1. You can join via phone or computer to access audio. Please keep yourself muted to avoid background noise and turn off your webcam.

2. Please ensure that you list your full name by hovering over your name on the participant list, clicking “More” and clicking “Rename.” This is important so we know who you are.

3. If you have questions during the meeting, please send them via the chat box on your Zoom dashboard, which will be monitored by the meeting facilitators.
Housekeeping cont.

• How to use active speaker view
  o To view speaker’s video as a large Active Speaker panel, click the Active Speaker Panel icon above the video panel.

• How to pin video
  o At the top of your screen, hover over the three dots on the video of the speaker you want to pin and click Pin Video
National Academies of Medicine Report: *Optimizing Strategies for Clinical Decision Support*

James E. Tcheng, MD – Duke University
james.tcheng@duke.edu
Project Background

• **Partnership:** National Academy of Medicine (NAM) & Office of the National Coordinator for Health IT (ONC)

• **Aim:** To reflect on the current CDS environment, then identify potential approaches & recommend practical strategies for improving CDS practices and adoption

• **Leadership:** External Planning Committee

• **Deliverable:** Special NAM Publication (Nov 2017)
Planning Committee Members

• James Tcheng, Duke University (Chair)
• Suzanne Bakken, Columbia University
• David Bates, Brigham and Women’s Hospital
• Hugh Bonner III, Saint Francis Hospital
• Tejal Gandhi, National Patient Safety Foundation
• Meredith Josephs, Privia Health
• Edwin A. Lomotan, AHRQ
• Erin Mackay, National Partnership for Women & Families
• Jonathan Teich, Harvard University
• Scott Weingarten, Cedars-Sinai Health System
Developing Priorities for Action

• Over the course of the project, a comprehensive key set of actions was identified. Participants prioritized the following actions for optimizing strategies for CDS adoption and use, offered actionable collaborative steps that could be initiated over the next 5 years.

• These actions will require commitment by multiple stakeholders and are intended to move forward the discussion in a way that complements and enhances clinical practice.
# Workgroups

<table>
<thead>
<tr>
<th>Presenter</th>
<th>Institution and Role</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>James Tcheng, MD</td>
<td>Professor, Duke University Chair, NAM Planning Committee</td>
<td>Overview of National Academy of Medicine (NAM) CDS initiative</td>
</tr>
<tr>
<td>Kensaku Kawamoto, MD, PhD, MHS</td>
<td>Associate CMIO, Univ. of Utah</td>
<td>Strategies for CDS content</td>
</tr>
<tr>
<td>Scott Weingarten, MD, MPH</td>
<td>SVP &amp; Chief Clinical Transformation Officer, Cedars-Sinai</td>
<td>Strategies for CDS implementation</td>
</tr>
<tr>
<td>Blackford Middleton, MD, MPH, MS</td>
<td>Chief Informatics &amp; Innovation Officer, Apervita, Inc.</td>
<td>Strategies for CDS dissemination</td>
</tr>
<tr>
<td>James Tcheng, MD</td>
<td>Professor, Duke University Chair, NAM Planning Committee</td>
<td>Cross-cutting recommendations</td>
</tr>
</tbody>
</table>
Priorities for Action

1. Establish Clinical Decision Support (CDS) technical standards.
   • Develop coordinated activities to stand up standard intervention templates, methods, artifacts, and intervention repositories.
   • Develop a standard set of each of the core CDS operational elements such as EHR trigger points, action items, and supporting data [leveraging existing work such as the 2012 NQF Expert Panel report and existing HL7 standards] to increase predictability of the EHR environment.
   • Establish repeatable conventions [e.g., FHIR resources, APIs] to pass data and context/situational info from the EHR to the CDS and to accept recommendations from the CDS back to the EHR.
   • Stand up an entity of appropriate stakeholders to resolve governance issues and drive EHR vendor acceptance for support of CDS standards.
Priorities for Action

• **Develop, test, establish, validate, and apply standards**
  – Establish CDS technical standards
  – Provide federal funding for CDS standards management
  – Create a CDS technical information resource

• **Encourage adoption, use & assessment at the delivery system level**
  – Disseminate best practices
  – Create a national CDS repository network
  – Measure CDS usage
  – Develop tools to assess CDS efficacy
  – Publish performance evaluations
  – Leverage meaningful financing and measurement incentives
  – Market CDS to stakeholders

• **Establish a national CDS infrastructure**
  – Create a CDS legal framework
  – Develop a multi-stakeholder CDS learning community to inform usability
  – Establish a federal investment program in CDS research
Optimizing Strategies for Clinical Decision Support
| Summary of a Meeting Series

https://nam.edu/optimizing-strategies-clinical-decision-support/
Interoperable CDS to Support Dissemination and Implementation of New Clinical Knowledge: Evidence from Two Pain Management Projects

Roland Gamache, PhD, MBA, FAMIA, Staff Fellow, Division of Digital Healthcare Research, AHRQ
Kristen E. Miller, DrPH, CPPS, National Center for Human Factors in Healthcare, MedStar Health
Joshua E. Richardson PhD, MS, MLIS, RTI International
• Welcome and AHRQ Perspective – Roland Gamache, PhD, MBA, FAMIA

• Clinical Decision Support (CDS) for Chronic Pain Management – Kristen Miller, DrPH, CPPS

• Shareable Clinical Decision Support for Chronic Pain Management to Promote Shared Decision-Making (CDS4CPM) – Joshua Richardson, PhD, MS, MLIS

• Summary

• Question and Answer Session
AHRQ’s Introduction to the Shareable Clinical Decision Support Pain Management Projects

Roland Gamache, PhD, MBA, FAMIA
Advancing evidence into practice through CDS and making CDS more shareable, standards-based and publicly-available

1. Engaging a stakeholder community
2. Creating prototype infrastructure for sharing CDS and developing CDS
3. Advancing CDS through grant-funded research
4. Evaluating the overall initiative

https://cds.ahrq.gov
Vision for the Future

- Clinical & Contextual
- Patient-generated

- Guidelines
- Relevant research findings

Needs to be computable and FAIR!

Advanced analytic techniques:
- Artificial intelligence
- Natural language processing
- Machine learning

- Findable
- Accessible
- Interoperable
- Reusable
The purpose is to develop, implement, disseminate, and evaluate CDS for both patients and clinicians in the area of chronic pain management

AHRQ developed and generated interest in CDS that:

• Is interoperable and publicly-shareable

• Meets the needs of both patients and clinicians
  ► Through both
    - patient-facing channels and formats
    - clinician-facing channels and formats

• Has demonstrable impact
  ► Can be evaluated using appropriate measures and outcomes
  ► Share lessons learned through presentations and publications
Brief Introduction to the Individual Projects

MedStar
• Focus on non-pain management specialists in primary care
• Optimizing pain therapy and support opioid-dose reductions

RTI
• Develop, implement, and disseminate two types of FHIR-based CDS for chronic pain management in primary care and pain clinics
Clinical Decision Support (CDS) for Chronic Pain Management

MedStar Team Members: Jim Houston, MD, Elias Shaya, MD, Peter Basch, MD, Bonnie Levin, PharmD, MBA, FASHP, Kathryn Walker, PharmD, Ella Franklin, MSN, RN, Long La, PharmD, Sidd Nambiar, PhD, Joseph Blumenthal, Shrey Mathur, MS, Shrenik Shah, MS, John Erkus, Peter Kuehl, MD, Deliya Wesley, MPH, PhD, Sadaf Kazi, PhD, Kelly Smith, PhD, Nawar Shara, PhD, Ronald Romero Barrientos, Christian Boxley, Deanna Busog

Development Team: Perk Health
Collaborators: Georgetown University Medical Center, George Washington University, IMPAQ Int.

Consultants: Alan Staples, II, CRCR, Ross Teague, PhD, Ranit Mishori, MD, MH
Opioid Tapering

• Liberal prescribing of opioids for chronic pain has acute and chronic problems for patients on long term opioid therapy

• Long-term opioid use: physical dependence, constipation and nausea, fatigue, depression…

• Patients may be reluctant to taper fearing increased pain and withdrawal symptoms: vomiting, hallucination, tremors…

• Clinicians must assess and weigh risks versus benefits to decide whether tapering is indicated

• Tapering plans should be individualized and should minimize symptoms of opioid withdrawal while maximizing pain treatment with nonpharmacologic therapies and nonopioid medications

• Barriers include challenging and exhausting communications, inadequate resources, and lack of training
Task Overview

• Goal: Optimize pain therapy and support opioid-dose reductions

• Clinician-facing CDS
  » Provide personalized evidence-based guidelines to support opioid tapering
  » Optimize presentation of patient generated and electronic health record data

• Patient-facing CDS
  » Track and manage pain and daily function to support reduced opioid use
  » Support continued patient engagement including education and resources

• Implementation and Evaluation
Application of Human Factors Engineering Methods

• Multi-Disciplinary Research Workgroups
  » Experts in pain management, behavioral science, patient reported outcomes, health IT, clinical medicine including chronic pain management, human factors engineering

• Stakeholder Interviews
  » Patients with chronic pain; family members of patients with chronic pain
  » Primary care providers; pain management specialists
  » Health IT developers focused on patient-facing and clinician-facing technologies

• Design Workshops

• Usability Testing
Application Flow

Initial Visit
1. Introduce a Taper
2. Set Taper Parameters
3. Confirm Medication Plan

Follow-Up Visit
1. Review Patient-Reported Data
2. Update Medication Plan

Home Experience
1. Track and Manage Pain and Daily Function
2. Support Continued Patient Engagement
EHR Patient Data Screen

Create Taper

- Patient Context
- Taper Settings
- Opioid Taper Plan
- Non-Opioid Plan
- Patient App

Patient Context

Current Opioid Medications

<table>
<thead>
<tr>
<th>Medication</th>
<th>Dosage</th>
<th>MME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxycodeone ER 40mg</td>
<td>80 mg</td>
<td>120 MME</td>
</tr>
<tr>
<td>Oxycodeone IR 5mg</td>
<td>30 mg</td>
<td>45 MME</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>165 MME</strong></td>
<td></td>
</tr>
</tbody>
</table>

PDMP

- (5/2/20) oxycodeone ER 40mg, Q12h, 60 tablets
- (5/2/20) oxycodeone IR 5mg, Q4h, 80 tablets
- (5/2/20) oxycodeone ER 40mg, Q12h, 60 tablets
- (5/2/20) oxycodeone IR 5mg, Q4h, 80 tablets
- (5/2/20) oxycodeone ER 40mg, Q12h, 60 tablets
- (5/2/20) oxycodeone IR 5mg, Q4h, 80 tablets

Controlled Substance Agreement Last updated 10/27/19
Last Urine Toxicology: Positive for Marijuana: 2/15/20

Other Current Medications

- Ibuprofen 600mg Q8h PO PRN Pain
- Metoclopramide 10mg Q6h PO PRN Nausea

Social History

- Marijuana

Current Relevant Diagnosis

- Chronic Pain, Diabetes

How to use Taper App - Placeholder

1. Use this tool to create a guidelines based opioid reduction, non-opioid pain plan, and withdrawal support plan for next taper interval.

2. Collect relevant Patient Reported Outcomes from the patient app.

Patient App - Placeholder

- Placeholder for PROMIS Measures
- Pain Journal
- Patient Education

Taper Guidelines - Placeholder

- Placeholder for links to VA/CDC
Create a Taper

Create Taper

Opioid Taper Plan
Starting 6/8/2020, for following 4 Weeks

Oxycodone (ER)
30 mg 1 tabs Q12h
Consider adding 14.5 mg (22 MME) for slow taper
Your Plan: 60 mg (90 MME) - 30mg, 30mg PO Q12hrs
For Slow Taper: 74.5 mg (112 MME)

Not Tapering Yet
Oxycodone (IR)
5 mg 1 tabs Q4h
Your Plan: 5mg Q4 hours - 30 mg (45 MME) / day
For Slow Taper: 30 mg (45 MME)

Your Plan
135 MME /day 18%
30 MME Reduction

For Slow Taper
157 MME /day 5%
8 MME Reduction

Previous
165MME /day
Oxycodone IR 5mg, 5mg PO Q4 hours
Total: 30 mg (45 MME) / day
Oxycodone ER 40mg, 40mg PO Q12hrs
Total: 80 mg (120 MME) / day

Done
Non-Opioid Pain Screen
Application Flow

**Initial Visit**

1. Introduce a Taper
2. Set Taper Parameters
3. Confirm Medication Plan

**Follow-Up Visit**

1. Review Patient-Reported Data
2. Update Medication Plan

**Home Experience**

1. Track and Manage Pain and Daily Function
2. Support Continued Patient Engagement
Good Morning, Mary

Weekly Pain Assessment

Your doctor would like you to answer some questions about your pain.

It should take less than 2 minutes to complete.

Welcome!

This app will help you

- Track your pain over time
- Automatically report your weekly pain scores to your doctor
- Track your daily medication and other activities that impact your pain.

Log in

Patient Home Screen

home

Pain Intensity
61 Moderate

Pain Interference
71 High
today

New Daily Pain Score

MON TUE WED THU FRI SAT SUN

You've successfully reduced your pain medication by 10%
today

10% Less

Start Now

Complete Journal

medication change

Coming Up

In 4 days your medication is scheduled to change
today

View Change

Your pain was higher than normal last week. What was different?
today

Your average pain is 2 points

home Journal me
### PROMIS

**Adult Item Bank: e.g. from Pain Interference**

<table>
<thead>
<tr>
<th>Question</th>
<th>Not At All</th>
<th>A Little Bit</th>
<th>Somewhat</th>
<th>Quite a Bit</th>
<th>Very Much</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the past 7 days... how difficult was it for you to take in new</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>information because of pain?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much did pain interfere with your day to day activities?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

### PROMIS

**Adult Item Bank: e.g. from Pain Intensity**

Please respond to each item by marking one box per row.

<table>
<thead>
<tr>
<th>Question</th>
<th>Not At All</th>
<th>A Little Bit</th>
<th>Somewhat</th>
<th>Quite A Bit</th>
<th>Very Much</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the past 7 days... how intense was your pain at its worst?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>How intense was your average pain?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>What is your level of pain right now?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

### In The Past 7 Days...

- **How much did pain interfere with your day to day activities?**
- **How much did pain interfere with your ability to participate in social activities?**
- **How intense was your pain at its worst?**
Thank You!

Your weekly pain scores have been recorded for your doctor to review at your next visit.

Results

Pain Intensity
How strong your pain is.

Moderate
61

30 70

Pain Interference
The amount your pain impacts your daily life.

Severe
71

15 85

My History

My Pain

My Activities

Physical Therapy

Take Notice

Your recent Pain Intensity score is 10 points worse than your baseline score.

This could be a significant change.

Please consider contacting your provider if your pain is:

- Unexplained
- Uncontrolled
- In a new spot
- Feels different (stabbing vs aching)
- Or, if you have concerns

Close

Done

Done

www.MedicalHFE.org
Today
My Pain Journal
Saturday, April 16

7/10

What did you do today?
Added by your clinician

- Physical Therapy
- Take Acetaminophen
- Cognitive Behavioral Therapy
- Other

Body Map

Pain History

4 April

Daily Journal

1 2 3 4 5 6 7 8 9 10 11 12
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Patient Engagement
Application Flow

Initial Visit
1. Introduce a Taper
2. Set Taper Parameters
3. Confirm Medication Plan

Home Experience
1. Track and Manage Pain and Daily Function
2. Support Continued Patient Engagement

Follow-Up Visit
1. Review Patient-Reported Data
2. Update Medication Plan
Provider Dashboard
- Taper History
- Opioid Plan Summaries
- Patient Reported Data
Implementation

- 3 Phase Roll-Out
  - February, March, April 2021
- 15 Individual Primary Care Sites
  - Small to large sites
  - MedStar Health
  - CAPRICORN network
  - George Washington University
- 3 Different Electronic Health Record Vendors
  - Cerner, Nextgen, Allscripts
Challenges to Date & Anticipated Challenges

Ethical, legal, policy challenges
- Escalation protocol
- Legal liability
- Security of patient-facing applications (HIPAA)

Technical challenges
- Local EHR customizations required for vendor sites that have not adopted current FHIR standards
- Not all the desired data can easily and consistently be found in the FHIR resources (or may be documented in multiple places)
- Varying EHR vendor whitelisting requirements for applications
Acknowledgment

Funding provided by the Agency for Healthcare Research and Quality

Contract Number: HHSP233201500022I

Kristen Miller, DrPH, CPPS
MedStar Health National Center for Human Factors in Healthcare
Washington, DC
Kristen.E.Miller@medstar.net
Shareable Clinical Decision Support for Chronic Pain Management (CDS4CPM) to Promote Shared Decision-Making

PD: Joshua E. Richardson, PhD, MS, MLIS
APD: Laura Haak Marcial, PhD
Team Members: Barry Blumenfeld, MD, MS; Stephen Brown, MS; Jessica DeFrank, PhD; Sonya Goode, MPH; Sara Jacobs, PhD; Stephanie Rizk, MS

Collaborators: Kensaku Kawamoto, MD, PhD, MHS; Vanderbilt University Medical Center; University of Chicago; Alphora, Inc.; Danny van Leeuwen, MPH, RN, CPHQ; MD Partners, Inc.; iParsimony, LLC. Glyn Elwyn, MD, PhD, MSc
Aim to Use CDS that Promotes Shared Decision-Making (SDM)

- **MyPAIN for Chronic Pain**
  - PROM based Pain Assessment
  - Non-Opioid Treatment Options
  - Information on Opioids
  - Pre-visit assessment Questionnaire

- **PainManager Dashboard**
  - Results from MyPAIN to facilitate SDM
  - Pertinent Patient History
  - Historical Treatments and Risk conditions
  - PDMP data
  - Structure note Generation for SDM

1. **A. Communicate**
   - Seek your patient’s participation

2. **B. Educate**
   - Provide details on treatment options

3. **C. Preferences**
   - Collect your patient’s values and preferences

4. **D. Discuss and Decide**
   - Discuss options and decide with your patient

5. **E. Evaluate**
   - Evaluate your patient’s decision
Overall System Architecture

1. Patient visit is scheduled
2. Phenotype
3. Generates message and launches MyPAIN
4. Patient receives an email invitation to access MyPAIN
   - Patient accesses SDM resources via MyPAIN
   - Patient records PROs via MyPAIN to prepare for SDM
5. PainManager
6. Results of SDM are saved to EHR
   - Patient and clinician meet to engage in SDM encounter and decide on a treatment plan
   - Clinician/health system collects and reviews data on decision(s) via PainManager
EHR Interactivity Achieved via a “FHIR Façade”

1. EHR Portal Invitation
2. Web Browsers
3. FHIR Facade
4. PDMP
MyPAIN to Collect Patient-Reported Outcomes

We’d like to ask you a few questions about your pain and how it is affecting your life.

