Machine Intelligence for Reducing Clinical Variation
session 110; Feb. 21, 2017 1:00pm

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Speakers

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- Atrius Health, Boston, MA
- CMO, Ayasdi, Menlo Park, CA
Conflict of Interest

• Dr. Stewart has no potential conflicts of interest to report
• Dr. Campion is an employee of Ayasdi, Inc., producer of artificial intelligence software referenced in this presentation.
Agenda

• Introduction of machine intelligence
• Hypothesis driven inquiry vs “unsupervised learning”
• Total Knee Replacement clinical pathway analysis
• Fundamentals of Topology – data has shape, shape has meaning
• Machine Intelligence for Precision medicine analysis
  – Diabetes
  – Asthma
• Population Health
  – segmentation
  – cost prediction
Learning Objectives

1. Contrast traditional, hypothesis-driven inquiry with “unsupervised” learning using machine learning and topological data analysis.
2. Outline strengths and weaknesses of large datasets from EHRs, claims and genetic analysis.
3. Demonstrate the use of topological data analysis for surgical pathway optimization.
4. Demonstrate new methods for understanding illness patterns in chronic disease populations using machine learning for claims data study and biomarker analysis.
In this presentation we will discuss the following HIMSS Steps:

- **Treatment** - Clinical pathway analysis
- **Electronic Data** – complex EHR + claims data analytics
- **Population Management** – segmentation and prediction
- **Savings** – optimizing care
About Mercy

Headquartered in St. Louis with a multi-state footprint.

Outreach ministries in Arkansas, Louisiana, Mississippi and Texas.

Opened the first of its kind virtual care center.

Serving millions each year.

1827 founded

45 hospitals

350 outpatient facilities

2,900 integrated providers

40,000 co-workers

>$5B revenue

Top 5 best performing large health system

1. Physicians & advanced practice clinicians
2. Truven Health 15 Top Health Systems 2016
What can we do with machine intelligence?

- *Discover* optimal and personalized care paths
- *Understand and manage* variation in care
- *Define* and apply best practices to reduce readmission rates
- *Predict* high-risk, high-cost patients
- *Segment* the patient population to identify unique characteristics
- *Understand* the impactful relationship between healthcare and non-healthcare data
- *Identify* the best ways to engage with patients and improving the patient experience.
Machine intelligence analytic approach

**Conventional Approach**
- Analysts
- Hypotheses
- Coding
- Data
- Insight
- Weeks/Months/ Years

**Machine Intelligence Approach**
- Data
- Algorithms
- Topological Models
- Insights
- Continuous Improvement

**Labor Intensive**
- More Data/ Complexity = More Cost, More Time, and Missed Opportunities
- Hypothesis-driven

**Automated**
- More Data/ Complexity = Deeper, More Comprehensive Insights
- Data-driven “unsupervised learning”
A better way

<table>
<thead>
<tr>
<th>DEVELOP</th>
<th>DEPLOY</th>
<th>MONITOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generate pathway candidates</td>
<td></td>
<td>Deploy</td>
</tr>
<tr>
<td>Explore &amp; Refine</td>
<td></td>
<td>Monitor &amp; Optimize</td>
</tr>
<tr>
<td>Evaluate &amp; Approve</td>
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</table>
Data Driven = Better Outcomes

**CHALLENGE**

Unmanaged variations cost Mercy hundreds of millions of dollars annually

**SOLUTION**

Mercy created optimized clinical pathways in days versus months – using their own data

**OUTCOME**

Mercy will save $50M over the next 3 years in direct variable costs – the most conservative metric possible
Machine Intelligence at Mercy: The Workflow

Machine intelligence developed clinical pathways to optimize surgical procedures
Machine intelligence view of Total Knee Replacement, n=1,315
Total Knee: 6 groups of “best care” patients were auto-generated by machine intelligence software

