Learning Health Systems: Using Patient-Reported Outcomes to Improve Care Delivery And Real-World Discovery Research

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- K24 DA029262
- T32 DA035165
- R01DA035484

Redlich Pain Research Endowment
Dodie and John Rosekrans Pain Research Endowment

*No industry conflicts*
Pain is a Public Health Problem

Relieving Pain in America A Blueprint for Transforming Prevention, Care, Education, and Research

• Up to $635 billion annually
• Chronic pain can become a disease in its own right
• Reduces quality of life
• Undertreated
• Disparities in prevalence and care
• Need better data!

Acute Pain
Chronic Pain
High Impact Pain
Disparities
Under-treatment and inappropriate treatment of pain among racial and ethnic minorities
Public Education & Communication
High quality, evidence based education programs for patients and the public
Prevention & Care
Increase substantially the accessibility and quality of pain care
Services & Reimbursement
Public health entities have a role in pain care and prevention
Professional Education
Improve professional education of all providers
Population Research
Improvements in state and national data are needed
CMS
Payers
Nursing
Psychology
PCP
APP
Pain MD
PT
National Pain Strategy
Sandra with Complex Regional Pain Syndrome (CRPS)

“It’s that feeling, if you’re digging through the bottom of a cooler, and you just get that burning sensation because your arm is so cold,”
How do you know whether you have made Sandra better?

How do you know when a certain treatment is better than another for a specific patient?
The Problem with Randomized Controlled Trials and Chronic Pain

10% of persons with chronic pain qualify for clinical trials

90% do not qualify!!!
RCTs do not generalize well....and do not address Sandra’s condition
The Systems Challenge and Complexity of Pain

**Sleep**
- Hypervigilance
- Avoidance
- Pain-Related Fear
- Pain Catastrophizing
- Pain Experience
- Spontaneous Discharge
- Inflammation
- Receptor Sensitization
- Convergence
- Descending Inhibition
- Receptor field expansion
- Injury Inflammation
- Biomechanical Alterations
- Atrophy
- Inc. Stiffness
- Augmented Muscle Activity
- Modified Motor Planning
- Spasms & Spindle Discharge
- Compromised Muscle Activity

**Biomedical**
- Surgeries
- Non-opioid Rx
- Opioid Use
- Opioid Tolerance
- Opioid-Induced Hyperalgesia
- Iatrogenesis
- Vascular Infectious Traumaic Autoimmune Metabolic Iatrogenic
- Biomedical Alterations
- Decreased Stiffness
- Increased Stiffness

**Psychological**
- Anxiety
- Anxiety Sensitivity
- Negative Affectivity Threatening Info
- Cognitive Repraisal Expressive Suppression
- Punishing Response
- Solicitous Response
- Acceptance
- Pain-Related Fear
- Hypervigilance Avoidance
- Somatization
- PTSD
- Aberrant Opioid Use
- Genetic Load
- Locus of Control
- Coping Skills
- Mindfulness
- Resilience
- Suicide
- Depression
- Substance Use Disorder
- Adverse Childhood Event
- Genetic Load

**From Ming Kao**
IOM Learning Healthcare Systems:
“We seek the development of a learning healthcare system in which science, informatics, incentives and culture are aligned for continuous improvement and innovation”
• Open source, open standard, highly flexible, and **free** health and treatment registry and platform for a Learning Health System (http://choir.stanford.edu)

• Point of care decision making
• Software based decision making
• Comparative effectiveness research
• Longitudinal outcomes research
• Pragmatic/real-world clinical trials
• Comprehensive assessment of:
  - Physical, psychological and social functioning and global health
CHOIR: System Features and Status

- Easy to use data entry for patients, staff and clinicians
- Staff and patient engagement
- Clinical workflow support (e.g. notify patient of survey URL prior to clinical appointment)
- Point of care reporting
- Over 20,000 patients and 60,000 longitudinal data assessments
- **Changed the culture of how we care for patients!**
The Power of PROMIS