Please describe the location(s) of any pain you have had in the past 7 days.

Select one or more locations

- Head
- Shoulders

What type of shoulder pain?

- Burning
- Aching
- Stabbing
- Throbbing
- Tingling
- Prickling

Other

Please describe

Thank you for using MyPAIN. FirstName

A summary of your responses is included below:

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Did it work?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stretching</td>
<td>somewhat</td>
</tr>
<tr>
<td>Sleep or position aids</td>
<td>somewhat</td>
</tr>
<tr>
<td>Over the counter creams</td>
<td>very much</td>
</tr>
<tr>
<td>Yoga</td>
<td>somewhat</td>
</tr>
</tbody>
</table>
We’d like to ask you a few questions about your pain and how it is affecting your life.

Please describe the pain you had in the past 7 days.

Select one of the descriptions below:

- Burning
- Throbbing
- Other (Please describe in text)

What type of pain did you experience in the past 7 days?

Thinking about your overall pain, in the past 7 days, please respond to the questions below:

- How intense was your pain at its worst?
  - No pain
  - Mild
  - Moderate
  - Severe
  - Very severe

- How intense was your average pain?
  - No pain
  - Mild
  - Moderate
  - Severe
  - Very severe

- What is your level of pain right now?
  - No pain
  - Mild
  - Moderate
  - Severe
  - Very severe

Thank you for using MyPAIN. First Name.

A summary of your responses is included below:

Treatments
You have noted trying the following in the last 6 months to help with your pain:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Did it work?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stretching</td>
<td>somewhat</td>
</tr>
<tr>
<td>Sleep or position aids</td>
<td>somewhat</td>
</tr>
<tr>
<td>Over the counter creams</td>
<td>very much</td>
</tr>
<tr>
<td>Yoga</td>
<td>somewhat</td>
</tr>
</tbody>
</table>

Review and Submit

Thank you for using MyPAIN, First Name.

A summary of your responses is included below:

Treatments
You have noted trying the following in the last 6 months to help with your pain:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Did it work?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stretching</td>
<td>somewhat</td>
</tr>
<tr>
<td>Sleep or position aids</td>
<td>somewhat</td>
</tr>
<tr>
<td>Over the counter creams</td>
<td>very much</td>
</tr>
<tr>
<td>Yoga</td>
<td>somewhat</td>
</tr>
</tbody>
</table>
MyPAIN to Collect Patient-Reported Outcomes

About my Goals

Thinking about your overall pain intensity and how it is affecting your daily life for the past 7 days, please respond to the following questions:

1. How intense was your pain at its worst?

   - No pain
   - Mild
   - Moderate
   - Intense
   - Extreme

2. How intense was your pain on a typical day?

   - No pain
   - Mild
   - Moderate
   - Intense
   - Extreme

3. What type of pain is it?

   - Burning
   - Throbbing
   - Other

   Please describe your pain:

   - Please describe...

4. What are your most important activity goals?

   - Please describe your goals...

   - Your most important activity goals...

Review and Submit

Thank you for using MyPAIN, FirstName. A summary of your responses is included below:

Treatments

You have noted trying the following in the last 6 months to help with your pain:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Did it work?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stretching</td>
<td>somewhat</td>
</tr>
<tr>
<td>Sleep or position aids</td>
<td>somewhat</td>
</tr>
<tr>
<td>Over the counter creams</td>
<td>very much</td>
</tr>
<tr>
<td>Yosai</td>
<td>somewhat</td>
</tr>
</tbody>
</table>
PainManager for Displaying Patient-reported Data

PainManager

Factors to Consider in Managing Chronic Pain

Pertinent Conditions
Current Treatments
Urine Drug Screening
Shared Decision Making

NOTE: This summary is not intended for patients who are undergoing end-of-life (hospice or palliative) or active cancer treatment.

The information below was provided by the patient on [MyPAIN submit date: XX/XX/YYYY] using the MyPAIN application:

ACTIVITY GOALS
I want to be able to walk to my mailbox free of pain. I'd like to get back to enjoying a walk in the neighborhood with my grandkids.

PAIN LOCATIONS (only yes responses shown)

<table>
<thead>
<tr>
<th>Location</th>
<th>Y/N</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Y</td>
<td>burning</td>
</tr>
<tr>
<td>Neck</td>
<td>Y</td>
<td>burning</td>
</tr>
<tr>
<td>Shoulders</td>
<td>Y</td>
<td>aching</td>
</tr>
<tr>
<td>Arms</td>
<td>Y</td>
<td>aching</td>
</tr>
</tbody>
</table>

ACTIVITY BARRIERS
On a bad day, I have trouble putting on my clothes or getting a shower. I need to take care of my cat but have trouble just taking care of myself some days.

PAIN INTENSITY AND INTERFERENCE

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>How intense was your pain at its worst?</td>
<td>Somewhat</td>
</tr>
<tr>
<td>How intense was your average pain?</td>
<td>Somewhat</td>
</tr>
<tr>
<td>What is your level of pain right now?</td>
<td>Somewhat</td>
</tr>
<tr>
<td>How much did pain interfere with your day?</td>
<td>Somewhat</td>
</tr>
</tbody>
</table>
PainManager for Displaying EHR-based Pertinent Conditions

### PainManager

<table>
<thead>
<tr>
<th>Pertinent Conditions</th>
<th>Factors to Consider in Managing Chronic Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHRONIC PAIN CONDITIONS (past 12 months)</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td></td>
</tr>
<tr>
<td>Fibromyalgia</td>
<td></td>
</tr>
<tr>
<td>Chronic neck pain</td>
<td></td>
</tr>
<tr>
<td>CO-MORBID CONDITIONS INCREASING RISK WHEN USING OPIOIDS (past 12 months unless otherwise noted)</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td></td>
</tr>
<tr>
<td>Diarrhea</td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td></td>
</tr>
<tr>
<td>Current Pain Treatments</td>
<td></td>
</tr>
<tr>
<td>Urine Drug Screening</td>
<td></td>
</tr>
<tr>
<td>Shared Decision Making</td>
<td></td>
</tr>
</tbody>
</table>
PainManager for Displaying Current Treatments + MME

### Factors to Consider in Managing Chronic Pain

#### Pertinent Conditions

#### Current Pain Treatments

**ACTIVE PRESCRIPTIONS**

<table>
<thead>
<tr>
<th>Medication</th>
<th>Date Prescribed</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cymbalta</td>
<td>1/1/2020</td>
<td>N/A</td>
</tr>
<tr>
<td>Clonazepam</td>
<td>1/1/2016</td>
<td>N/A</td>
</tr>
<tr>
<td>Docusate (colace)</td>
<td>4/1/2019</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Opioids**

<table>
<thead>
<tr>
<th>Medication</th>
<th>Date Prescribed</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxycodeone</td>
<td>1/1/2018</td>
<td>N/A</td>
</tr>
<tr>
<td>Narcan</td>
<td>4/1/2019</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**TOTAL MME/Day:** N/A

**SELF-REPORTED TREATMENTS FROM MyPAIN (past 6 months)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Effectiveness</th>
<th>Treatment</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical therapy</td>
<td>Sometimes</td>
<td>CBD oil</td>
<td>Never</td>
</tr>
<tr>
<td>Chiropractic</td>
<td>Sometimes</td>
<td>Pain relievers</td>
<td>Always</td>
</tr>
<tr>
<td>Meditation</td>
<td>Sometimes</td>
<td>Cortisone injection</td>
<td>Sometimes</td>
</tr>
<tr>
<td>Sleep therapy</td>
<td>Sometimes</td>
<td>Medical marijuana</td>
<td>Sometimes</td>
</tr>
</tbody>
</table>
Challenges CDS4CPM has Encountered

- Anticipating future developments for standards
  - Proprietary vs standard APIs
  - Evolving vendor challenges per information blocking regulations
  - What happens if/when the FHIR façade is no longer needed due to changes in vendor APIs?
- Managing data models (via FHIR façade) depending how US Core meets various needs
  - Extending US Core for QuestionnaireResponse (future versions?)
  - Dosage information requiring more specificity than what US Core currently provides, suggest for USCDI v2
- PDMP
  - Technical solution may not align with state capabilities and governance
  - Technical solution may not align with local governance
- Artifact Stewardship
  - Assigning long-term oversight of artifacts and value sets
  - Determining when oversight is best handed off to different parties
  - Covering costs of stewardship
Acknowledgment

Funding provided by The Agency for Healthcare Research and Quality: HSP233201500024I

Joshua E. Richardson, PhD, MS, MLIS
RTI International
Chicago, IL
jrichardson@rti.org
Summary Points

• Interoperable CDS Expectations
  ► Improve the spread of adoption/dissemination of medical knowledge and practice guidelines
  ► Reduce provider burden
  ► Provide tools for “shared decision making”

• Areas for improvement
  ► Data resources are not uniformly available at different sites
  ► Workflows for local CDS deployment is still being validated
  ► Validation of data streams outside of the EHR is a concern
AHRQ Announcements

• New FOA
  ▶ Disseminating and Implementing Patient-Centered Outcomes Research (PCOR) Evidence into Practice through Interoperable Clinical Decision Support

• Upcoming AHRQ Division of Digital Healthcare Research “2019 Year in Review” report

• Resources
  ▶ AHRQ CDS main page [https://cds.ahrq.gov](https://cds.ahrq.gov)
  ▶ AHRQ resource mailbox [ClinicalDecisionSupport@ahrq.hhs.gov](mailto:ClinicalDecisionSupport@ahrq.hhs.gov)
QUESTIONS?
Supporting Providers and Health Systems Through Electronic Clinical Decision Support Tools

Wesley Sargent, EdD, MA
Health Scientist
Division of Overdose Prevention
National Center for Injury Prevention and Control
September 15, 2020
3 Waves of the Rise in Opioid Overdose Deaths

- **Other Synthetic Opioids**: e.g., Tramadol and Fentanyl, prescribed or illicitly manufactured
- **Heroin**: Commonly Prescribed Opioids
  - Natural & Semi-Synthetic Opioids
  - Methadone

**Wave 1**: Rise in Prescription Opioid Overdose Deaths

**Wave 2**: Rise in Heroin Overdose Deaths

**Wave 3**: Rise in Synthetic Opioid Overdose Deaths

SOURCE: National Vital Statistics System Mortality File
RISE IN OPIOID OVERDOSE DEATHS IN AMERICA

A Multi-Layered Problem in Three Distinct Waves

450,000 people died from an opioid overdose (1999-2018)

1990s mark a rise in prescription opioid overdose deaths

2010 marks a rise in heroin overdose deaths

2013 marks a rise in synthetic opioid overdose deaths

Rx OPIOIDS
Include natural, semi-synthetic, and methadone and can be prescribed by doctors

HEROIN
An illegal opioid

SYNTHETIC OPIOIDS
By 2018, 2/3 of all opioid overdose deaths involved a synthetic opioid, such as illicitly manufactured fentanyl.

Learn more about the evolving opioid overdose crisis: www.cdc.gov/drugoverdose
CDC North Star

VISION
Prevent opioid-related harms & overdose death
Preventing Opioid Overdoses and Opioid-Related Harms

- Monitor trends
- Advance research
- Increase public awareness
- Build state, tribal, local, and territorial capacity
- Partner with public safety and community organizations
- Support health systems, healthcare providers, and payers
Overdose Data to Action OD2A

- Integrates previous funding into one announcement
- $300M per year for 3 years
- Seamless integration of data and prevention programs
- 66 jurisdictions funded including 47 states, DC, 2 territories, and 16 hard hit cities and counties
Support Health Systems and Providers

- Promote use of the *CDC Guideline for Prescribing Opioids for Chronic Pain*
- Train healthcare providers on implementation of Guideline
- Provide tools to help integrate into clinical practice
Primary care providers

Patients 18 years or older with chronic pain

Outpatient settings

Outside of active cancer, palliative, and end of life care
Organization of Guideline Recommendations

12 recommendations grouped into 3 conceptual areas:

- Determining when to initiate or continue opioids for chronic pain
- Opioid selection, dosage, duration, follow-up, and discontinuation
- Assessing risk and addressing harms of opioid use
Provider Resources

- Clinical Tools
- Mobile App
- Trainings (CME)
- Digital & Print Resource

To learn more: https://www.cdc.gov/drugoverdose/prescribing/resources.html
Health Systems Interventions

- Clinical Quality Improvement and Care Coordination
- EHR and PDMP (prescription drug monitoring program) Data Integration
- Clinical decision support (CDS) tools embedded into electronic health records (EHRs)
Electronic CDS Evaluation

- Implemented pilot CDS tools at four participating healthcare systems:
  - Regional primary care health system based in Kansas
  - Large metropolitan hospital with outpatient clinics in Texas
  - Large hospital and outpatient care system in New York City
  - Regional hospital and primary care health system in Pennsylvania
- Evaluated implementation process, use, and utility of CDS tools:
  - Pre-/post- of EHR-generated measures using existing data
  - Conducted semi-structured interviews (n=8) with project champions and IT leads at participating healthcare systems
Electronic CDS Evaluation

- Each participating health system developed EHR-embedded CDS tools that align directly with the CDC Guideline recommendations and integrated directly into system clinical workflow. CDS tools developed included:
  - Alerts
  - Access to prescription drug monitoring program (PDMP) data
  - Patient registries
  - Auto-population of prescription fields (e.g., quantity)
  - Order sets (e.g., SmartSet)
  - Morphine milligram equivalents (MMEs) calculators
  - Templates for clinical notes and referrals
Evaluation Results

- The number of patients with counseling on opioid risks and benefits increased from 5% to 7.5% (TX)
- Short-term follow-up increased slightly at (TX)
- Use of immediate release opioids when obtaining a new opioid prescription increased from 91% to 96% (TX)
- Urine drug testing increased by 50% (PA)
- Naloxone counseling increased by six-fold (PA)
- Use of PDMP information increased by 60% (KS)
Lessons Learned

- Development and implementation of CDS tools aligned with the CDC Guideline has the potential to promote safer opioid prescribing and improve patient care.
- Design, validation, and implementation process for CDS tools can be highly variable.
- Healthcare systems’ capabilities and resources are critical in determining which CDS modules to implement and how.
- Flexibility in creating CDS tools and data definitions is KEY to successful integration into clinical workflow.
Lessons Learned Continued

- **Facilitators:**
  - In-house IT staff expertise and availability
  - Access to and relationship with EHR service advisor
  - EHR system-specific administrative regulations and clinical policies
  - Shared learning with other systems

- **Barriers/Challenges:**
  - EHR system-specific limitations to how data are captured, or need to be built
  - Length of time to build, test, iterate, and implement
  - Limited resources available
  - Lacking internal expertise or IT experience with opioid-related data
Current Electronic CDS Projects

- Health systems can help encourage the uptake and use of the CDC Guideline for Prescribing Opioids for Chronic Pain
- CDC-funded effort to create electronic CDS tools that map to the 12 Guideline recommendations
  - Contributors: ONC, AHRQ, Yale, Indiana University, Duke, and Security Risk Solutions
- Current work includes further refinement and development of electronic CDS to be used in electronic health records (EHRs), at the point-of-care
Electronic CDS Implementation Guide

1.0.0 Opioid Prescribing Support Implementation Guide

1.1.0 Introduction

This implementation guide provides resources and discussion in support of applying the Centers for Disease Control and Prevention (CDC) Opioid Prescribing Guidelines:

CDC guideline for prescribing opioids for chronic pain

This implementation guide was developed as part of the Clinical Quality Framework Initiative, a public-private partnership sponsored by the Centers for Medicare & Medicaid Services (CMS) and the U.S. Office of the National Coordinator for Health Information Technology (ONC) to identify, develop, and harmonize standards for clinical decision support and electronic clinical quality measurement.

This project is a joint effort by the Centers for Disease Control and Prevention (CDC) and the Office of the National Coordinator for Health IT (ONC) focused on improving processes for the development of standardized, shareable, computable decision support artifacts using the CDC Opioid Prescribing Guideline as a model case.

