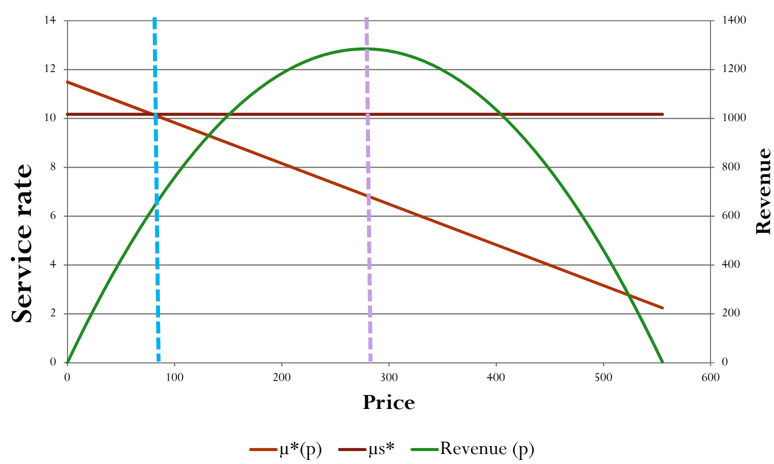
II. As the "***distance***" cost per mile <u>increases</u> the optimal service rate of the specialist <u>decreases</u>:

- The optimal decisions of the **revenue maximizer** and the **welfare maximizer** diverge.

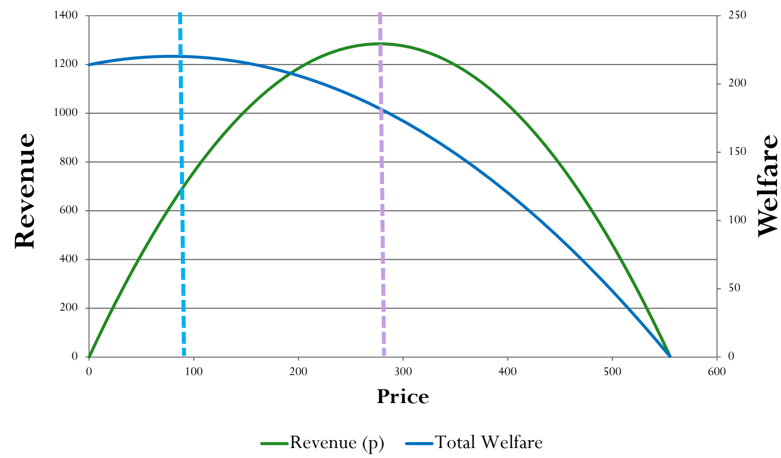
The impact of “Distance” Cost



Fixed Prices Case (Before TM)



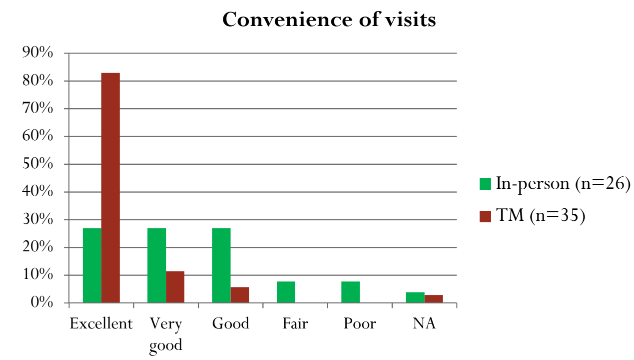
Fixed Prices Case (Before TM)



What does Telemedicine change?