<table>
<thead>
<tr>
<th>group</th>
<th>#patients</th>
<th>Direct Variable Cost</th>
<th>LOS</th>
<th>diabetes</th>
<th>hypertension</th>
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<tbody>
<tr>
<td>1</td>
<td>67</td>
<td>$7,595</td>
<td>2.42</td>
<td>3.0%</td>
<td>25.4%</td>
</tr>
<tr>
<td>2</td>
<td>65</td>
<td>$6,852</td>
<td>2.29</td>
<td>1.5%</td>
<td>58.5%</td>
</tr>
<tr>
<td>3</td>
<td>47</td>
<td>$6,907</td>
<td>2.45</td>
<td>4.3%</td>
<td>53.2%</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>$6,190</td>
<td>2.50</td>
<td>2.5%</td>
<td>17.5%</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>$5,798</td>
<td>2.70</td>
<td>0.0%</td>
<td>12.1%</td>
</tr>
<tr>
<td>6</td>
<td>31</td>
<td>$7,634</td>
<td>2.06</td>
<td>12.9%</td>
<td>61.3%</td>
</tr>
</tbody>
</table>
Total Knee: Pre-op pregabalin was associated with lowest length of stay

The computer identified that two surgeons who prescribed pregabalin 2 hours pre-operatively and had lowest length of stay across the hospital network (group 6 patients).
Total knee: Implant supply cost variation

Group 5 implant costs are almost $1,000 more per patient than Group 6.
Consensus pathway auto-generated by machine intelligence
Optimizing the TKR clinical pathway

• Rapidly identify best practices from across all 10 hospitals and 60+ orthopedic surgeons

• Real world data showed efficiencies in
  – Pain management
  – Prosthesis and cement selection
  – Early ambulation
  – DVT prevention
Monitor adherence by hospital and physician group

### Operational Dashboard

<table>
<thead>
<tr>
<th>SURGEON</th>
<th>NUM</th>
<th>ADH</th>
<th>DVC</th>
<th>STAY</th>
<th>HTN</th>
<th>DIA</th>
<th>READM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physician 178</td>
<td>31</td>
<td>67.9%</td>
<td>$6,700.51\textbf{0\textdagger} $7,624.90 - $13,511.90</td>
<td>days - 2,7</td>
<td>71.0%</td>
<td>32.3%</td>
<td>3.2%</td>
</tr>
<tr>
<td>Physician 94</td>
<td>30</td>
<td>65.2%</td>
<td>$8,304.38\textbf{0\textdagger} $7,233.47 - $10,627.65</td>
<td>days - 2,5</td>
<td>63.3%</td>
<td>6.7%</td>
<td>3.3%</td>
</tr>
<tr>
<td>Physician 51</td>
<td>32</td>
<td>64.8%</td>
<td>$8,942.17\textbf{0\textdagger} $7,309.29 - $16,901.76</td>
<td>days - 2,5</td>
<td>84.4%</td>
<td>12.5%</td>
<td>15.6%</td>
</tr>
<tr>
<td>Physician 8</td>
<td>33</td>
<td>62.0%</td>
<td>$8,323.04\textbf{0\textdagger} $7,014.71 - $11,674.71</td>
<td>days - 2,4</td>
<td>69.7%</td>
<td>33.3%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Physician 161</td>
<td>15</td>
<td>56.4%</td>
<td>$9,727.80\textbf{0\textdagger} $8,711.01 - $13,801.69</td>
<td>days - 2,5</td>
<td>46.7%</td>
<td>20.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Physician 191</td>
<td>47</td>
<td>56.1%</td>
<td>$9,638.33\textbf{0\textdagger} $8,732.90 - $15,913.87</td>
<td>days - 2,6</td>
<td>61.7%</td>
<td>14.9%</td>
<td>4.3%</td>
</tr>
<tr>
<td>Physician 45</td>
<td>6</td>
<td>55.1%</td>
<td>$8,033.76\textbf{0\textdagger} $7,297.70 - $8,619.73</td>
<td>days - 1,2</td>
<td>93.3%</td>
<td>16.7%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Physician 248</td>
<td>15</td>
<td>52.9%</td>
<td>$10,467.36\textbf{0\textdagger} $9,481.98 - $14,127.34</td>
<td>days - 3,5</td>
<td>20.0%</td>
<td>13.3%</td>
<td>6.7%</td>
</tr>
<tr>
<td>Physician 26</td>
<td>12</td>
<td>52.7%</td>
<td>$9,192.56\textbf{0\textdagger} $4,446.60 - $10,655.13</td>
<td>days - 3,5</td>
<td>58.3%</td>
<td>25.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
Monitor adherence by physician

Physician detail for Physician 69.