1.2.0 Scope

This implementation guide includes support for the following guideline recommendations:

- Recommendation #1 - Nonpharmacologic and Nonopioid Pharmacologic Therapy Consideration
- Recommendation #2 - Opioid Therapy Goals Discussion
- Recommendation #3 - Opioid Therapy Risk/Benefit Discussion
- Recommendation #4 - Opioid Release Rate When Starting Opioid Therapy
- Recommendation #5 - Lowest Effective Dose
- Recommendation #6 - Prescribe Lowest Effective Dose and Duration
- Recommendation #7 - Opioid Therapy Risk Assessment
- Recommendation #8 - Naloxone Consideration
- Recommendation #9 - Consider Patient’s History of Controlled Substance Prescriptions
- Recommendation #10 - Urine Drug Testing
- Recommendation #11 - Concurrent Use of Opioids and Benzodiazepines
- Recommendation #12 - Evidence-based Treatment for Patients with Opioid Use Disorder

1.3.0 Getting Started

For a quick start to get up and running and see how the artifacts work, refer to the Quick Start
CDC Resources

CDC Opioid Overdose Prevention Website
www.cdc.gov/drugoverdose

State Efforts
https://www.cdc.gov/drugoverdose/states/index.html

CDC Guideline for Prescribing Opioids for Chronic Pain
https://www.cdc.gov/mmwr/volumes/65/rr/rr6501e1.htm

Resources for Patients
https://www.cdc.gov/drugoverdose/patients/index.html

Resources for Providers
https://www.cdc.gov/drugoverdose/providers/index.html

Clinical Decision Support Resources

• Implementation Guide Output: http://build.fhir.org/ig/cqframework/opioid-cds-r4/
• Source for the implementation guide: https://github.com/cqframework/opioid-cds
• Supporting Java packages for the CQL-to-ELM translator and CQL Engine: https://github.com/cqframework/opioid-cds-logic
Contact:
Wes Sargent
Wsargent@cdc.gov

Please note that the findings and conclusions in this presentation are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.
Project Overview - From Evidence to Executable CDS

Greg White
Security Risk Solutions, Inc.
CDC Prescribing Guideline Decision Support

• Goal: provide point-of-care support for [CDC Guideline for Prescribing Opioids for Chronic Pain](#)

• Process: Progress from narrative to executable CDS

• CDC-sponsored effort. Contributors: ONC, AHRQ, Yale, Indiana University, Duke, Security Risk Solutions Inc., Epic, Cerner, and many others.

• Approach:
  • Leverage health IT standards for representing clinical knowledge & integrating into EHRs
  • Pilot with multiple healthcare organizations and EHR products
Current Guideline Development and Implementation

Develop guidelines

- Research Results
- Literature Review
- Meta-analysis

Guideline Narrative

Interpret guidelines

- Guideline released
- Clinicians hear about guideline
- Additional/conflicting guidelines?
- Converse internal clinical workgroup
- Determine which guideline (and which part(s)) to implement

- Adjust CDS as needed
- Test within workflow with actual users
- Multiple system tests
- Implement CDS tool in test system
- Search existing CDS tools
- Conduct workflow analysis

- Release CDS tool into production system
- Monitor CDS tool for issues & monitor for updates to guidelines
- Create CDS tool

Improve guidelines

96% of ~5500 hospitals utilize a certified EHR
80% of ~355,000 MDs utilize a certified EHR

https://dashboard.healthit.gov/quickstats/quickstats.php

Slide courtesy of Maria Michaels, Centers for Disease Control and Prevention
Utilization of Standards-Based Dissemination

- **EHR data retrieval: HL7 FHIR**
  - FHIR = Fast Healthcare Interoperability Resources

- **Guideline knowledge representation: HL7 CQL**
  - CQL = Clinical Quality Language
  - CQL can be utilized within a CDS service or directly executed within a health information system

- **EHR workflow integration: HL7 CDS Hooks**

- **EHR app integration: HL7 SMART**
  - SMART = Substitutable Medical Apps, Reusable Technologies

- **Key enabler: EHR vendor support for these standards**
<table>
<thead>
<tr>
<th>Knowledge Level</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>Narrative CDC Prescribing Guideline</td>
<td>Guideline for a specific disease that is written in the format of a peer-reviewed journal article</td>
</tr>
<tr>
<td>L2</td>
<td>Semi-structured Functional Descriptions</td>
<td>Flow diagram, decision tree, or other similar format that describes recommendations for implementation (HUMAN READABLE)</td>
</tr>
<tr>
<td></td>
<td>Process Flow Diagrams</td>
<td></td>
</tr>
<tr>
<td>L3</td>
<td>Structured</td>
<td>Standards-compliant specification encoding logic with data model(s), terminology/code sets, value sets that is ready to be implemented (COMPUTER/MACHINE READABLE)</td>
</tr>
<tr>
<td></td>
<td>CQL, FHIR Resources, Terminology Libraries</td>
<td></td>
</tr>
<tr>
<td>L4</td>
<td>Executable</td>
<td>CDS implemented and used in a local execution environment (e.g., CDS that is live in an electronic health record (EHR) production system) or available via web services</td>
</tr>
<tr>
<td></td>
<td>Pilot sites: University of Utah, Duke, Yale, Indiana University</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from: Boxwala, AA, et al.. A multi-layered framework for disseminating knowledge for computer-based decision support. *J Am Med Inform Assoc* 2011(18) i132-i139.
Thank You!

Greg White
gw@securityrs.com
CDS Knowledge Artifacts, Pilots, and Lessons Learned

Kensaku Kawamoto, MD, PhD, MHS
Vice Chair for Clinical Informatics, Department of Biomedical Informatics
Associate Chief Medical Information Officer
University of Utah
Determining when to initiate or continue opioids for chronic pain
1. Opioids are not first-line therapy
2. Establish goals for pain and function
3. Discuss risks and benefits

Opioid selection, dosage, duration, follow-up, and discontinuation
4. Use immediate-release opioids when starting
5. Use the lowest effective dose; appreciate daily morphine milligram equivalents
6. Prescribe immediate-release opioids only for short durations for acute pain
7. Evaluate benefits and harms frequently

Assessing risk and addressing harms
8. Use strategies to mitigate risk
9. Review PDMP data
10. Use urine drug testing
11. Avoid concurrent opioid and benzodiazepine prescribing
12. Offer treatment for opioid use disorder
Artifacts for all 12 recommendation statements are available in an Opioid Prescribing Support FHIR IG

http://build.fhir.org/ig/cqframework/opioid-cds-r4/
Level 2 Process Flow Diagrams

1. **Medication select**
   - Benzodiazepine or opioid with ambulatory misuse potential prescribed?
     - No → **Stop**
     - Yes → **Opioid review useful?**
2. **Opioid review useful?**
   - Yes → **Receiving both opioid with ambulatory abuse potential and benzodiazepine?**
     - Yes → **Avoid prescribing opioid pain medication and benzodiazepine concurrently**
     - No → **Will revise**
   - No → **Benefits outweigh risks, snooze 3 months**
3. **Receiving both opioid with ambulatory abuse potential and benzodiazepine?**
   - Yes → **Avoid prescribing opioid pain medication and benzodiazepine concurrently**
   - No → **Benefits outweigh risks, snooze 3 months**

**Legend:**
- EHR Triggering Event
- Calculation Logic
- Configurable calculation logic
- Sub-routine calculation logic
- User Interaction
Level 3 Artifact Example (CQL, Rec. #11)

```cql
36  define "Inclusion Criteria":
37    AgeInYears() >= 18
38         and (  
39            exists (Common."Active Ambulatory Benzodiazepine Rx")
40            and exists (Common."Active Ambulatory Opioid Rx")
41         )
42
43  define "Get Indicator":
44    if "Inclusion Criteria"
45       then 'warning'
46    else null
47
48  define "Get Summary":
49    if "Inclusion Criteria"
50       then 'Patient has active prescriptions for opioid pain medication and benzodiazepines'
51    else null
52
53  define "Get Detail":
54    if "Inclusion Criteria"
55       then 'Avoid prescribing opioid pain medication and benzodiazepines concurrently whenever possible'
56    else null
```
Standardized CDS Approaches and Pilots

• Direct CQL execution – Indiana University and Cerner
  • Enables fast execution, even across large populations of patients
  • Requires native EHR vendor system to understand CQL

• CDS Hooks – Yale, Duke
  • Alert or reminder; could contribute to alert fatigue
  • Emerging EHR vendor support, including for required “hooks”

• SMART on FHIR – University of Utah
  • Accessible as a tab in the EHR
  • Broad EHR vendor support