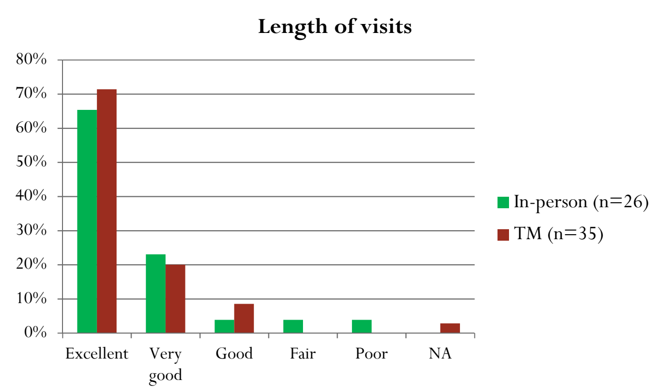
- **Telemedicine "almost" removes the distance factor from the equation.**
  - The distance "cost" reduces but is not removed altogether.
- Patients may bear an initial fixed set-up cost **($ S)** if they opt for telemedicine.
- Out-of-pocket costs for the patient per visit **($ $\boldsymbol{\beta p_t}$)**
- Patients, based on their utility may choose to (i) opt out of treatment or (ii) choose treatment in person or (iii) choose treatment through telemedicine

Patients Feedback Data: The Relative Convenience of Visits



More Patients Found TM Convenience to Dominate In-Person Visits Overall

Patients Perceptions about their Length of Visit with the Doctor Data



Patients Perceptions were Identical for both Modalities

Yet: In-Person: $\mu_i = 2$, and for TM $\mu_t=3$

Utility function for Patients Choosing Telemedicine

α	Fraction TM visits and $(1-\alpha)$ in-person visits
s	Fixed Setup cost of Telemedicine
r	Proportion of time for in-person visits
$m_t - m_i$	Difference in medical utility for telemedicine and in-person visits

$$(1-\alpha)\left(m_i - t(x) - Q(\mu_i) - \beta p_i - \frac{c}{r\mu_i - \lambda_i}\right) +$$

$$\alpha\left(m_t - Q(\mu_t) - \beta p_t - \frac{c}{(1-r)\mu_t - \lambda_t}\right) - s.$$

Medical Utility

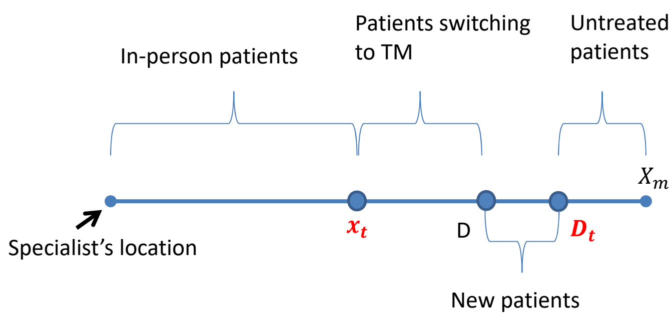
Disutility of Fast Service

Co-insurance

Opportunity cost of time

Fixed setup costs of TM

Equilibrium for Both Patients Groups



$$\lambda_{in} = \Lambda \int_0^{X_m} g_x(i)\, f(x)\, \mathrm{d}x\,.$$

$$\lambda_{tm} = \Lambda \int_0^{X_m} g_x(t) f(x)\, \mathrm{d}x\,.$$

July 2016 6

Coverage Parity vs. Payment Parity

- Coverage Parity – requires plans to cover services delivered via telehealth **to the same extent** the plan already covers the services in-person
  - Scope of services is unchanged
  - Language may also protect patients from cost-shifting
- Payment Parity – requires plans to pay providers for services delivered via telehealth **at the same rate** the plan pays the provider when the service is provided in-person.

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好大夫还好吗？北京发文禁医生与商业公司合作加号

2016-03-01 10:31

搜狐健康 文/周亦川

据《财经》网消息，北京市卫生计生委最新文件曝光，要求清理“医务人员通过商业公司预约挂号加号谋取不正当利益”，措辞非常严厉。

这一文件按照事业单位管理的相关文件，将医务人员与商业公司的合作界定为“利用工作之便为本人或者他人谋取不正当利益”；“限2016年3月25日，所有有此类行为的医务人员，应当自行解除与商业公司的合作，并将个人自查自纠（包括合作商业公司的名称、合作内