- 45.2% adherence
- 67 encounters
- 4.48% readmission
- 5.97% diabetic
- 56.7% hypertensive

<table>
<thead>
<tr>
<th>event</th>
<th>category</th>
<th>sub category</th>
<th>time</th>
<th>adherence</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL KNEE - CEMENTED K-1 ZIMM</td>
<td>Surgery</td>
<td>OPERATING ROOM COMPLEX</td>
<td>SURGERY</td>
<td>74.6%</td>
</tr>
<tr>
<td>BASIC METABOLIC PANEL</td>
<td>Labs</td>
<td>LAB</td>
<td>POST OP 3 hrs 16 mins</td>
<td>74.6%</td>
</tr>
<tr>
<td>IP CONSULT TO HOSPITALIST</td>
<td>Orders</td>
<td>CON</td>
<td>POST OP 3 hrs 16 mins</td>
<td>73.1%</td>
</tr>
<tr>
<td>oxyCODONE CR (OXYCONTIN) tablet ...</td>
<td>Labs</td>
<td>ANALGESICS</td>
<td>POST OP 1 day 17 hrs 49 mins</td>
<td>71.6%</td>
</tr>
<tr>
<td>CEFAZOLIN 2000 MG INFUSION SO</td>
<td>Labs</td>
<td>ANTIBIOTICS</td>
<td>POST OP 14 hrs 53 mins</td>
<td>71.6%</td>
</tr>
<tr>
<td>BASIC METABOLIC PANEL</td>
<td>Labs</td>
<td>LAB</td>
<td>PRE OP 13 days 21 hrs</td>
<td>71.6%</td>
</tr>
</tbody>
</table>
Machine intelligence advantages

- Automates the discovery of all variations
- Identifies best practices – using local data
- Drives pathway adoption and adherence
CAREVOLUTION
Mercy Hospital Oklahoma City

Huron Consulting Group

analyticsMD

LOGISTIC HUB
- Bed Board
- Hospitalist
- Staffing
- Rapid Access
- EVS
- Transport
- Scheduling

Coordinated patient flow

ED
OR
ICU
Ortho
Lab
Imaging
CTS
Med/Surg
Peds
PACU
Onc
• Process re-engineering
• Predictive analytics/Real time data
• Logistical control (Hub)
• Change management (AIM)
<table>
<thead>
<tr>
<th>Access</th>
<th>Care Delivery</th>
<th>Transition</th>
<th>Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid Access Consolidation</td>
<td>Goal length of stay</td>
<td>Resource optimization</td>
<td>Discharge Preparation</td>
</tr>
<tr>
<td>Clinical Bed-board</td>
<td>Staffing based on acuity</td>
<td>Interdisciplinary coordination</td>
<td>Coordinate w/Post Acute Care Setting</td>
</tr>
<tr>
<td>Centralized patient placement</td>
<td>Scheduling of diagnostics, evaluations, and treatments</td>
<td>Appropriate weekend resources</td>
<td>Appropriate utilization of lowest cost labor</td>
</tr>
<tr>
<td>Designated Hospitalist admitter</td>
<td>Patient and Staff itinerary</td>
<td>Safe and reliable handoffs between departments</td>
<td>Optimized bed turnaround process</td>
</tr>
<tr>
<td>Staffing based on anticipated demand</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- Red circles indicate processes that are currently in progress.
- Green circles indicate processes that are complete.
- Orange circles indicate processes that are planned for future implementation.

**HIMSS17**
Branch of Artificial Intelligence focused on big-data problems
Machine Learning + Topological Data Analysis (TDA)
Mt. Sinai: Breakthrough in Diabetes

**PROBLEM**

Understanding disease subtypes by analyzing thousands of patients’ EMR and genotype information

**SOLUTION**

Uncovered three new Type-2 Diabetes patient subgroups with their precise clinical and genetic characteristics

**OUTCOME**

Supports more precise diagnoses, targeted treatment protocols, and better patient outcomes in the future
“Our approach demonstrates the utility of applying the precision medicine paradigm in T2D and the promise of extending the approach to the study of other complex, multi-factorial diseases.”