• Approaches are complementary and can be synergistic
  • E.g., SMART on FHIR app uses CDS Hooks service, which in turn uses direct CQL execution
Direct CQL Execution

```cql
In [2]:
library Opioids_StUD_REC_10 version '0.1.0'
using FHIR version '3.0.0'
include FHIRHelpers version '3.0.0' called FHIRHelpers
include Opioids-StUD-StUD Common Constants version '3.0.0'

In [3]:
from fhir_database.
fhir_data.
version = fhir_data.version

In [28]:
read_results

Out[28]: 113227

Recommendation Outcomes

<table>
<thead>
<tr>
<th>Has Di CHF</th>
<th>Gender</th>
<th>Age Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>All</td>
</tr>
</tbody>
</table>

Total Population: 113,227  
Total Met: 36,602  
Excluded: 26,167

Criteria Met

- Metric 1: 15,808
- Metric 2: 22,061
- Metric 3: 3,455
- Metric 4: 9,326
- Metric 5: 800
Patient’s average oral morphine equivalence (OME) is **192.33 mg/day**.

**Daily Average OME (mg/day)**

<table>
<thead>
<tr>
<th>(reassess)</th>
<th>(avoid/justify)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>90</td>
<td></td>
</tr>
<tr>
<td>192.33</td>
<td>(current)</td>
</tr>
</tbody>
</table>

For adults, CDC recommends reassessing evidence of individual benefits and risks when increasing dosage to \( \geq 50 \) OME/day, and avoid increasing dosage to \( \geq 90 \) OME/day or carefully justifying such a decision.

**Active Opioid Rx**

- **New Oxycodone Hydrochloride 15 MG Oral Tablet**
- **FENTANYL CITRATE 200 MCG BU LPOP**

**Sig:** Place 1 each (200 mcg) inside cheek every 2 hours as needed. Use prior to bowel movements, maximum 4 per day.

- Morphine equivalence: 130x. For 1 lozenge, OME = 26 mg.
- Rx by Smith, John on 02/07/18. Disp 20 each, Refills 0.
- Start date: 02/07/18. End date (estimated): 02/12/18. Based on dispense quantity and max daily dose in sig.

**Daily dose (avg):** Fentanyl Oral Lozenge 20 dispense * 0.2 mg / 30d supply (assumed) = 0.13 mg.

**Daily dose (max):** Fentanyl Oral Lozenge 4 (daily max per sig) * 0.2 mg = 0.8 mg.

For Epic aspects: ©2020 Epic Systems Corporation.
BestPractice Advisory

Advisory (1)

Patient has active prescriptions for opioid pain medication and benzodiazepines

⚠ Avoid prescribing opioid pain medication and benzodiazepines concurrently whenever possible

Source: CDC guideline for prescribing opioids for chronic pain

©2020 Epic Systems Corporation.
Outpatient Opioid Oral Morphine Equivalence (OME) Calculator

Patient’s average oral morphine equivalence (OME) is 57.33 mg/day.

Daily Average OME (mg/day)

For adults, CDC recommends reassessing evidence of individual benefits and risks when increasing dosage to >= 50 OME/day.

Active Opioid Rx

FENTANYL CITRATE 200 MCG BU LPOP
- Verify taking, Rx may have expired
- 17.33 mg

HYDROCODONE-ACETAMINOPHEN 10-325 MG PO TABLET
- Verify taking, Rx may have expired
- Not adding OME for presumed redundant Rxs with start dates of 02/07/18 and 03/07/18.
- 40 mg

Total Average OME/Day

Avg OME/day* 57.33 mg

*Avg OME = (city dispensed) / days supply), 30e supply assumed unless otherwise noted in Sig or note to pharmacy.

For Epic aspects: ©2020 Epic Systems Corporation.
Summary and Lessons Learned

- Standards-based CDS knowledge artifacts are now available for all 12 recommendations in CDC guideline
- Pilot implementations have spanned direct CQL execution, CDS Hooks, SMART on FHIR, and combinations thereof
- Performance optimization must be a key focus
- Shareable CDS could reduce the time taken to develop, test and deploy CDS, expediting guideline adoption
- Local skills are still required for deployment, testing, and maintenance; should be reduced as approach matures
- Additional EHR capabilities are desired for optimal user experience (e.g., triggering based off of ordering workflow, 1-click execution of recommended actions)
Thank you

Kensaku Kawamoto, MD, PhD, MHS

kensaku.kawamoto@utah.edu
Acknowledgments (Partial List)

• Adam Stevenson
• Angie Glostein, RN, BSN
• Alan Staples, BS
• Bob Parr, BS
• Chris Schuler
• Christopher Harle, PhD
• Clay Musser, MD
• Cole Erdmann
• Dalia Mack, PharmD, BCPS
• Ed Hammond, PhD
• Eugenia McPeek Hinz MD, MS
• Isaac Vetter
• Jana Malinowski
• Jill Sindt, MD
• Jonathan Percival
• Lindsey Sanner, MPH
• Matt Varghese, MS
• Megan Rexing
• Myung Woo, MD
• Nitu Kashyap, MD, FAMIA
• Olena Mazurenko, PhD, MD
• Phillip Warner, MS
• Rick Shiffman, MD
• Scott Junkins, MD
• Susan Spratt, MD
• Tres Brown III, BS
• Vivian West, PhD, MBA, RN
• Whitney Allen
• Yauheni Solad, MD, MH
CDS for CDC Team

- ONC
  - JaWanna Henry
  - Lolita Kachay
  - Mera Choi

- CDC
  - Jan Losby
  - John Le
  - Wes Sargent

- Security Risk Solutions, Inc.
  - Amber Patel
  - Greg White
  - Johnathan Coleman

- Project Subject Matter Experts
  - Bryn Rhodes
  - Floyd Eisenberg
  - Ken Kawamoto
  - Rob McClure
Discussion

• Can you share anything your organization is engaged in that is similar?
• Do you see opportunities for this approach to be applied to your work and priorities?
• What concerns would you have surrounding implementing standardized CDS in your environment?
CDS for the CDC Prescribing Guideline Resources

- CDC Guideline for Prescribing Opioids for Chronic Pain
  https://www.cdc.gov/drugoverdose/prescribing/guideline.html

- Opioid Prescribing Support Implementation Guide FHIR R4
  http://build.fhir.org/ig/cqframework/opioid-cds-r4/

- Opioid Prescribing Support Implementation Guide FHIR STU3 and DTSU2
  http://build.fhir.org/ig/cqframework/opioid-cds

The content of this document does not necessarily reflect the views or policies of the US Department of Health and Human Services, the Centers for Disease Control and Prevention, the Office of the National Coordinator for Health IT, or the other organizations involved, nor does the mention of trade names, commercial products, or organizations imply endorsement by the U.S. Government.
Contact ONC

Lolita Kachay, Lolita.Kachay@hhs.gov
Jawanna.Henry@hhs.gov
Wesley Sargent, Wsargent@cdc.gov
Greg White, gw@securityrs.com
Kensaku Kawamoto, kensaku.kawamoto@utah.edu

Phone: 202-690-7151
Health IT Feedback Form: https://www.healthit.gov/form/healthit-feedback-form
Twitter: @onc_healthIT
LinkedIn: Search “Office of the National Coordinator for Health Information Technology”

Subscribe to our weekly eblast at healthit.gov for the latest updates!
Break
Please return by 11:40 am EDT
SHIELD: Harnessing National COVID-19 Test Data to Provide Customizable Decision Support for Patients with Underlying Medical Conditions

Michael Waters, Ph.D.
SHIELD\textsubscript{x} Team Lead/OIR RWE Representative

COVID-19 National Response Operations: HHS Data Strategy and Execution Workgroup (DSEW)

OHT 7: Office of In Vitro Diagnostics and Radiological Health (OIR) Center for Devices and Radiologic Health (CDRH) Food and Drug Administration (FDA)
Mission:
SHIELDx is a public-private partnership focused on the adoption/development, harmonized application and implementation of diagnostic data standards to advance innovation.

70+ Stakeholders:
FDA (CDRH, CDER, CBER), CDC, NIH, ONC, CMS, VA, CAP, IVD Manufacturers, EHR Vendors, Laboratories, Standards Developers, PEW Charitable Trusts, NEST/MDIC, Academia

COVID-19 Laboratory Data Reporting Requirements

Daily COVID-19 Laboratory Data Reporting Required – March 29, 2020
HHS COVID-19 Laboratory Data Reporting Guidance – June 4, 2020

• Under CARES Act 116-136, § 18115(a)
• Applies to all testing performed in CLIA labs and home use settings
• Outlines the data elements for COVID-19 test data submission to HHS
• Implementation deadline: August 1, 2020
• References SHIELD COVID-19 test mapping (published by CDC)
  https://www.cdc.gov/csels/dls/sars-cov-2-livd-codes.html

Data needs to be understood to be useful!
How do COVID-19 tests get to market?

- Emergency Use Authorization (EUA)……………………………………………………………..
- Notification (with intent to attain an EUA)……………………………………………………………..

Types of COVID-19 tests:
Do you have SARS-CoV-2 Virus?
- RNA Amplification Tests (e.g. RT-PCR)……………………………………………………………..
- Antigenic Tests (e.g., proteins – spike, envelope, nucleocapsid………

Do you have antibodies to SARS-CoV-2?
- Serology Tests (e.g., IgM, IgG, IgA)……………………………………………………………..

Notes:
Data reviewed by FDA
Self-validation

Notes:
Indicates viral presence
Indicates viral presence
Indicates exposure
1) Collect nasopharyngeal transport prepare

2) Ask Question:
e.g., Does the nasopharyngeal swab contain SARS-CoV-2 RNA by PCR?

Type Test Performed (LOINC code: 94500-6)

Specimen Type (SNOMED-CT code: 258500001)

3) Provide Answer:
e.g., SARS-CoV-2 RNA is:

Detected (SNOMED-CT code: 260373001)

Not Detected (SNOMED-CT code: 260415000)
COVID-19 Tests: Types, #s and Authorized Settings

Lab/Site Complexity:
- Complex
  - High
  - Moderate
  - CLIA Waived
  - Home
- Simple

Test Complexity:
- Complex
  - High
  - Moderate
  - CLIA Waived
- Simple
  - Prescription Home Use
  - Over-the-Counter

CLIA Certified
- Waived 75%
- Accreditation 6%
- Compliance 7%
- Microscopy 12%

Total # Labs = 266,516 (March 2020)

Test Complexity:
- Waived 8%
- Moderate 15%
- High 78%

Total # Tests = 243 (September 2020)

Lab Definitions:
42 USC 263a

Test Definitions:
21 CFR 809.3
Daily Reportable Data Elements for All COVID-19 Tests
(summary; reportable to federal/state/local authorities, as appropriate)

Test orders:
- Test ordered
- Ordering provider name & NPI
- Ordering provider location/contact

Test results:
- Test result
- Device Identifier
- Specimen source
- Date specimen collected
- Test Result date
- Accession #/Specimen ID
- Performing facility name/CLIA#
- Performing facility location

Patient Demographics:
- Unique patient identifier
- Patient name
- Patient date of birth/age
- Patient race
- Patient ethnicity
- Patient sex
- Patient location/contact
- Patient occupation
- Patient congregate care/living setting
- Patient symptoms
- Patient test & hospitalization history
- Patient pregnancy status

Harmonization Tools

HHS COVID-19 Guide:
https://www.hhs.gov/answers/is-additional-information-including-technical-specifications-available-to-support-laboratories-with-implementation/index.html
<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Vendor Analyte Name</th>
<th>Vendor Specimen Description</th>
<th>Vendor Result Description</th>
<th>LOINC Code</th>
<th>LOINC Long Name</th>
<th>LOINC Order Code</th>
<th>Testkit Name ID</th>
<th>Equipment UID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roche</td>
<td>6800/8800 Systems</td>
<td>cobas® SARS-CoV-2</td>
<td>nasopharyngeal (NP) swabs (258500001)</td>
<td>SARS-CoV-2 RNA is Detected (260373001)</td>
<td>94500-6</td>
<td>SARS coronavirus 2 RNA [Presence] in Respiratory specimen by NAA with probe detection</td>
<td></td>
<td>cobas® SARS-CoV-2_6800</td>
<td>084302150465203</td>
</tr>
<tr>
<td>Mesa Biotech</td>
<td>Accula SARS-CoV-2 Test™</td>
<td>SARS-CoV-2 Interpretation</td>
<td>nasal swab (445297001)</td>
<td>Positive Test for SARS-CoV-2 (260373001)</td>
<td>95409-9</td>
<td>SARS-CoV-2 (COVID-19) N gene [Presence] in Nose by NAA with probe detection</td>
<td>854009 COVID1000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>#</th>
<th>Data Element</th>
<th>Reporting Requirement*</th>
<th>Technical Specifications</th>
<th>Notes</th>
<th>Example</th>
<th>HL7 Field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test result (performed)</td>
<td>Yes</td>
<td>Must use harmonized LOINC codes, when available</td>
<td>Test conducted by lab</td>
<td>Example LOINC: 94640-9: SARS coronavirus 2 S gene [Presence] in Respiratory specimen by NAA with probe detection</td>
<td>OBX-4</td>
</tr>
<tr>
<td></td>
<td>Test result (values)</td>
<td>Yes</td>
<td>Qualitative tests: Must use harmonized SNOMED-CT value set codes</td>
<td></td>
<td>Example SNOMED-CT Qualitative Values:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Quantitative tests: Must use harmonized LOINC, when available</td>
<td></td>
<td>- 2603273001: Detected</td>
<td>OBX-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>See LIVD file ‘LOINC Mapping’ Tab, column F: ‘LOINC Code’</td>
<td></td>
<td>- 260415000: Not detected</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>- 935231000: Not detected in pooled specimen</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• # of specimens pooled</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Example 462371000124106: Detected in pooled specimen</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• 419984006: Inconclusive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Device Identifier</td>
<td>Yes</td>
<td>Must use harmonized Device Identifiers (DI), when available. The DI is contained within the unique device identifier (UDI), created by manufacturer</td>
<td>Manufacturer requests UDI issuance, then provides DI, or pull from GLIDID database</td>
<td>Example Device: 01234567891011</td>
<td>OBX-17, OBX-18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>See LIVD file ‘LOINC Mapping’ Tab, column M: ‘Test Kit Name ID’ for assay and column Q: ‘Equipment UID’ for instrument</td>
<td>If DI unavailable: Use ‘Trade Name_Manufacturer Name’ (a unique element controlled under 21 CFR 209.10(b)(1))</td>
<td>Example Trade Name: SARS-CoV-2 Test_Company</td>
<td></td>
</tr>
</tbody>
</table>
# COVID-19 Lab Data Reporting Implementation Specifications

<table>
<thead>
<tr>
<th>Data Element</th>
<th>Reporting Requirement*</th>
<th>Technical Specifications</th>
<th>Notes</th>
<th>Example</th>
<th>HL7 Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>Federal / CDC / HHS</td>
<td>State / Local PHD</td>
<td>Ordering Provider / EHR</td>
<td></td>
<td>LOINC: 82810-3</td>
</tr>
<tr>
<td>33 AOE: Pregnant</td>
<td>Requested</td>
<td>Requested</td>
<td>Pregnant Not Pregnant UNK - Unknown</td>
<td>SNOMED-CT Pregnancy Status: 77385005 Pregnant 60001007 Not Pregnant 201665008 Unknown 27572000 Null</td>
<td>03X5</td>
</tr>
</tbody>
</table>

### Reporting Requirements:

This table represents a visual, side-by-side comparison of which entities ultimately receive each of the reported data elements. For example, not all data elements reported to the State / Local PHD are reported to the Federal authorities.

- This table is not meant to indicate how data elements are reported in terms of their flow between entities. Current information on reporting requirements for laboratories and associated FAQs are available on CDC's website: "How to Report COVID-19 Laboratory Data"

### Requirement / Request Level:

- Yes = Required to be reported by August 1st, 2020
- Requested = Every reasonable effort should be made to achieve reporting by August 1st, 2020
- Optional = Strongly encouraged to begin reporting by August 1st, 2020, if possible
- No = Not required to be reported

---

**New - National ELR Flat File and HL7 Generator Tool Package**

https://preparedness.cste.org/?page_id=136
Completeness and Harmonization of One Data Element

~77 million reported PCR test results *as of 9/11

>99% of transmitted results report data element “Test Result”

12.4% of test results don’t use harmonized LOINC codes

Top three codes
1. NOVELCORONAPCR
2. COVID19
3. Null (empty field)

Data harmonization is improving!
Rapid Acceleration of Diagnostics (RADx) for COVID-19

Goal:
Deployment of COVID-19 tests anywhere.

RADx Programs
- RADx Tech
- RADx Underserved Populations (RADx-UP)
- RADx Radical (RADx-rad)
- RADx Advanced Technology Platforms (RADx-ATP)

https://www.nih.gov/research-training/medical-research-initiatives/radx/radx-programs
Mapping Underlying Medical Conditions

- 11.7 COVID-19 gastrointestinal and hepatic underlying condition
- 11.8 COVID-19 hemoglobinopathy underlying condition
- 11.9 COVID-19 ICD 10 Diagnosis
- 11.10 COVID-19 immune underlying condition
- 11.11 COVID-19 renal underlying condition
- 11.12 COVID-19 respiratory underlying condition
- 11.13 COVID-19 SNOMED Diagnosis
- 11.14 COVID-19 Symptoms Absent
- 11.15 COVID-19 Symptoms Present
- 11.16 COVID-19 unclassified underlying condition
- 11.17 COVID-19 cardiovascular underlying condition
- 11.18 COVID-19 immunocompromised underlying condition
- 11.19 COVID-19 General Comorbidities Absent
- 11.20 COVID-19 General Comorbidities Present
- 11.21 COVID-19 metabolic underlying condition
- 11.22 COVID-19 neurologic underlying condition

https://covid-19-ig.logicahealth.org/toc.html
Ensuring Maximal Data Utility
Goal: Provider & Patient Utility from At-Anywhere Tests

- Just took a home test... now what?
- Should I go back to work/school?
- I have underlying medical conditions, is there are special considerations for me?
- Can we get supplies?
- Should I get tested? When? Where?
Clinical Response through Emerging Technology (CRET)
An Integrated Health IT Tool for Providers to Respond to Public Health Hazards

Daniel Chaput; ONC; daniel.chaput@hhs.gov
September 15, 2020
What is CRET?

The Clinical Response through Emerging Technology (CRET) program is an HHS initiative to improve clinical response to emerging public health hazards using EHRs and IT tools and infrastructure.

**Purpose:**

CRET’s goal is to provide clinicians with near-real-time updates to information and best practices to improve their medical response to a broad range of natural and manmade hazards.
The Need for CRET

When health hazards occurs, each response is slightly different. CRET addresses the critical in-the-moment information needs of the medical community:

- Immediate access to the latest science about response without the need for extensive research when time is of the essence
- Translation of public health agency guidance into computer-readable information that can be shared with computer systems (including EHRs and clinical decision support) to deliver needed information to doctors at the point of care.

**CRET provides clinicians with the latest science and response protocols from federal, state, tribal, local, and territorial public health communities by delivering critical knowledge to clinical decision support tools within existing clinical workflows.**
Common Hazards Requiring CRET Response

- Infectious diseases
- Environmental, chemical, and biological hazards
- Events based on (intentional or unintentional) human behavior
- Natural events such as extreme weather
CRET is adaptable for different audiences (e.g., clinicians, clinical software vendors, average citizens). It addresses:

- **Risk Identification**: Exposures (e.g., travel, residence, occupation, recreational activities), symptoms, physical findings, and diagnostic tests (e.g., laboratory, imaging and pathology)
- **Risk Reduction and Mitigation**: Isolation, personal protective equipment, exposure avoidance, treatment and supportive care
- **Education**: Recommendations for individuals at risk (patients, caregivers, employment sites)
Currently, IT professionals “translate” — interpret and implement — many clinical guidelines into EHR-based decision support.

Slow, idiosyncratic, manual process at each site

Inconsistent Info Delivery

Currently, ad-hoc dissemination of updated science is performed without definitions and data standards. Lack of flexibility to re-use logic to rapidly address new threats is a significant challenge.

Current Manual Process for Information Distribution
CRET: Changing The Picture

CRET framework and tools = an approach to share information on evolving threats

- Rapid dissemination of the most updated, accurate science