Computer Adaptive Testing (CAT)
  Reduces time to characterize domain of interest
Normative scores referenced to the US general population
  Mean = 50, SD = 10

https://dhs.stanford.edu/spatial-humanities/comparing-population-density-and-wikipedia-density-on-gis-day/
Stanford Pain Management Center

- Interdisciplinary, coordinated comprehensive approach to pain management
- Use of validated outcomes assuring optimal patient assessment and care
- Over 20,000 patient visits (2016)
- 21 Physician Pain Faculty All Boarded in Pain Medicine
  - Anesthesiology
  - Internal Medicine
  - Physiatry
  - Neurology
  - Addiction Medicine
- 4 Pain Psychologists Faculty
  - Pain Psychology training program
- Physical therapy, Nutrition, Biofeedback, Acupuncture
- Strong connection and translation with pain research group
Stanford Pain Management Center: Integrated Comprehensive Model of Care

- **GI Pain** (Collaboration with GI Medicine)
- **Headache** (Collaboration with Neurology)
- **Pelvic Pain** (Collaboration with Urology)
- **Orofacial Pain** (Collaboration with Dentistry, ENT, Neurology, Neurosurgery)
- **Pain and Addiction** (Collaboration with Psychiatry)
- **Peripheral Nerve Pain** (Collaboration with Radiology, Plastic Surgery)

Stanford Pain Management Center
Pain Medicine Physicians, Pain Psychology, Physical Therapy, Nutrition, Acupuncture, Biofeedback, Nursing, Pain Registry, Research Infrastructure
Initial and Follow-Up Surveys

- **Initial Survey** – 22 min
  - Demographics
  - Prior Treatments, Pain Beliefs
  - Interactive Body Map
  - PROMIS 14 domain measures:
    - Pain Intensity, Pain Behavior, Pain Interference, Fatigue, Physical Function, Depression, Anxiety, Sleep Disturbance, Sleep Related Impairment, Social Functioning
  - Opioid Risk Tool
  - Pain Catastrophizing Questionnaire (PCS)

- **Follow up Survey** – 9 min
  - Interactive Body Map
  - PROMIS 14 domain measures as above
  - PCS
## CHOIR CAT

<table>
<thead>
<tr>
<th>Domain</th>
<th>CHOIR CAT v1</th>
<th>Buss-Perry Aggression Questionnaire (BPAQ)</th>
<th>Generalized Anxiety Disorder 7-item (GAD-7)</th>
<th>Beck Depression Inventory II (BDI-II)</th>
<th>Functional Assessment of Chronic Illness Therapy-Fatigue (FACIT-F)</th>
<th>Health Assessment Questionnaire-Disability Index (HAQ-DI)</th>
<th>Brief Pain Inventory</th>
<th>Sleep Disorders Questionnaire (SDQ)</th>
<th>Epworth Sleepiness Scale (ESS)</th>
<th>Burden Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anger</td>
<td>6.24 ± 1.21</td>
<td>29</td>
<td>7</td>
<td>21</td>
<td>40</td>
<td>20</td>
<td>7</td>
<td>12</td>
<td>8</td>
<td>78%</td>
</tr>
<tr>
<td>Anxiety</td>
<td>4.93 ± 0.97</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30%</td>
</tr>
<tr>
<td>Depression</td>
<td>4.97 ± 1.07</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>76%</td>
</tr>
<tr>
<td>Fatigue</td>
<td>4.78 ± 0.76</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>88%</td>
</tr>
<tr>
<td>Physical Function</td>
<td>4.11 ± 0.48</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>79%</td>
</tr>
<tr>
<td>Pain Interference</td>
<td>4.19 ± 0.71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40%</td>
</tr>
<tr>
<td>Sleep Disturbance</td>
<td>4.95 ± 1.41</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>59%</td>
</tr>
<tr>
<td>Sleep-Related Impairment</td>
<td>4.54 ± 1.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>43%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>38.7 ± 7.9</strong></td>
<td><strong>144</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>73%</strong></td>
</tr>
</tbody>
</table>
Why not use Epic or your favorite electronic medical record (EMR)?