China: China's Health Authorities Issue New Rules on Telemedicine

Last Updated: 26 September 2018
Article by Katherine Wang
Ropes & Gray LLP

Your LinkedIn Connections at Firm

On September 14, 2018, the PRC National Health Commission ("NHC") promulgated three administrative measures [1] (the "Measures") to regulate telemedicine. The Measures recognize the legitimacy of emerging internet-based healthcare services, in addition to traditional telemedicine services defined by the existing regulations. By way of background, the NHC defined telemedicine narrowly in its 2014 Circular. Telemedicine only referred to physician-to-physician consultations by means of modern information and communication technologies. The Measures broaden the scope of telemedicine to include internet-based diagnosis and treatment offered by hospitals to their existing patients, as well as internet hospitals that offer online diagnosis and treatment of common and chronic illnesses to all patients.

Remote physician-to-physician consultations

The Chinese authorities began to regulate remote physician-to-physician consultations in 1999. [2] The Measures further clarify that remote physician-to-physician consultations cover two major scenarios:

a. One medical institution renders remote healthcare services at the request of another, to assist with patient diagnosis and treatment through information technology.

b. A medical institution or a third party establishes a telemedicine platform; another medical institution registers on this platform as a user to render remote healthcare services at the request of the inviting medical institution or through matching services by the third party.

The Clinical/OM/ECON Impact of TM for Chronic Care – Key (Analytical & Empirical) Conclusions

Impact on Patients:

- (+) Better/same overall care quality.
- (+) Total Patients' welfare increases.
- (+) The price per visit goes down.
- (-) Increased waiting times for appointments.
- (-) The expected face-to-face times get shorter.
- (+/-) Yet, not all patients share the same TM benefits:
  - Patients nearby will suffer from reduced utility.
  - Patients located "farther away" benefit relatively more.
  - The 'Demographic Impact' issue

Impact on Specialists:

- (+) Visit length gets shorter.
- (+) MD Utilization increases.
- (+) Treats more patients
  - **MD Capacity Increases.**
- (-) Price per visit will go down.
  - Optimal to partially subsidize the Patients' technology setup costs.
- (+) Yet, the overall revenue will increase.
- (+/+) In the long run:
  - Gain market power
  - Reduce clinical office costs
  - Partition the visits:
    - Interventional do F2F
    - Pre/Follow-ups with TM

Important Applications
Data-Intensive Medical Research

- I. **Diagnosis support research** from common conditions to complex diseases typically build upon comparative AI/Stat studies with similar persons
- II. **Consumer-directed diagnostic testing** from fertility at-home to blood or saliva samples mailed testing
- III. **Image analytics for radiological diagnostics** aim to support early detection, treatment planning and disease monitoring in oncology, cardiology and other areas.

Important Applications
Data-Intensive Medical Research

- IV. **Price transparency** aimed at allowing patients a more personalized view into their treatment options.
- V. **Provider search and ratings** should allow patients to read reviews of potential providers in hopes of making informed care decisions.
- III. **Physicians' staffing, appointments and scheduling** including wait times at urgent care clinics, allowing users to book appointments, most within (two hours), manage the timing of specialty procedures and deal with last minute Patient or MD cancellations of an appointment.

Our Talk Today

- **Lessons from Galileo Galilei**
  - Observations can be misleading…
- **1. Information *Hang-overs* in Healthcare Service Systems**
  - The value of systematic (end to end) process flow analytics
- **2. Does Technology Substitute for Nurses?**
  - The data and economics of process flow automation
- **3. The Operational Effects of Telemedicine on Chronic Care**
  - MDs and Patients as players in complex Non-Atomic Games
- **Overall Data & Analytics Insights from it all**
  - Why Medical Schools start teaching Medical Informatics

Overall……

- **Data** will tell us what did happen
- **Models** can tell us what an 'alternative future' may look like, and explain the data we see
- **Ideally**, use both in your research to calibrate and to verify
- **In Physics:** To get a Nobel, each new theory (Model) requires experimental validation (Data)

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Thank You!

Avi

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