- Information delivery using clear data standards and definitions
- Flexibility and re-use of logic to rapidly address new threats
Emerging Infectious Diseases: 2019nCoV Coronavirus

Guidance With CRET

**SYMPTOMS:**
- FEVER AND SYMPTOMS OF LOWER RESPIRATORY ILLNESS (COUGH, DIFFICULTY BREATHING)
- FEVER OR SYMPTOMS OF LOWER RESPIRATORY ILLNESS (COUGH, DIFFICULTY BREATHING)

**EXPOSURE:**
- IN THE LAST 14 DAYS BEFORE SYMPTOM ONSET, A HISTORY OF TRAVEL FROM WUHAN, CHINA, OR
- IN THE LAST 14 DAYS BEFORE SYMPTOM ONSET, CLOSE CONTACT WITH A PERSON WHO IS UNDER INVESTIGATION FOR 2019-CoV WHILE THAT PERSON IS ILL
- IN THE LAST 14 DAYS BEFORE SYMPTOM ONSET, CLOSE CONTACT WITH AN ILL, LABORATORY-CONFIRMED 2019-CoV PATIENT

**RECOMMENDATIONS:**
- NOTIFY INFECTION CONTROL AND LOCAL HEALTH DEPARTMENT
- HEALTH DEPARTMENT WILL COLLECT, STORE AND SHIP SPECIMENS TO CDC
- AIRBORNE ISOLATION ROOM – STANDARD, CONTACT AND AIRBORNE PRECAUTIONS AND EYE PROTECTION.

Clinicians must understand complex and rapidly evolving guidelines

- Currently, IT professionals “translate” — interpret and implement — many clinical guidelines into EHR-based decision support
- This process can lead to inconsistent and inaccurate implementation

Let’s consider an example and its implications:

ACUTE LYME
After tick bite, some patients present with erythema migrans (EM) rash. The rash is diagnostic for Lyme disease, unlike non-specific symptoms, which are inconclusive. Do all clinicians know this?
Acute Lyme: A Dangerous Reality

**Wasted Steps Without CRET**

- **OBSERVATION/SYMPTOM CONFIRMATION: EM RASH**
- **LABORATORY TESTING: ELISA TEST**
- **LABORATORY TESTING: WESTERN BLOT**
- **TREATMENT: ANTIBIOTICS**

**Accurate Guidance With CRET**

- **OBSERVATION/SYMPTOM: EM RASH**
- **TREATMENT: ANTIBIOTICS**

Each step = time lost

**vs.**
## CRET For Acute Lyme: Take-aways

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Legacy IT without shared standards or interpretation</td>
<td>• Flexible, scalable platform (extendable to many hazards) with shared standards</td>
</tr>
<tr>
<td>• Complex guidelines “translated” by IT professionals</td>
<td>• Complex guidelines “translated” by SMEs</td>
</tr>
<tr>
<td>• One-way communication</td>
<td>• Bidirectional communication</td>
</tr>
<tr>
<td>• EHR updates fail to keep pace with evolving state of science</td>
<td>• EHR updates are rapid with near-real time information</td>
</tr>
</tbody>
</table>
CRET emphasizes traits critical to rapid response to health threats:

- Flexibility
- Diversity of experiences
- Ability to handle uncertainty
Thanks to

• Rachel Abbey, ONC
• Floyd Eisenberg, iParsimony
• James Daniel, Amazon Web Services (formerly with CTO)
• Michael Wittie, ONC
• Kristen Honey, CTO
• Alexander Wilson, CTO
• Rachel Melo, CTO
Q&A Discussion
Lunch Break
Please return by 1:30 pm EDT
CPG-on-FHIR: Computable Guidelines for CDS and Beyond

Maria Michaels
Centers for Disease Control and Prevention

Matthew Burton
Apervita, Inc.

Bryn Rhodes
Database Consulting Group

September 15, 2020
The Data Lifecycle & Impacts to the Public’s Health

Guidelines
Recommendations
Guidance
Public Health Policies or Mandates

Delivering actionable knowledge

Point of Care
Emergency Response
Public Health Departments
Community Services

UPDATING
SCIENTIFIC
EVIDENCE

INFORMATION

Analysis
Data Science
Analytics
Data Linkages
Data Visualization

Fast Healthcare Interoperability Resources (FHIR®)

Analyzing data to advance evidence

Action

Health Impacts & Outcomes

Data

EHRs
Registries
Public Health Info Systems
Community Info Systems
...many potential sources
Redesigning Guideline Development and Implementation

**CURRENT STATE**

- Guidelines
- Informatics
- CDS
- Implementation
- Evaluation (maybe)
- CQMs

10s-100s of translations

100s-1000s of translations

Inconsistent (or nonexistent) feedback loop

**PROPOSED FUTURE STATE**

- Guidelines
- Informatics
- Communication
- CQMs
- Patient Care
- Implementation
- Concurrent guideline development, translation, & implementation with early engagement and iteration
- Local Implementation & Evaluation

Consistent feedback loop

**SEQUENTIAL & SILOED**

**PARALLEL & ITERATIVE**
One Translation
Many Ways to Implement It
CPG-on-FHIR

Setting the standard for a new approach for evidence to practice
Quality Improvement Ecosystem

1. RESEARCH, PAYER & PUBLIC HEALTH SURVEILLANCE
   - What is ACTUALLY happening and why?

2. GUIDELINES (Professional Societies, CDC, etc.)
   - What SHOULD happen. What do we want to happen?

3. CLINICAL DECISION SUPPORT
   - MAKING it happen within local workflow.

4. CLINICAL CARE
   - Clinician and Patient Workflow.

5. MEASUREMENT ANALYTICS
   - What DID happen? What processes and outcomes have been achieved?

6. REPORTING
   - Public Health
   - Quality
   - Safety
Separation of Concerns

**Case** – patient “clinical pathophysiological processes”, their manifestations and qualifications thereof

**Plan** – the approach to the patient’s current, historical, and potential future state of disease and well-being including medical decision-making

**Workflow** – how the Plan is implemented through interactions with clinical information systems and/or through real-world human tasks and activities
CPG Basic Components

**Plan**
- Pathway
- Strategy
- Recommendation

**Case**
- Case Feature
- Derived Case Feature
- Case Feature (Request)
- Case Feature (Events)

**Care Plan**
- Proposal
- Request
- Event
Conceptual CPG Knowledge
Expressed as (Profiled) FHIR Plan Definitions + CQL

http://build.fhir.org/ig/HL7/cqf-recommendations/index.html
CDS Reminder (Event-Condition-Action Rule)

(Profiled) FHIR Plan Definition + CQL
Clinical Quality Measure (eCQM)

FHIR Measure + CQL
eCase Report (Registries)

(Profiled) FHIR Composition + CQL

http://hl7.org/fhir/us/ecr/2018Sep/
Deep Learning & Cognitive Computing on Case Features

With Hybrid ‘Knowledge’ and a mix of Humans and Machines as Intelligent Agents
Agile Approach to CPG Development

Feedback Loop & Iteration during Development

Potential for Feedforward or Fast Track

Localized Version

EBM on FHIR

Feedback & Iteration during Development

CDS
CPG-on-FHIR Example Use Case

Enabling Opioid-related Quality Improvement
<table>
<thead>
<tr>
<th>Knowledge Level</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>Narrative</td>
<td>Guideline for a specific disease that is written in the format of a peer-reviewed journal article</td>
</tr>
<tr>
<td>L2</td>
<td>Semi-structured</td>
<td>Flow diagram, decision tree, or other similar format that describes recommendations for implementation <em>(HUMAN READABLE)</em></td>
</tr>
<tr>
<td>L3</td>
<td>Structured</td>
<td>Standards-compliant specification encoding logic with data model(s), terminology/code sets, value sets that is ready to be implemented <em>(COMPUTER/MACHINE READABLE)</em></td>
</tr>
<tr>
<td>L4</td>
<td>Executable</td>
<td>CDS implemented and used in a local execution environment (e.g., CDS that is live in an electronic health record (EHR) production system) or available via web services</td>
</tr>
</tbody>
</table>

Requirements to Running Code

T1 – Data
- Glossaries
- Domain Concepts
- Indicator descriptions

T2 – Logic
- Guideline narrative
- Evidence Summaries
- Tables & Figures

T3 – Forms
- Case Examples
- Paper Forms
- User Stories
- Personas

L1 – Narrative
- Wire Frames
- Flow Diagrams

L2 – Semi-Structured
- Workflows
- Decision Trees
- Triggers

L3 – Structured
- Library (CQL)
- ActivityDefinition
- PlanDefinition
- Questionnaire (SDC)

L4 – Executable
- User-interface Forms
- Visualizations
- Interaction Model
- Application Services
- Health Record Systems
- Decision Services
- Systems of Record
- Registries and Exchanges
- Data Services
Levels of Representation Reconceptualized

Framework for Describing *Nature* of Representation (NOT Process)

**Tradition Knowledge Engineering Approach:**
- Process Steps that mimicked Progression of Levels-
  - L2 only on Final L1
  - L3 only on completion of L2

**Agile KE:**
- Concurrent, iterative, integrated, and cross-functional
- Different Expertise work on Different Levels concurrently
- Knowledge Increments across Levels

---

**Waterfall**
GDP, KE, CDS, & Implementation

- L1
- L2
- L3
- L4

---

**Agile Integrated Cross-functional CPG-IG Approach**

- Shared Tooling
- Shared Information
- Incremental
- Concurrent Development
- Iterative, Rapid Feedback
- Test-Driven
- Reuse Content
Opioid-related Projects
# AHRQ Pain Management Summary

![CDS Connect](https://github.com/AHRQ-CDS/AHRQ-CDS-Connect-PAIN-MANAGEMENT-SUMMARY)

## Factors to Consider in Managing Chronic Pain

**TAKEN NOTICE:** This summary is not intended for patients who are undergoing end-of-life care (hospice or palliative) or cancer treatment.

## Recommendations

### Requests And Responses (1)

<table>
<thead>
<tr>
<th>Name</th>
<th>Result</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibromyalgia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lumbar post-laminectomy syndrome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low back pain</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Pertinent Medical History (4)

- Brenda Jackson
- 63 YRS
- FEMALE
- Total Entries: 15
- Total Flags: 10

---

Opioid eCQMs

<table>
<thead>
<tr>
<th>eQM Title</th>
<th>Potential Opioid Overuse</th>
</tr>
</thead>
<tbody>
<tr>
<td>eQM Identifier (Measure Authoring Tool)</td>
<td>460</td>
</tr>
<tr>
<td>ROP Number</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Measurement Period</td>
<td>January 1, 20XX through December 31, 20XX</td>
</tr>
<tr>
<td>Measure Steward</td>
<td>Centers for Medicare &amp; Medicaid Services (CMS)</td>
</tr>
<tr>
<td>Measure Developer</td>
<td>Mathematica</td>
</tr>
<tr>
<td>Endorsed By</td>
<td>None</td>
</tr>
</tbody>
</table>

Description:
Percentage of patients aged 16 years and older who receive opioid therapy for 90 days or longer with no more than a 7-day gap between prescriptions with a daily dosage of 90 morphine milligram equivalents (MME) or more.

Copyright:
Limited proprietary coding is contained in the Measure specifications for user convenience. Users of proprietary code sets should obtain all necessary licenses from the owners of the code sets. Mathematica disclaim all liability for use or accuracy of any third party codes contained in the specifications.

Disclaimer:
These performance measures are not clinical guidelines, do not establish a standard of medical care, and have not been tested for all potential applications.

Due to technical limitations, registered trademarks are indicated by (®) or (™) and unregistered trademarks are indicated by (TM) or (™).

Measure Scoring:
Proportion

Measure Type:
Process

Stratification:
None

Risk Adjustment:
None

Rate Aggregation:
None

Rationale:
More than 100 million people in the United States suffer from chronic pain (Institute of Medicine, 2011). An estimated 200 million opioid prescriptions to manage pain were written in the United States in 2011, approximately half of which were written by primary care providers (Cox et al., 2013). From 2000 to 2013, mortality from opioid-specific drug poisoning in the United States tripled, resulting in a reduction in life expectancy for non-Hispanic white individuals (Dowell, Mearganc, & Chou, 2016).

Although all opioids can be dangerous, chronic use of opioids at high doses are more likely to result in fatalities and other adverse drug events (Edlund et al., 2014; Morse et al., 2010; Aliku, Abiko, & Sudarshan, 2012; Paolozzi et al., 2014). Recent guidelines recommend that providers use the lowest dose possible when initiating opioid therapy and that they carefully justify prescribing doses above 90 morphine milligram equivalents (MME) per day, considering the benefits and harms of the dose they select (Dowell et al., 2016).

In a large cohort study of almost 18 million commercially insured patients in the United States, about 15 percent of opioid recipients received a daily dose of 100 MME or higher, and 12 percent received more than a 90-day supply (Liu et al., 2015).
AHRQ Chronic Pain Management

1. Patient visit is scheduled

2. DNA phenotype

3. Generates message

4. Receives message and launches MyPAIN

5. Clinician Invokes PainManager

6. Results of SDM are saved to EHR

- Patient receives an email invitation to access MyPAIN
- Patient accesses SDM resources via MyPAIN
- Patient records PROs via MyPAIN to prepare for SDM
- Patient and clinician meet to engage in SDM encounter and decide on a treatment plan
- Clinician/health system collects and reviews data on decision(s) via PainManager
CDC Opioid Prescribing IG

http://build.fhir.org/ig/cqframework/opioid-cds-r4/
Recommendation #11 – L2

Clinicians should avoid prescribing opioid pain medication and benzodiazepines concurrently whenever possible (recommendation category: A; evidence type: 3).

26.0.1 Functional Description

- When
  - Provider is prescribing an opioid analgesic with ambulatory misuse potential in the outpatient setting.
  - Provider is prescribing a benzodiazepine medication.
  - Opioid review is useful for this patient:
    - Patient is 18 or over
    - Patient does not have findings indicating limited life expectancy
    - Patient does not have orders for therapies indicating end of life care
    - Patient is not undergoing active cancer treatment:
      - Patient has had at least 2 encounters within the past year with any diagnosis of cancer.
    - Patient prescribed opioid analgesics with ambulatory misuse potential and benzodiazepine medication concurrently

Then

- Recommend to avoid prescribing opioid pain medication and benzodiazepine concurrently:
  - Will revise
  - Benefits outweigh risks, snooze 3 months
  - N/A - see comment; snooze 3 months

### Recommendation 11

<table>
<thead>
<tr>
<th>Definition</th>
<th>Answer to Proceed</th>
<th>Details</th>
<th>Data (Terminology) Requirement</th>
</tr>
</thead>
</table>
| Order for opioid analgesics with ambulatory misuse potential? | Yes               | Trigger based on a new prescription (order) for opioid analgesics with ambulatory misuse potential – ideally the prescription should be selected prior to being committed to the system. Provide indication either:  
  - The opioid prescription request is concurrent with an active benzodiazepine prescription. Avoid prescribing opioid pain medication and benzodiazepine concurrently whenever possible. | Opioid analgesics with ambulatory misuse potential                                           |
| Order for benzodiazepine medications?            | Yes               | Trigger based on a new prescription (order) for opioids or benzodiazepines in the relevant value sets – ideally the prescription should be selected prior to being committed to the system. Provide indication either:  
  - The benzodiazepine prescription request is concurrent with an active opioid analgesic prescription. Avoid prescribing opioid pain medication and benzodiazepine concurrently whenever possible. | Benzodiazepine medications                                                                 |
| Opioid review useful?                           | Yes               | Use sub-routine 1                                                      |                                                                                             |
| Receiving both opioid with ambulatory use potential and benzodiazepine? | Yes               | New prescription is for an opioid and existing use of benzodiazepine inhere, OR  
  New prescription is for benzodiazepine and existing use of opioids evident.            | Opioid analgesics with ambulatory misuse potential benzodiazepine medications               |
Requirements to Running Code

L1 – Narrative
- Case Examples
- Paper Forms
- User Stories
- Personas

L2 – Semi-Structured
- Wire Frames
- Flow Diagrams
- Workflows
- Decision Trees
- Triggers

L3 – Structured
- Questionnaire (SDC)
- Library (CQL)
- ActivityDefinition
- PlanDefinition
- Terminologies
- Data Dictionary
- Indicators
- CodeSystem
- ValueSet
- StructureDefinition
- Measure

L4 – Executable
- User-interface Forms
- Visualizations
- Interaction Model
- Application Services
- Health Record Systems
- Decision Services
- Systems of Record
- Registries and Exchanges
- Data Services
L3 – Terminology

30.25.1 Opioid Analgesics With Ambulatory Misuse Potential

Summary

Version: 4.0.0
Name: Opioid_Analgesics_With_Ambulatory_Misuse_Potential
Status: Experimental
Title: Opioid Analgesics With Ambulatory Misuse Potential

Definition: All opioid clinical drugs except cough medications, antispasmodics, or those restricted to surgical use only in injectable form.

Publisher: Centers for Disease Control and Prevention (CDC)
Copyright: © CDC 2016.

Source: Resource: XML / JSON / Turtle

References

This value set is not used

30.25.1.1 Content Logical Definition
30.25.1.2 Definition

This value set contains 1177 concepts

All codes from system http://www.nlm.nih.gov/research/umls/rxnorm

<table>
<thead>
<tr>
<th>Code</th>
<th>Display</th>
</tr>
</thead>
<tbody>
<tr>
<td>564334</td>
<td>Alfentanil 0.5 MG/ML [Alfenta]</td>
</tr>
<tr>
<td>576376</td>
<td>Buprenorphine 8 MG [Subutex]</td>
</tr>
<tr>
<td>566435</td>
<td>Buprenorphine 0.3 MG/ML [Buprenex]</td>
</tr>
<tr>
<td>1010601</td>
<td>Buprenorphine 2 MG / Naloxone 0.3 MG [Suboxone]</td>
</tr>
</tbody>
</table>
L3 – Profiles (Data Elements)

30.2.1 StructureDefinition: CDC_MedicationRequest

Profile of MedicationRequest for use with CDC Opioid Prescribing Guidelines

The official URL for this profile is:

http://fhir.org/guides/cdc/opioid-cds/StructureDefinition/cdc-medicationrequest

30.2.1.1 Formal Views of Profile Content

Description of Profiles, Differentials, Snapshots and how the different presentations work.

This structure is derived from CPGMedicationRequest

<table>
<thead>
<tr>
<th>Name</th>
<th>Flags</th>
<th>Card.</th>
<th>Type</th>
<th>Description &amp; Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>MedicationRequest</td>
<td></td>
<td>0..*</td>
<td>CPGMedicationRequest</td>
<td>Ordering of medication for patient or opioid analgesics with ambulatory misuse potential.</td>
</tr>
<tr>
<td>medication[x]</td>
<td>S</td>
<td>1..1</td>
<td>CodeableConcept</td>
<td>Medication to be taken.</td>
</tr>
<tr>
<td>dosageInstruction</td>
<td>S</td>
<td>1..1</td>
<td>Dosage</td>
<td>How the medication should be taken.</td>
</tr>
<tr>
<td>timing</td>
<td>S</td>
<td>1..1</td>
<td>Timing</td>
<td>When medication should be administered.</td>
</tr>
<tr>
<td>repeat</td>
<td>S</td>
<td>1..1</td>
<td>Element</td>
<td>When the event is to occur.</td>
</tr>
<tr>
<td>frequency</td>
<td>S</td>
<td>1..1</td>
<td>positiveInt</td>
<td>Event occurs frequency times per period.</td>
</tr>
<tr>
<td>period</td>
<td>S</td>
<td>1..1</td>
<td>decimal</td>
<td>Event occurs frequency times per period.</td>
</tr>
<tr>
<td>periodUnit</td>
<td>S</td>
<td>1..1</td>
<td>code</td>
<td>x</td>
</tr>
<tr>
<td>esNeeded[x]</td>
<td>S</td>
<td>0..1</td>
<td>boolean</td>
<td>Take &quot;as needed&quot; (for x).</td>
</tr>
</tbody>
</table>

Recommendation 11

<table>
<thead>
<tr>
<th>Recommendation 11</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order for opioid</td>
<td>Trigger based on a new prescription (order) for opioid analgesics with ambulatory misuse potential - ideally the opioid analgesics with ambulatory misuse potential should be selected prior to being committed to the system.</td>