We identified three distinct subgroups of T2D
- Subtype 1: High BMI, diabetic nephropathy and retinopathy
- Subtype 2: higher rates of cancer malignancy and cardiovascular diseases
- Subtype 3: cardiovascular and neurological diseases, allergies, and HIV infections

Southampton: Breakthrough in Asthma

**PROBLEM**

Cannot easily discern the subtypes of asthma. Hard to pinpoint predictors of severe asthma from millions of patient attributes.

**SOLUTION**

Machine learning helped identify six patient sub-populations – that had previously gone unnoticed.

**OUTCOME**

Opportunity to identify the biomarkers that are predictors of the disease and devise targeted therapies.
Southampton: Breakthrough in Asthma

The machine intelligence platform identified six sub-populations of asthma patients using combination of sputum inflammatory biomarkers, genetic data, clinical findings and physiologic parameters.
Today, 4,660 Americans will be diagnosed with diabetes. Nearly 30 million Americans have diabetes. 86 million Americans have prediabetes, more than the population of the east coast from Connecticut to Georgia.

Diabetes and prediabetes cost America $322 billion per year.

1 in 5 health care dollars is spent caring for people with diabetes. 1 in 3 Medicare dollars is spent caring for people with diabetes. People with diagnosed diabetes have health care costs 2.3 times higher than if they didn’t have the disease.
One size does not fit all

### Population Characteristics
- **~50% of Costs**
  - Multiple chronic conditions
  - Frequent hospital visits
- **~30% of Costs**
  - Limited, stable chronic conditions
- **~20% of Costs**
  - Some risk factors
- **Low Cost**
  - Minor issues
  - Overall healthy

### Care Priorities
- **Complex Case Management – Standardized care**
  - Discharge planning, virtual care
  - Remote monitoring, timely intervention
- **Disease Management – Team based care**
  - Systematic and coordinated care
  - Care gap analysis and virtual care
- **Preventive Care**
  - Patient engagement
  - Care gap analysis and closure
- **Wellness Care**
  - Patient engagement
  - Patient education

---

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~50% of Costs
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~30% of Costs
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Care Priorities

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Where the brightest minds in health and IT meet
115K Medicare patients. Automatically identified 4 distinctive member groups using unbiased segmentation.

Topological Models (Similarity Maps)
- Nodes are groups of similar members
- Connected
Group profiles: Comorbidity and Cost

Clinical Risk - Comorbidities

Number of Comorbidities

Low

High

Financial Risk - Utilization

Total Payments

Low

High
Prediction Embedded into Care Management Flows

Pre-Built Predictive Topological Model

- Diabetes, CKD
- Diabetes, Depression
- TIA, Cancer

Incoming patient data

Predict API: Online Prediction

Care Coordinator

Clinical SME

Existing Care Management Application

Predictive score, Prescriptive Guidance

PopRisk UI: Examine patterns, capture clinical guidance
Suggestions for deploying machine intelligence and other technologies

1. Don’t park innovative technology in an R&D center on the side
2. Be prepared to iterate quickly and evolve - commit to fast timelines
3. Don’t worry about bad data - engineer systems to improve over time
4. Consider using ALL of your available data for learning
5. Initially run new system in parallel with current process
6. Expect and embrace need for process change
7. Build a Center of Excellence – analytic services across health system
The goal of Artificial Intelligence

Mimic what people do, using software.
AI most people think about
What about problems that are not solved easily by people? Many problems are not intuitive or may have more than one good answer.

**The goal of Machine Intelligence**

Offer a complete pallet of solutions, such that insightful weak data signals aren’t being drowned out by blunt strong signals.
The core of machine intelligence is an array of predictive models and cognitive heuristics that offer an extensive set of possible solutions.

**Machine Intelligence massively accelerates understanding and powers automation.**
In this presentation we will discuss the following HIMSS Steps:

- Treatment - Clinical pathway analysis
- Electronic Data – complex EHR + claims data analytics
- Population Management – segmentation and prediction
- Savings – optimizing care
Thank you for your interest in

Healthcare optimization using machine intelligence

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