</tr>
</tbody>
</table>
# Requirements to Running Code

## T1 – Data
- Glossaries
- Domain Concepts
- Indicator descriptions

## T2 – Logic
- Guideline narrative
- Evidence Summaries
- Tables & Figures
- Workflows
- Decision Trees
- Triggers

## T3 – Forms
- Case Examples
- Paper Forms
- User Stories
- Personas

## L1 – Narrative
- Case Examples
- Paper Forms
- User Stories
- Personas

## L2 – Semi-Structured
- Wire Frames
- Flow Diagrams
- Workflows
- Decision Trees
- Triggers

## L3 – Structured
- Questionnaire (SDC)
- Library (CQL)
- ActivityDefinition
- PlanDefinition
- CodeSystem
- ValueSet
- StructureDefinition
- Measure

## L4 – Executable
- User-interface Forms
- Visualizations
- Interaction Model
- Application Services
- Health Record Systems
- Decision Services
- Systems of Record
- Registries and Exchanges
- Data Services
context Patient

define "Opioid Analgesic with Ambulatory Misuse Potential Prescriptions":
  Common."Is Opioid Analgesic with Ambulatory Misuse Potential?"( ContextPrescriptions )

define "Benzodiazepine Prescriptions":
  Common."Is Benzodiazepine?"( ContextPrescriptions )

define "Patient Is Being Prescribed Opioid Analgesic with Ambulatory Misuse Potential":
  exists( "Opioid Analgesic with Ambulatory Misuse Potential Prescriptions" )

define "Patient Is Being Prescribed Benzodiazepine":
  exists( "Benzodiazepine Prescriptions" )

define "Is Recommendation Applicable?":
  "Inclusion Criteria"
  and not "Exclusion Criteria"

define "Inclusion Criteria":
  ( ( "Patient Is Being Prescribed Opioid Analgesic with Ambulatory Misuse Potential"
      and exists Common."Active Ambulatory Benzodiazepine Rx"
    )
   or ( "Patient Is Being Prescribed Benzodiazepine"
        and exists Common."Active Ambulatory Opioid Rx"
    )
  )
  and Routines."Is Opioid Review Useful?"

define "Exclusion Criteria":
  Common."End of Life Assessment"
L3 – Recommendation
L3 – Recommendation (cont)
CQL Ingestion Integration

Clinical Reasoning-enabled EMR/CDR

- Recommendations
- Clinician Workflow
- CQL Evaluation
- Clinical data/transactions
- Data Requirements
- EMR
- CDR
- ETL/warehousing

Import/Ingest

PlanDefinition

CQL Libraries
CDS Hooks Integration

EHR order-select

CDS Hooks Request with Patient Data

CDS Hooks API

CDS Hooks Response

Clinical Reasoning Implementation

PlanDefinition

CQL Libraries

$apply operation

CarePlan with RequestGroup
Integration of Expert Systems in Clinical Radiology: NIH Perspective

Ronald M. Summers, M.D., Ph.D.
Senior Investigator
Imaging Biomarkers and CAD Laboratory
Radiology and Imaging Sciences
NIH Clinical Center, Bethesda, MD

github.com/rsummers11
www.cc.nih.gov/drd/summers.html
Opportunities

- Integration of lab results, omics, medical record
- Routine automated quantitation
- Triage and critical result monitoring
- Prognosis prediction
- Global health
- Opportunistic screening
Broad Scope of Applications

- Detection (Lung nodules, TB, Breast masses)
- Segmentation (organ & lesion volumetrics)
- Quantification and measurement (RECIST)
- Workflow optimization (CXR & ICH triage)
- Image reconstruction (Accelerated MRI)
- NLP of reports

Youbao Tang et al. MICCAI 2018
Universal Lesion Detector

(a)  (b)  (c)

(d)  (e)  (f)

Yan et al. MICCAI 2018
Comprehensive Spine Oncology Analysis

O’Connor et al. Radiology 2007; Yao et al. JMI 2017; Burns et al. JBMR 2020
Large-scale Body Composition Analysis

CT scan images from original screening study

Automated CT algorithms

- Visceral-to-subcutaneous fat ratio at L1 level
- Muscle density (HU) at L3 level
- Mean volumetric liver density (HU)
- Aortic calcification score (Agatston) from L1-L4
- Vertebral trabecular density (HU) at L1

Pickhardt et al. Lancet Digital Health 2020
NIH Clinical Center provides one of the largest publicly available chest x-ray datasets to scientific community

The dataset of scans is from more than 30,000 patients, including many with advanced lung disease.
ChestX-ray8 Dataset

- “ChestX-ray8 Dataset”
- 112,120 frontal-view chest radiographs, 30,805 unique patients
- 42 GB
- Metadata for all images
- Bounding boxes for 1000 images
Case Study: Prostate Cancer Detection

Greer et al. Eur Radiol 2018
Challenges & Questions

- Interpretability / explainability
- Brittleness
- Domain shift
- Ethics / Trustworthy AI

Sandfort et al. Sci Reports 2019
Challenges & Questions

• Dataset annotation is expensive; how to do it much more cost-effectively?
• Multi-institutional data; how to get it?
• Radiologists can diagnose 1000’s of diseases; how to do this with ML?
• Radiologists can do “one-shot” learning, e.g., for rare diseases; how to do this with ML?
To Learn More …

E-mail: rms@nih.gov

www.cc.nih.gov/drd/summers.html

github.com/rsummers1

X Wang et al. RSNA 2016
Deep Medicine
Generating insights into complex disease patterns, risks and treatment effects

Dr. Dexter Canoy
University of Oxford
dexter.canoy@wrh.ox.ac.uk
http://deepmedicine.medsci.ox.ac.uk/
Deep Medicine Research Programme

An overview

Approach
- Data: large-scale, complex data
- Methods: Established analytics and machine intelligence
- People: Interdisciplinary team (clinical medicine, epidemiology, data science, computer science/engineering)

Research aimed at generating insights to
- Predict the risk of developing chronic disease
- Assess consequences of chronic diseases and their clustering (multimorbidity)
- Identify best practices and interventions
UK electronic health records (EHR)

• 97% of UK population are registered with a general practice as part of the National Health Service

• Primary care EHR linked to national databases for mortality, hospitalisations, and various disease registries
  • Clinical Practice Research Datalink (www.cprd.com)

• Data preparation/pre-processing – transforming raw data into meaningful markers (‘phenotyping’) using advanced algorithms
  • Data are highly imbalanced
  • Handling multi-modal data: irregular patient visits, numerous medical concepts, and non-numerical information
  ❑ ‘Minimal processing’
Machine intelligence as applied in EHR data analysis

1. EHR, longitudinal data, and single risk factor
   • Long-term SBP in incident CVD risk prediction

2. Machine learning models and multiple predictors
   • Emergency admission prediction

3. Deep learning – which model?
   • Comparing performance of different models as applied to a single dataset

4. BEHRT model
   • Incorporating richness and complexity of EHR

5. BEHRT and some applications (ongoing work)
   • Risk prediction
   • Measuring uncertainty
   • Improving interpretability

6. Non-negative matrix factorization techniques
   • Multimorbidity – disease cluster and progression
Machine intelligence as applied in EHR data analysis

1. EHR, longitudinal data, and single risk factor
   • Long-term SBP in incident CVD risk prediction

2. Machine learning models and multiple predictors
   • Emergency admission prediction

3. Deep learning – which model?
   • Comparing performance of different models as applied to a single dataset

4. BEHRT model
   • Incorporating richness and complexity of EHR

5. BEHRT and some applications (ongoing work)
   • Risk prediction
   • Measuring uncertainty
   • Improving interpretability

6. Non-negative matrix factorization techniques
   • Multimorbidity – disease cluster and progression
Long-Term Exposure to Elevated Systolic Blood Pressure in Predicting Incident Cardiovascular Disease: Evidence From Large-Scale Routine Electronic Health Records

Jose Roberto Ayala Solarz, PhD; Dexter Canoy, MD, PhD; Francesca Elisa Diletta Raimondi, PhD; Vajie Zhu, PhD; Abdolah Reza Salim-Khorshidi, DPhil; Jenny Tran, MD; Emma Copland, MSc; Mariagrazia Zottoli, MSc; Ana-Catarina Pinho-Gomes, MD; Milad Nazarzadeh, MSc; Kazem Rahimi, FRCP
1. EHR, longitudinal data, and single risk factor
   • Long-term SBP in incident CVD risk prediction
2. Machine learning models and multiple predictors
   • Emergency admission prediction
3. Deep learning – which model?
   • Comparing performance of different models as applied to a single dataset
4. BEHRT model
   • Incorporating richness and complexity of EHR
5. BEHRT and some applications (ongoing work)
   • Risk prediction
   • Measuring uncertainty
   • Improving interpretability
6. Non-negative matrix factorization techniques
   • Multimorbidity – disease cluster and progression
Predicting the risk of emergency admission with machine learning using linked EHR

Model discrimination for different predictor sets and modelling techniques: Validation cohort.

<table>
<thead>
<tr>
<th>Predictor set</th>
<th>Model</th>
<th>CPH</th>
<th>RF</th>
<th>GBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>QA</td>
<td>0.736</td>
<td>0.736</td>
<td>0.796</td>
<td></td>
</tr>
<tr>
<td>QA+</td>
<td>0.743</td>
<td>0.799</td>
<td>0.810</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>0.788</td>
<td>0.810</td>
<td>0.826</td>
<td></td>
</tr>
</tbody>
</table>

Predictor set T and GBC modelling constantly perform better than their counterparts. The results conform to the pattern observed in internal cross-validation.

CPH, Cox proportional hazards; GBC, gradient boosting classifier; RF, random forest.

https://doi.org/10.1371/journal.pmed.1002695.t004

Model calibration for different predictor sets and modelling techniques.

Machine intelligence as applied in EHR data analysis

1. EHR, longitudinal data, and single risk factor
   • Long-term SBP in incident CVD risk prediction

2. Machine learning models and multiple predictors
   • Emergency admission prediction

3. Deep learning – which model?
   • Comparing performance of different models as applied to a single dataset

4. BEHRT model
   • Incorporating richness and complexity of EHR

5. BEHRT and some applications (ongoing work)
   • Risk prediction
   • Measuring uncertainty
   • Improving interpretability

6. Non-negative matrix factorization techniques
   • Multimorbidity – disease cluster and progression
### Table 7
Comparison for the Demographics + Diagnoses + Medications scenario (Emergency Admission).

<table>
<thead>
<tr>
<th>Model</th>
<th>AUROC</th>
<th>AUPRC</th>
<th>F1-Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>eNRBM</td>
<td>0.831 (0.831–0.832)</td>
<td>0.071 (0.071–0.071)</td>
<td>0.063 (0.062–0.063)</td>
</tr>
<tr>
<td>Deep Patient</td>
<td>0.813 (0.813–0.813)</td>
<td>0.060 (0.060–0.061)</td>
<td>0.059 (0.059–0.059)</td>
</tr>
<tr>
<td>DeepR</td>
<td>0.829 (0.828–0.831)</td>
<td>0.069 (0.067–0.071)</td>
<td>0.131 (0.118–0.144)</td>
</tr>
<tr>
<td>RETAIN</td>
<td><strong>0.847 (0.845–0.849)</strong></td>
<td><strong>0.083 (0.082–0.083)</strong></td>
<td><strong>0.153 (0.151–0.154)</strong></td>
</tr>
<tr>
<td>BOW + LR</td>
<td>0.646 (0.576–0.717)</td>
<td>0.019 (0.015–0.023)</td>
<td>0.054 (0.046–0.063)</td>
</tr>
<tr>
<td>RBM</td>
<td>0.840 (0.840–0.840)</td>
<td>0.072 (0.072–0.073)</td>
<td>0.066 (0.066–0.066)</td>
</tr>
</tbody>
</table>

*Data represented as: Mean (95% Confidence Interval).*

### Table 8
Comparison for the Demographics + Diagnoses + Medications scenario (Heart Failure).

<table>
<thead>
<tr>
<th>Model</th>
<th>AUROC</th>
<th>AUPRC</th>
<th>F1-Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>eNRBM</td>
<td>0.920 (0.920–0.921)</td>
<td>0.020 (0.019–0.021)</td>
<td>0.014 (0.014–0.014)</td>
</tr>
<tr>
<td>Deep Patient</td>
<td>0.947 (0.947–0.948)</td>
<td>0.040 (0.039–0.041)</td>
<td>0.023 (0.022–0.023)</td>
</tr>
<tr>
<td>DeepR</td>
<td>0.949 (0.947–0.952)</td>
<td>0.039 (0.032–0.046)</td>
<td>0.085 (0.049–0.120)</td>
</tr>
<tr>
<td>RETAIN</td>
<td><strong>0.950 (0.946–0.954)</strong></td>
<td><strong>0.054 (0.053–0.056)</strong></td>
<td><strong>0.117 (0.098–0.136)</strong></td>
</tr>
<tr>
<td>BOW + LR</td>
<td>0.682 (0.613–0.752)</td>
<td>0.006 (0.002–0.009)</td>
<td>0.019 (0.011–0.027)</td>
</tr>
<tr>
<td>RBM</td>
<td>0.917 (0.917–0.917)</td>
<td>0.023 (0.022–0.023)</td>
<td>0.014 (0.014–0.014)</td>
</tr>
</tbody>
</table>

*Data represented as: Mean (95% Confidence Interval).*
Machine intelligence as applied in EHR data analysis

1. EHR, longitudinal data, and single risk factor
   • Long-term SBP in incident CVD risk prediction
2. Machine learning models and multiple predictors
   • Emergency admission prediction
3. Deep learning – which model?
   • Comparing performance of different models as applied to a single dataset
4. BEHRT model
   • Incorporating richness and complexity of EHR
5. BEHRT and some applications (ongoing work)
   • Risk prediction
   • Measuring uncertainty
   • Improving interpretability
6. Non-negative matrix factorization techniques
   • Multimorbidity – disease cluster and progression
BEHRT: Transformer for Electronic Health Records

Bidirectional electronic health records transformer

Embedding Diagram and BEHRT Architecture

Data based on 1.6 million patients with ≥5 clinic visits
**BEHRT: TRANSFORMER FOR ELECTRONIC HEALTH RECORDS**


A deep neural sequence transduction model for EHR, capable of simultaneously predicting the likelihood of 301 conditions in one’s future visits.

| Model Name | Next Visit (APS|AUROC) | Next 6 M (APS|AUROC) | Next 12 M (APS|AUROC) |
|------------|------------------------|-----------------------|------------------------|
| BEHRT      | 0.462|0.954             | 0.525|0.958             | 0.506|0.955             |
| Deepr      | 0.360|0.942             | 0.393|0.943             | 0.393|0.943             |
| RETAIN     | 0.382|0.921             | 0.417|0.927             | 0.413|0.928             |

**Table 1. Model performances in the prediction tasks.**

| Model Name | Next Visit (APS|AUROC) | Next 6 M (APS|AUROC) | Next 12 M (APS|AUROC) |
|------------|------------------------|-----------------------|------------------------|
| BEHRT      | 0.216|0.904             | 0.228|0.907             | 0.226|0.905             |
| Deepr      | 0.095|0.800             | 0.104|0.814             | 0.098|0.805             |
| RETAIN     | 0.108|0.836             | 0.115|0.845             | 0.109|0.836             |

**Table 2. Model performances in the prediction tasks - First Incidence of Diseases.**
Machine intelligence as applied in EHR data analysis

1. EHR, longitudinal data, and single risk factor
   • Long-term SBP in incident CVD risk prediction

2. Machine learning models and multiple predictors
   • Emergency admission prediction

3. Deep learning – which model?
   • Comparing performance of different models as applied to a single dataset

4. BEHRT model
   • Incorporating richness and complexity of EHR

5. BEHRT and some applications (ongoing work)
   • Risk prediction
   • Measuring uncertainty
   • Improving interpretability

6. Non-negative matrix factorization techniques
   • Multimorbidity – disease cluster and progression
Ongoing work

• Incorporating more ‘features’ in the EHR
• Using BEHRT model in disease predictions
• Interpretability
• Multimorbidity trajectories and outcomes
Machine intelligence as applied in EHR data analysis

1. EHR, longitudinal data, and single risk factor
   • Long-term SBP in incident CVD risk prediction
2. Machine learning models and multiple predictors
   • Emergency admission prediction
3. Deep learning – which model?
   • Comparing performance of different models as applied to a single dataset
4. BEHRT model
   • Incorporating richness and complexity of EHR
5. BEHRT and some applications (ongoing work)
   • Risk prediction
   • Measuring uncertainty
   • Improving interpretability
6. Non-negative matrix factorization techniques
   • Multimorbidity – disease cluster and progression
Learning multimorbidity patterns from EHR using non-negative matrix factorisation

Identification of disease clusters

Progression of disease clusters to another cluster

Figure 5: Disease clusters for male and female patients (on the left and right sides, respectively). The figure shows the transposed version ($B^T$) of $B$ matrices, after gamma correction (so that small values are visible).

Untangling the complexity of multimorbidity with machine learning
Abdelaal Hassaine, Gholamreza Salimi-Khorshidi, Dexter Canoy, Kazem Rahimi
Mechanisms of Ageing and Development 190 (2020) 111325
Deep Medicine

Programme Directors
Kazem Rahimi (PI)
Simon Lovestone  Stephen Smith  Andrea Vivaldi

Research team
Reza Khorshidi  Debbie Hedgecott  Dexter Canoy
Rema Ramakrishnan  Abdelaali Hassaine  Samuel Yutong Cai
Emma Copland  Zeinab Bidel  Milad Nazarzadeh
Shishir Rao  Yikuan Liu  Wendy Turpie
Ivan Tomic  Daniel Cunning  Harry Gibson
Jeannette Majert  Thomas Fisher  Naseem Akhtar

Funders
Oxford Martin School  NIHR Oxford Biomedical Research Centre British Heart Foundation
Integrating Deep Learning into Routine Care Delivery

Mark Sendak, MD, MPP
Population Health & Data Science Lead
Duke Institute for Health Innovation

September 15, 2020
Duke Institute for Health Innovation
Duke Institute for Health Innovation

Our Mission: **Catalyze health innovation**
Catalyze transformative innovation in health and healthcare through high-impact research, leadership development and workforce training and the cultivation of a community of entrepreneurship

Our Approach: **Innovation by design**
Understand user workflow, desired outcomes and problems (needs) and then collaboratively develop concepts and prototypes, and iterate through to finalize solution
Health Care Possibility Frontier

High Quality Services

Low Cost Services
Health Care Possibility Frontier

Low Cost Services

High Quality Services
DIHI : We dare to do it @ Duke!

- Explore the horizon
- Enable others to operate at the horizon
- Expand the horizon
- Help define the next horizon

- Up-to-date representation of health status of all patients and prediction of change in health status at all moments
  - Complete continuum of care coverage for patients in any DUHS or DUHS partner setting

- Innovation as self-service model at Duke – anyone at Duke should be able to use DIHI products and services to implement and evaluate changes in their clinical practice
  - Seamless A/B testing for rapid iteration of new care models using integrated technology
Sourcing Innovations: Structured and Opportunistic

DIHI RFA approach

“Top-down + Bottom-Up” approach to sourcing innovations

- Duke Health leadership carefully develops mission-aligned strategic themes for innovation pilots
- Front-line faculty and staff propose "problems" aligned themes and novel solutions
- Systematic review and due diligence: Assessments on team, feasibility, resource needs, impact and value to patients
- 8-12 innovation pilots chosen and funded each year; Duration: 12-15 months
- DIHI members embedded within project innovation teams to rapidly catalyze the innovations
- Pivots as needed to support rapid evolution to create value
- Metrics: clinical utility, economic utility, cultural impact, IP and academic outputs

DIHI Innovation Jam

A Health focused Shark Tank at Duke

- Solicits and identifies high-potential healthcare and health innovations ready for commercialization
- Duke Leadership as Sharks:
  - DUHS leaders, Department Chairs, Deans of School of Medicine, Nursing, Engineering, OLV, I&E, MedBlue, Center and Institute Directors
- Innovation proposals from students, faculty, trainees and staff across campus
- Funding to support entrepreneurship / formation of company and also develop the product/service etc.
- Inventors offer portion of their share of Duke internal returns for investment from the sharks
- Internal syndicated investment agreements documented through MOUs.

7 Years Catalyzing Innovations
55+ Innovation Pilots
250+ Proposals

5 Years of Jamming
30+ Pitches
10 Companies Incubated
All faculty, staff, students and trainees are invited to submit novel ideas to:

△ Improve value of care through novel strategies
△ Create digital solutions for care and monitoring (home monitoring, wearables etc.)
△ Advance health equity

△ Enhance provider and staff experience and well-being
△ Accelerate population health solutions and strategies
△ Enhance patient engagement and experience

Visit dihi.org/events/dihi-rfa or email DIHIrfa@duke.edu

Applications Due: Midnight, Friday, October 9, 2020.
### DIHI Spectrum of Value Creation

<table>
<thead>
<tr>
<th>Inpatient Innovations</th>
<th>Transition Setting</th>
<th>Outpatient/Gap in Care</th>
<th>Patient &amp; Community</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality Models</td>
<td>High-utilizer dashboard</td>
<td>Pre-Operative Optimization</td>
<td>PrEP for HIV</td>
</tr>
<tr>
<td>(inpatient / 30-day)</td>
<td>Complex Care Plans</td>
<td>Home BMT</td>
<td>ePRO for Cancer Patients</td>
</tr>
<tr>
<td>Operational Enhancement</td>
<td>Index Admissions with MSSP</td>
<td>Pallalytics</td>
<td>Sickle Cell – Selfie App</td>
</tr>
<tr>
<td>Procedure Safety</td>
<td>Readmissions (Social Drivers for HF)</td>
<td>High Value Analytes</td>
<td>Cancer Distress Coach</td>
</tr>
<tr>
<td>Medication Safety</td>
<td>SNF transition</td>
<td>PSA Screening Tool</td>
<td>Autism and Beyond</td>
</tr>
<tr>
<td>Early Detection of Deterioration</td>
<td>CKD population health rounding</td>
<td>CKD population health rounding</td>
<td>Voices of Duke</td>
</tr>
</tbody>
</table>

**Immersion in innovation and data science**

- Medical Students Scholarship
- Data Science in Health masters course in BME
- Summer Fellowship in Data Science
- Case Studies and Data Camp
- Journal Club

**Technology Infrastructure**

**Research**

**Education and Training**

*Duke Institute for Health Innovation [ DIHI ] – Spectrum of value creation across the ecosystem*
DIHI Spectrum of Value Creation

Inpatient Innovations
- Mortality Models (inpatient / 30-day)
- Operational Enhancement
- Procedure Safety
- Medication Safety
- Early Detection of Deterioration

Transition Setting
- High-utilizer dashboard
- Complex Care Plans
- Index Admissions with MSSP
- Readmissions (Social Drivers for HF)
- SNF transition

Outpatient/Gaps in Care
- Pre-Operative Optimization
- Home BMT
- Pallalytics
- High Value Analytes
- PSA Screening Tool
- CKD population health rounding

Patient & Community
- PrEP for HIV
- ePRO for Cancer Patients
- Sickle Cell – Selfie App
- Cancer Distress Coach
- Autism and Beyond
- Voices of Duke

Immersion in innovation and data science
- Medical Students Scholarship
- Data Science in Health masters course in BME
- Summer Fellowship in Data Science
- Case Studies and Data Camp
- Journal Club

Technology Infrastructure
Research
Education and Training

Duke Institute for Health Innovation [ DIHI ] – Spectrum of value creation across the ecosystem
Sepsis Watch
Sepsis

- Most common cause of in-hospital deaths in the United States
- 20% of all global deaths (49 million incident cases per year, 11 million deaths per year)
- At Duke, 68% of sepsis cases occur within 24 hours of presenting to hospital
  - ~20 cases per day, ~2 deaths per day
“The Human Body is a Black Box”

“it is an elusive task to generate a single all-encompassing definition”
The Challenge

• Sepsis as a label is not explainable or interpretable to clinicians (even experts)
• Urgency to improve the detection and management of a deadly condition
  – Once diagnosed, implement guideline-recommended care
• Needed broad adoption by front-line clinical staff, health system leadership, and medical community
  – 3 hospitals, nearly 2,000 hospital beds
The Challenge

- Sepsis as a label is not explainable or interpretable to clinicians (even experts)
- Urgency to improve the detection and management of a deadly condition
- Needed broad adoption by front-line clinical staff, health system leadership, and medical community

Given the circumstances, what are the best strategies to build trustworthiness and accountability with various stakeholder groups?
<table>
<thead>
<tr>
<th>STRATEGIES TO PROMOTE TRUSTWORTHINESS, TRANSPARENCY, &amp; ACCOUNTABILITY</th>
<th>Idea generation &amp; resource gathering</th>
<th>Model development &amp; validation</th>
<th>Tool design, development &amp; evaluation</th>
<th>Workflow development, integration &amp; education</th>
<th>Handoff, maintenance &amp; improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem formulation</td>
<td>Problem-based project selection; Clinician initiated and led</td>
<td>Local and context-specific training data used; Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Iterative tool refinement with stakeholders; Recognition of socio-technical dimensions</td>
<td>Boundaries of appropriate use defined; Infrastructure and testing to meet enterprise user requirements</td>
<td>Tool usage limited to original boundaries of intervention; Ongoing monitoring of relevant clinical research</td>
</tr>
<tr>
<td>Stakeholder relationship building</td>
<td>Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration</td>
<td>Sustained engagement with ML researchers; Close clinical collaboration</td>
<td>Full time role created to support integration; Sustained engagement with tech vendors; Close clinical collaboration</td>
<td>Stakeholder capacity-building around tech literacy; Close clinical collaboration</td>
<td>Collaborating with existing institutional performance monitoring; Close clinical collaboration</td>
</tr>
<tr>
<td>Stakeholder feedback loops</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Regular meetings to create space for feedback; Trial “silent phase” integration</td>
<td>Multi-stakeholder governance committee established; Full time role manages and supports project integration</td>
<td>Ongoing technical monitoring by dev team; Multi-stakeholder governance committee oversight</td>
</tr>
<tr>
<td>Upholding professional discretion</td>
<td>Explicit goal: to augment, not replace clinicians</td>
<td>Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Designed as an “algorithm in the loop”; Register clinical trial and report outcomes</td>
<td>Elevate the work and expertise of integrating the tool into clinical care</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
</tr>
<tr>
<td>STRATEGIES TO PROMOTE TRUSTWORTHINESS, TRANSPARENCY, &amp; ACCOUNTABILITY</td>
<td>Idea generation &amp; resource gathering</td>
<td>Model development &amp; validation</td>
<td>Tool design, development &amp; evaluation</td>
<td>Workflow development, integration &amp; education</td>
<td>Handoff, maintenance &amp; improvement</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Problem formulation</td>
<td>Problem-based project selection; Clinician initiated and led</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stakeholder relationship building</th>
<th>Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholder feedback loops</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upholding professional discretion</td>
<td>Explicit goal: to augment, not replace clinicians</td>
<td>Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Designed as an “algorithm in the loop”</td>
<td>Elevate the work and expertise of integrating the tool into clinical care</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SIRS ≥2</th>
<th>sSOFA ≥2</th>
<th>SIRS ≥2 + any culture ordered</th>
<th>SIRS ≥2 + any culture ordered + element of organ damage</th>
<th>SIRS ≥2 + blood culture ordered + element of organ damage</th>
<th>sSOFA ≥2 + any culture ordered</th>
<th>ICD diagnosis code associated with sepsis</th>
<th>SIRS ≥2 + bacteremia</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td># of encounters</td>
<td>32928</td>
<td>17423</td>
<td>14327</td>
<td>13358</td>
<td>9184</td>
<td>7110</td>
<td>2884</td>
<td>1419</td>
</tr>
<tr>
<td>Median length of stay in days (lower-upper quartiles)</td>
<td>4.6 (2.8-8.1)</td>
<td>5.9 (3.2-10.7)</td>
<td>6.4 (3.7-12.1)</td>
<td>6.9 (3.9-12.8)</td>
<td>7.3 (4.1-14.6)</td>
<td>8.3 (4.5-16.3)</td>
<td>7.5 (4.1-15.4)</td>
<td>11.0 (5.9-23.7)</td>
</tr>
<tr>
<td>Inpatient mortality rate (%)</td>
<td>3.7%</td>
<td>6.7%</td>
<td>6.9%</td>
<td>7.4%</td>
<td>9.7%</td>
<td>12.6%</td>
<td>16.3%</td>
<td>15.0%</td>
</tr>
<tr>
<td>ICU requirement rate (%)</td>
<td>21.3%</td>
<td>32.0%</td>
<td>28.7%</td>
<td>30.0%</td>
<td>34.5%</td>
<td>45.0%</td>
<td>46.4%</td>
<td>38.9%</td>
</tr>
<tr>
<td>Antibiotic administration rate (%)</td>
<td>62.4%</td>
<td>69.0%</td>
<td>82.8%</td>
<td>83.2%</td>
<td>90.0%</td>
<td>85.5%</td>
<td>98.5%</td>
<td>97.8%</td>
</tr>
<tr>
<td>IV fluid administration rate (%)</td>
<td>38.0%</td>
<td>37.8%</td>
<td>47.4%</td>
<td>48.5%</td>
<td>56.7%</td>
<td>49.6%</td>
<td>86.7%</td>
<td>67.1%</td>
</tr>
<tr>
<td>Vasopressor administration rate (%)</td>
<td>10.2%</td>
<td>17.1%</td>
<td>15.0%</td>
<td>16.0%</td>
<td>19.4%</td>
<td>27.3%</td>
<td>32.8%</td>
<td>28.8%</td>
</tr>
<tr>
<td>STRATEGIES TO PROMOTE TRUST &amp; ACCOUNTABILITY</td>
<td>Idea generation &amp; resource gathering</td>
<td>Model development &amp; validation</td>
<td>Tool design, development &amp; validation</td>
<td>Workflow development, integration</td>
<td>Handoff, maintenance &amp; improvement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-------------------------------------</td>
<td>------------------------------</td>
<td>--------------------------------------</td>
<td>---------------------------------</td>
<td>---------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Problem formulation</strong></td>
<td>Problem-based project selection; Clinician initiated and led</td>
<td>Local and context-specific training data used</td>
<td>Sustained engagement with ML researchers; Close clinical collaboration</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>Stakeholder capacity-building around tech literacy; Close clinical collaboration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stakeholder relationship building</strong></td>
<td>Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration</td>
<td>Sustained engagement with ML researchers; Close clinical collaboration</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stakeholder feedback loops</strong></td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Upholding professional discretion</strong></td>
<td>Explicit goal: to augment, not replace clinicians</td>
<td>Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Dataset**

- **42,000+** inpatient encounters at Duke Hospital over 14 months, **21.3%** with a sepsis event; no specific inclusion/exclusion criteria.
- **34** physiological variables (5 vitals, 29 labs).
  - At least one value for each vital in 99% of encounters.
  - Some labs rarely measured (2-4%), most measured 20-80% of the time.
- **35** baseline covariates (e.g. age, transfer status, comorbidities).
- **10** medication classes (antibiotics, opioids, heparins).
- **32+ million data points**: 25 million vital sign measurements, 2 million med admins and 5.2 million labs.
**STRATEGIES TO PROMOTE TRUST & ACCOUNTABILITY**

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem formulation</td>
<td>Problem-based project selection; Clinician initiated and led</td>
</tr>
<tr>
<td>Stakeholder relationship building</td>
<td>Stakeholder mapping; Multiple modes of stakeholder engagement</td>
</tr>
<tr>
<td>Stakeholder feedback loops</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
</tr>
<tr>
<td>Upholding professional discretion</td>
<td>Explicit goal: to augment, not replace clinicians</td>
</tr>
</tbody>
</table>

**User Interface Design**

**Clinical Informatics**

**Machine Learning**

**Data Engineering**

**Workflow development, integration & education**

**Handoff, maintenance & improvement**

**Problem formulation**

**Stakeholder relationship building**

**Stakeholder feedback loops**

**Upholding professional discretion**

**STRATEGIES TO PROMOTE TRUST & ACCOUNTABILITY**

**Idea generation & resource gathering**

**Model development & validation**

**Tool design, development & evaluation**

**Workflow development, integration & education**

**Handoff, maintenance & improvement**

**IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;**

**Local monitoring & validation by clinicians & dev team**

**Iterative tool refinement with stakeholders; Recognition of socio-technical dimensions**

**Boundaries of appropriate use defined; Infrastructure and testing to meet enterprise user requirements**

**Tool usage limited to original boundaries of intervention; Ongoing monitoring of relevant clinical research**

**Collaborating with existing institutional performance monitoring; Close clinical collaboration**

**Multi-stakeholder governance committee; Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!**

**Emergency Medicine**

**Hospital Medicine**

**Critical Care**

**Infectious Diseases**

**Nursing**

**Champions include Hospital Presidents, CMOs, CIO**
### STRATEGIES TO PROMOTE TRUST & ACCOUNTABILITY

<table>
<thead>
<tr>
<th>STRATEGIES TO PROMOTE TRUST &amp; ACCOUNTABILITY</th>
<th>Idea generation &amp; resource gathering</th>
<th>Model development &amp; validation</th>
<th>Tool design, development &amp; evaluation</th>
<th>Workflow development, integration &amp; education</th>
<th>Handoff, maintenance &amp; improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem formulation</td>
<td>Local and context-specific training data</td>
<td>Iterative tool refinement with stakeholders</td>
<td>Boundaries of appropriate use defined</td>
<td>Tool usage limited to original boundaries of intervention</td>
<td></td>
</tr>
<tr>
<td>Stakeholder relationship building</td>
<td>Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration</td>
<td>Sustained engagement with ML researchers; Close clinical collaboration</td>
<td>Full time role created to support integration; Sustained engagement with tech vendors; Close clinical collaboration</td>
<td>Stakeholder capacity-building around tech literacy; Close clinical collaboration</td>
<td></td>
</tr>
<tr>
<td>Stakeholder feedback loops</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled; Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Regular meetings to create space for feedback; Trial “silent phase” integration</td>
<td>Multi-stakeholder governance committee established; Full time role manages and supports project integration</td>
<td>Ongoing technical monitoring by dev team; Multi-stakeholder governance committee oversight</td>
<td></td>
</tr>
<tr>
<td>Upholding professional discretion</td>
<td>Explicit goal: to augment, not replace clinicians</td>
<td>Designed as an “algorithm in the loop”</td>
<td>Elevate the work and expertise of integrating the tool into clinical care</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
<td></td>
</tr>
</tbody>
</table>

#### User Interface

- **Leverage Sepsis Care Team**
  - RRT nurses and hospitalists
- **Support primary providers**
  - ...without causing alarm-fatigue
- **Improve patient care over entire cycle high risk through treatment**
**STRATEGIES TO PROMOTE TRUST & ACCOUNTABILITY**

- **Idea generation & resource gathering**
- **Model development & validation**
- **Tool design, development & evaluation**
- **Workflow development, integration & education**
- **Handoff, maintenance & improvement**

---

**Problem formulation**
- Problem-based project selection; Clinician initiated and led
- Local and context-specific training data used; Local monitoring & validation by clinicians & dev team
- Iterative tool refinement with stakeholders; Recognition of socio-technical dimensions
- Boundaries of appropriate use defined; Infrastructure and testing to meet enterprise user requirements
- Tool usage limited to original boundaries of intervention; Ongoing monitoring of relevant clinical research

---

**Stakeholder relationship building**
- Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration
- Sustained engagement with ML researchers; Close clinical collaboration
- Full time role created to support integration; Sustained engagement with tech vendors; Close clinical collaboration
- Stakeholder capacity-building around tech literacy; Close clinical collaboration
- Collaborating with existing institutional performance monitoring; Close clinical collaboration

---

**Stakeholder feedback loops**
- IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled; Local monitoring & validation by clinicians & dev team
- Regular meetings to create space for feedback; Trial “silent phase” integration
- Multi-stakeholder governance committee established; Full time role manages and supports project integration
- Ongoing technical monitoring by dev team; Multi-stakeholder governance committee oversight

---

**Upholding professional discretion**
- Explicit goal: to augment, not replace clinicians
- Local monitoring & validation by clinicians & dev team
- Designed as an “algorithm in the loop”
- Elevate the work and expertise of integrating the tool into clinical care
- Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated

---

**Iterative tool refinement with stakeholders**

---

**Triage**

**Monitor**

**Treat**
## Strategies to Promote Trust & Accountability

<table>
<thead>
<tr>
<th>Problem formulation</th>
<th>Idea generation &amp; resource gathering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem-based project selection; Clinician initiated and led</td>
<td>Local and context-specific training data used; Local monitoring &amp; validation by clinicians &amp; dev team</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stakeholder relationship building</th>
<th>Model development &amp; validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration</td>
<td>Sustained engagement with ML researchers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stakeholder feedback loops</th>
<th>Tool design, development &amp; evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRB approved research protocol; Data-safety monitoring board created</td>
<td>Local monitoring &amp; validation by clinicians &amp; dev team</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Upholding professional discretion</th>
<th>Workflow development, integration &amp; education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Futoma, Hariharan, Heller ICML 2017</td>
<td>Handoff, maintenance &amp; improvement</td>
</tr>
<tr>
<td>Futoma, Hariharan, Sendak et al MLHC 2017</td>
<td></td>
</tr>
<tr>
<td>Bedoya, Futoma, et al JAMIA Open 2020</td>
<td></td>
</tr>
</tbody>
</table>

*Image of a graph showing observed data, Gaussian Process + RNN, and a figure showing a workflow of RNNs.*
**Model Facts**

**Model name:** Deep Sepsis  
**Locals:** Duke University Hospital

**Approval Date:** 09/12/2019  
**Last Update:** 09/29/2019  
**Version:** 1.0

**Summary**
This model uses EHR input data collected from a patient's current inpatient encounter to estimate the probability that the patient will meet sepsis criteria within the next 4 hours. It was developed in 2016-2019 by the Duke Institute for Health Innovation. The model was licensed to Cohere Med in July 2019.

**Mechanism**
- **Outcome:** sepsis within the next 4 hours, see (1) for sepsis criteria  
- **Input data source:** electronic health record (EHR)  
- **Input data type:** demographics, analyses, vital, medication administration  
- **Training data location and time-period:** DUH, 10/2014 - 12/2015  
- **Model type:** Recurrent Neural Network

**Validation and performance**

<table>
<thead>
<tr>
<th>Prevalence</th>
<th>AUC</th>
<th>PPV @ Sensitivity of 60%</th>
<th>Sensitivity @ PPV of 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Retrospective</td>
<td>0.89</td>
<td>0.88</td>
<td>0.14</td>
</tr>
<tr>
<td>Local Temporal</td>
<td>0.64</td>
<td>0.54</td>
<td>0.20</td>
</tr>
<tr>
<td>Local Prospective</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

**Uses and directions**
- **Operational use case(s):** Every hour, data is pulled from the EHR to calculate risk of sepsis for every patient at the DUH ED. A rapid response team nurse reviews every high-risk patient with a physician in the ED to confirm whether or not to initiate treatment for sepsis.
- **General use:** This model is intended to be used by clinicians to identify patients for further assessment for sepsis. The model is not diagnostic for sepsis and is not meant to guide or drive clinical care. This model is intended to complement other pieces of patient information related to sepsis as well as a physical evaluation to determine the need for sepsis treatment.

**Warnings**
- **General warnings:** This model was not trained or evaluated on patients receiving care in the ICU. Do not use this model in the ICU setting without further evaluation. This model was trained to identify the first episode of sepsis during an inpatient encounter. During long inpatient stays with multiple sepsis episodes, model accuracy needs to be further evaluated. The model is not interpretable and does not provide rationale for high risk scores. Clinical endpoints are expected to place model output in context with other clinical information to make final determination of diagnosis.

**Boundary of appropriate use defined**

**Other information**
- **Outcome Definition:** https://doi.org/10.1101/648907
- **Related model:** http://doi.org/10.1001/jama.2015.0288
- **Model development & validation:** arXiv.org/abs/1708.05894
- **Model implementation:** jmir.org/preprint/15182
- **Clinical trial:** clinicaltrials.gov/ct2/show/NCT03655626
- **Clinical impact evaluation:** TBD
- **For inquiries and additional information:** please email mark-sendak@duke.edu
### Proprietary and Confidential

**STRATEGIES TO PROMOTE TRUST & ACCOUNTABILITY**

<table>
<thead>
<tr>
<th>Problem formulation</th>
<th>Stakeholder relationship building</th>
<th>Stakeholder feedback loops</th>
<th>Upholding professional discretion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idea generation &amp; resource gathering</td>
<td>Model development &amp; validation</td>
<td>Tool design, development &amp; evaluation</td>
<td>Workflow development, integration &amp; education</td>
</tr>
<tr>
<td>Idea generation &amp; resource gathering</td>
<td>Model development &amp; validation</td>
<td>Tool design, development &amp; evaluation</td>
<td>Workflow development, integration &amp; education</td>
</tr>
<tr>
<td>Infrastructure and testing to meet enterprise user requirements</td>
<td>Tool usage limited to original boundaries of intervention; Ongoing monitoring of relevant research</td>
<td>Infrastructure and testing to meet enterprise user requirements</td>
<td>Tool usage limited to original boundaries of intervention; Ongoing monitoring of relevant research</td>
</tr>
</tbody>
</table>

### Infrastructure and Testing

- Secure Environment
- Dev/Stage
- Tableau or SuperNet Operational Dashboards
- RW/IE and HBR
- Registry/CCM
- Model Outputs
- Dashboards

### EHR & Other Data sources

- Control & Monitor
- Task scheduler
- Task Queue
- Data Extraction
- Data Cleaning
- Data Monitoring
- Docker + Kubernetes
- Airflow
- RabbitMQ
- Ansible
- GitLab
- Data normalization standardization
- CCS class grouping
- ICD9 - ICD10 crosswalk
- Concurrency groupings
- Lab grouping
- Meds therapeutic class
- Provider grouping

### Problem formulation

- Problem-based project selection; Clinician initiated and led
- Local and context-specific training data used; Local monitoring & validation by
- Iterative tool refinement with stakeholders; Recognition of socio-technical dimensions
- Boundaries of appropriate use defined; Infrastructure and testing to meet enterprise user requirements
- Tool usage limited to original boundaries of intervention; Ongoing monitoring of relevant research

### Stakeholder relationship building

- Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration
- Sustained engagement with ML researchers; Close clinical collaboration
- Full time role created to support integration; Sustained engagement with tech vendors; Close clinical collaboration
- Stakeholder capacity-building around tech literacy; Close clinical collaboration
- Collaborating with existing institutional performance monitoring; Close clinical collaboration

### Stakeholder feedback loops

- IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled; Local monitoring & validation by clinicians & dev team
- Regular meetings to create space for feedback; Trial "silent phase" integration
- Multi-stakeholder governance committee established; Full time role manages and supports project integration
- Ongoing technical monitoring by dev team; Multi-stakeholder governance committee oversight

### Upholding professional discretion

- Explicit goal: to augment, not replace clinicians
- Local monitoring & validation by clinicians & dev team
- Designed as an "algorithm in the loop"
- Elevate the work and expertise of integrating the tool into clinical care
- Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!
<table>
<thead>
<tr>
<th>Strategies To Promote Trust &amp; Accountability</th>
<th>Idea generation &amp; resource gathering</th>
<th>Model development &amp; validation</th>
<th>Tool design, development &amp; evaluation</th>
<th>Workflow development, integration &amp; education</th>
<th>Handoff, maintenance &amp; improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem formulation</td>
<td>Problem-based project selection; Clinician initiated and led</td>
<td>Local and context-specific training data used; Local monitoring</td>
<td>Iterative tool refinement with stakeholders;</td>
<td>Boundaries of appropriate use defined; Infrastructure and testing to meet enterprise user requirements</td>
<td>Tool usage limited to original boundaries of intervention; Ongoing monitoring of relevant clinical research</td>
</tr>
<tr>
<td>Stakeholder relationship building</td>
<td>Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration</td>
<td>Stakeholder capacity-building around tech literacy; Close clinical collaboration</td>
<td>Stakeholder capacity-building around tech literacy; Close clinical collaboration</td>
<td>Collaborating with existing institutional performance monitoring; Close clinical collaboration</td>
<td>Ongoing technical monitoring by dev team; Multi-stakeholder governance committee oversight</td>
</tr>
<tr>
<td>Stakeholder feedback loops</td>
<td>Multi-stakeholder governance committee established;</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
</tr>
<tr>
<td>Upholding professional discretion</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
</tr>
<tr>
<td>STRATEGIES TO PROMOTE TRUST &amp; ACCOUNTABILITY</td>
<td>Idea generation &amp; resource gathering</td>
<td>Model development &amp; validation</td>
<td>Tool design, development &amp; evaluation</td>
<td>Workflow development, integration &amp; education</td>
<td>Handoff, maintenance &amp; improvement</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-------------------------------------</td>
<td>-------------------------------</td>
<td>--------------------------------------</td>
<td>---------------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Problem formulation</td>
<td>Problem-based project selection; Clinician initiated and led</td>
<td>Local and context-specific training data used; Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Iterative tool refinement with stakeholders; Recognition of socio-technical dimensions</td>
<td>Boundaries of appropriate use defined; Infrastructure and testing to meet enterprise user requirements</td>
<td>Tool usage limited to original boundaries of intervention; Ongoing monitoring of relevant clinical research</td>
</tr>
<tr>
<td>Stakeholder relationship building</td>
<td>Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration</td>
<td>Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration</td>
<td>Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration</td>
<td>Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration</td>
<td>Collaborating with existing institutional performance monitoring; Close clinical collaboration</td>
</tr>
<tr>
<td>Stakeholder feedback loops</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
</tr>
<tr>
<td>Upholding professional discretion</td>
<td>Explicit goal: to augment, not replace clinicians</td>
<td>Explicit goal: to augment, not replace clinicians</td>
<td>Explicit goal: to augment, not replace clinicians</td>
<td>Explicit goal: to augment, not replace clinicians</td>
<td>Explicit goal: to augment, not replace clinicians</td>
</tr>
</tbody>
</table>

Ongoing technical monitoring by dev team; Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!
<table>
<thead>
<tr>
<th>STRATEGIES TO PROMOTE TRUST &amp; ACCOUNTABILITY</th>
<th>Idea generation &amp; resource gathering</th>
<th>Model development &amp; validation</th>
<th>Tool design, development &amp; evaluation</th>
<th>Workflow development, integration &amp; education</th>
<th>Handoff, maintenance &amp; improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>“And it’s cool you know, it’s a totally new job title under the RRT role. And a new responsibility and one I welcome.”</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **RRT interviewee**

Elevate the work and expertise of integrating the tool into clinical care

---

“And it’s cool you know, it’s a totally new job title under the RRT role. And a new responsibility and one I welcome.”

- **RRT interviewee**

Elevate the work and expertise of integrating the tool into clinical care
<table>
<thead>
<tr>
<th>Strategies To Promote Trustworthiness, Transparency, &amp; Accountability</th>
<th>Idea generation &amp; resource gathering</th>
<th>Model development &amp; validation</th>
<th>Tool design, development &amp; evaluation</th>
<th>Workflow development, integration &amp; education</th>
<th>Handoff, maintenance &amp; improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Problem formulation</strong></td>
<td>Problem-based project selection; Clinician initiated and led</td>
<td>Local and context-specific training data used; Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Iterative tool refinement with stakeholders; Recognition of socio-technical dimensions</td>
<td>Boundaries of appropriate use defined; Infrastructure and testing to meet enterprise user requirements</td>
<td>Tool usage limited to original boundaries of intervention; Ongoing monitoring of relevant clinical research</td>
</tr>
<tr>
<td><strong>Stakeholder relationship building</strong></td>
<td>Stakeholder mapping; Multiple modes of stakeholder engagement leveraged; Close clinical collaboration</td>
<td>Sustained engagement with ML researchers; Close clinical collaboration</td>
<td>Full time role created to support integration; Sustained engagement with tech vendors; Close clinical collaboration</td>
<td>Stakeholder capacity-building around tech literacy; Close clinical collaboration</td>
<td>Collaborating with existing institutional performance monitoring; Close clinical collaboration</td>
</tr>
<tr>
<td><strong>Stakeholder feedback loops</strong></td>
<td>IRB approved research protocol; Data-safety monitoring board created; Multi-disciplinary team assembled;</td>
<td>Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Regular meetings to create space for feedback; Trial “silent phase” integration</td>
<td>Multi-stakeholder governance committee established; Full time role manages and supports project integration</td>
<td>Ongoing technical monitoring by dev team; Multi-stakeholder governance committee oversight</td>
</tr>
<tr>
<td><strong>Upholding professional discretion</strong></td>
<td>Explicit goal: to augment, not replace clinicians</td>
<td>Local monitoring &amp; validation by clinicians &amp; dev team</td>
<td>Designed as an “algorithm in the loop”, Register clinical trial and report outcomes</td>
<td>Elevate the work and expertise of integrating the tool into clinical care</td>
<td>Multi-stakeholder governance committee draws on multiple forms of expertise; New projects initiated!</td>
</tr>
</tbody>
</table>
On the Horizon
Building a Data Science & Innovation Network

Health System Learning Network

- Rapid and continuous integration and evaluation of data science and machine learning technologies and innovations across sites
- Unified, EHR agnostic infrastructure to integrate into operational IT systems
- Close collaboration between IT, clinical, and operational leaders
- Funding opportunities through federal agencies and sponsored research studies
Thank You

mark.sendak@duke.edu

@DukeInnovate, https://dihi.org

Sepsis Watch Team

Clinicians
Physicians
Cara O’Brien
Armando Bedoya
Meredith Clement
Jason Theiling
Rebecca Donahoe

Nurses
Elizabeth Alderton
Dina Sorro
Dustin Tart
Cory Miller
Kelly Kester

Students
Masters, Statistics
Brian Cozzi

Medical Students
Nathan Brajer
Anthony Lin

PhD, Statistics
Joseph Futoma

Health System Leadership

IT Leadership
Chris Fowler
Tres Brown
Armando Bedoya
Eric Poon
Jeffrey Ferranti

Bill Fulkerson
Tom Owens
Mary Ann Fuchs
Tracey Gosselin
Mary Lindsay
Jill Engel
Allan Kirk
Charles Gerardo
Appendix
Academic Output

• Sepsis Watch model manuscripts

• Sepsis Watch implementation manuscripts
  – https://medinform.jmir.org/2020/7/e15182/

• Machine learning best practices manuscripts
  – https://www.nature.com/articles/s41591-019-0548-6
  – https://www.nature.com/articles/s41746-020-0253-3
Future Directions for Clinical Decision Support

Sarah M. Preum
Postdoctoral Fellow
HCII, School of Computer Science, CMU
Data Sources
- Smart Health Apps
  - Intervention or Advice
  - Monitoring & Tracking
- Drug User Guidelines
- Health Websites
- Clinical Guidelines
- Knowledge Bases
- EHR
- Social Media
- Other

Types of Data
- Textual Data
- Audio Data
- Video Data
- Other Data
- Raw Sensor Data
- Inferred Sensor Data
- Domain Knowledge

Core Technical Challenges
- Information Extraction
  - Domain-specific Concept Extraction
  - Semantic Inference
- Information Fusion
  - Conflict Detection
  - Multimodal Data Aggregation
  - Domain Knowledge Integration

Applications
- Personalized Recommendation
- Emergency Medicine Decision Support
- Clinical Decision Support
- Intelligent Assistant
- Knowledge Discovery

spreum@andrew.cmu.edu
Emergency site

Wearable Interface

Secured Cloud

Protocols/Guidelines

Historical Data Analytics and Models

Real-time Sensing and Computing

Embedded System

Voice recordings

Voice feedback/reminders

Data from other first responders

Patient Vitals

Cardiac Monitor

EMS Network

ER community
Future Directions for CDS

• Big data or better quality of data?
  • Data quality and data validation process
  • Heterogeneous data aggregation
  • Robustness and generalization
  • Medical errors and health disparity

• Decision support to improve health outcome
  • Under stress and time constraints
    • Emergency medicine, ICU, ER
  • Personalized intelligent assistant / cognitive assistant
Healthcare Cognitive Assistants (HCA)

A Review of Cognitive Assistants for Healthcare: Trends, Prospects, and Future Directions, ACM CSUR, 2020

spreum@andrew.cmu.edu

Care recipient
- At-risk patients
- Patients with a chronic illness
- Patients with acute illness
- Healthy patients
- Elderly
- Children
- Families
- Athletes
- Pregnant women
- Rural communities
- Others

Care provider
- Caregivers & families
- Hospital staffs
- Radiologists
- Emergency responders
- Nurses
- General practitioners
- Physiotherapists
- Psychotherapists
- Surgeons
- Specialist doctors
- Others

Preventative medicine
Diagnosis
Emergency healthcare
Tele-medicine
Treatment
Surgery
Rehabilitation
Remote monitoring
Post-operative
Home healthcare
Context-aware
Interactive
Adaptive
HCA
- Sensing
- Actuation
- Control & computation

ICU
Others

Page 239
Healthcare Cognitive Assistants (HCA)

Features of HCAs
- Temporal context
- Spatial context
- User context
- Environmental context

Adaptive
- Adaptive to user's behavior
- Adaptive to user's action
- Adaptive to user's need
- Adaptive to environment

Context-aware

Interactive
- Entity of interaction
- Mode of interaction
- Verbal
- Nonverbal
- Natural interaction
- Proactive or reactive interaction

Neuro-symbolic AI
- Modeling technique
- Data-driven Knowledge Extraction and representation

spreum@andrew.cmu.edu
Moving Beyond Decision Support

John Zimmerman
Tang Family Prof of AI and HCI
Carnegie Mellon University
CDS frame problem as clinician medical error; they love alerts! Clinicians NOT motivated to use CDS.
People love things that help them becoming the person they desire to be.
Data from one family’s activities for 6-months: routines and deviations

More than 90% of days are not routine
Person-place-time-view
Prevents forgetting children
CDS frame problem as clinician medical error; they love alerts! Clinicians NOT motivated to use CDS. Quality of EHR data is often poor. Data is sparse, more oriented towards billing than health.
People love things that help them becoming the person they desire to be.
Data-driven innovation has transformed innovation in the tech community.
CDS frame problem as clinician medical error; they love alerts! Clinicians NOT motivated to use CDS. Quality of EHR data is often poor. Data is sparse, more oriented towards billing than health.

CDS support textbook cases. Machine intelligence helps with cases where clinicians need the least help.
People love things that help them becoming the person they desire to be.

Data-driven innovation has transformed innovation in the tech community.

AI great for automating repetitive, procedural tasks.
CDS frame problem as clinician medical error; they love alerts! Clinicians not motivated to use CDS. Quality of EHR data is often poor. Data is sparse, more oriented towards billing than health.

CDS support textbook cases. Machine intelligence helps with cases where clinicians need the least help.

Interactions with EHR reduce rapport with patients.
People love things that help them becoming the person they desire to be.
Data-driven innovation has transformed innovation in the tech community.
AI great for automating repetitive, procedural tasks.
Great healthcare involves clinicians, patients, and informal caregivers.
Vision of the Future
Medical Decisions
Patient Experience

Medical Decisions
Automate Most Repetitive Procedural Work

Patient Experience

Medical Decisions

Co-worker Interactions

Quality Data Collection
Moving Beyond Decision Support

John Zimmerman
Tang Family Prof of AI and HCI
Carnegie Mellon University