• Short version – you can’t do it.
• Computational complexity of modern patient reported outcomes (PROs) are beyond what can be provided by traditional EMR.
• With modern PROs, software decision support, and development of learning based systems, need rapid algorithm development and frequent code revisions.
• Solution is to off-load modern PRO processing/infrastructure to a separate system
• Also allows rapid development and implementation of features
CHOIR’s ability to rapidly iterate and improve

**EMR code review/release process**
- A necessity given the wide ranging critical roles of EMRs
- **Typically measured in months**

**CHOIR code review/release process**
- IOM released report on April 28, 2015
- Mackey sent to group at 3:14pm
- CHOIR Provider new Core Metrics user interface live on April 30, 2015 at 7:31am
- **CHOIR: from concept to live beta in 40 hours**
Why not use REDCap

- REDCap more project centric; CHOIR is more patient centric
- Patient experience is not performant (network and engine latency for official remote service)
- Significant customization required for automated assessments based on scheduled appointments
- Significant customization required for PDF physician reports
- No streamlined user interfaces and workflows for new patient coordinators and clinic front desk
- Details of how assessments are implemented (security, sessions, restarting where left off) are more carefully thought through than REDCap (biased opinion)
#1 Reason for clinical informatics system failure: Lack of buy in

CHOR is designed to provide value to all stakeholders in the patient’s experience.
CHOIR Provider: Clinically useful reports and tools to aid assessment and decision making

**Stanford Pain Management Center Outcomes**

- **Body Map**
  - Pain Intensity vs. Time
  - Worst vs. Average
  - Date: 1 Oct 13, 1 Jan 14, 1 Apr 14, 1 Jul 14

- **PROMIS Outcomes Measures**
  - Depression, Anxiety, Anger
  - Score % Category

- **Measures**
  - Physical Function, Pain Intensity, Pain Behavior
  - Score % Category

- **Conditions**
  - Pain Experience, Chronic Pain
  - Locations

- **Treatments**
  - Medications, Behavioral, Other treatments

- **Experimental**

**Opioid Risk Mitigation**

- **Opioid Taper Tool**
  - Morphine, Methadone
  - Daily Dose

- **Prescription Frequency**
  - Every 4 weeks

- **Preferred tapering agents**
  - Methadone, Morphine

- **Incomplete Cross-tolerance**
  - 50% reduction
CHOIR as a Platform in Clinical Practice and Research

INTERNAL AND EXTERNAL SCAN
Identify problems and innovative solutions

DESIGN
Design care and evaluation based on evidence generated here and elsewhere

EVALUATE
Collect data, rapidly analyze results to show what works and what doesn’t.

IMPLEMENT
Apply plan in pilot and control settings.

ADJUST
Use evidence to influence for continuous quality improvement

DISSEMINATE
Share results to improve care For everyone

CHOIR
Research influences practice
Practice influences research
CHOIR as a Platform in Pain Research and Clinical Practice

Research

• Generation of preliminary data
• Dynamic studies of pain
• Systems studies of pain
• Comparative effectiveness
• Large simple trials/pragmatic trials

Clinical Practice

• Recording individual patient data
• Dynamic treatment of pain
• Systems treatment of pain
• Learning based systems of pain
CHOIR: Using Dynamic Outcomes to Inform Care for Sandra

Desipramine
Low-dose Naltrexone

No change in Function!
CHOIR: Using Dynamic Outcomes to Inform Care for Sandra

- Desipramine
- Low-dose Naltrexone
- Health Education
Physical Function and Pain Interference Only Weakly Related Over Treatment Course

\[
\begin{align*}
\text{Intercept PI } & \quad \text{Mean} = 66.72 \\
\text{Intercept PF } & \quad \text{Mean} = 38.30 \\
\beta_{\text{PI}} &= 0.16^* \\
\beta_{\text{PF}} &= 0.18^{**} \\
\end{align*}
\]
Using CHOIR to generate “research quality” clinical data

Data with equal quality of a clinical trial

Quality data can be used for:
• Clinical trials
  • Pilot data
  • Large simple trial designs
• Clinical decision making
• Improving quality care and monitoring
• Comparative effectiveness research

Social satisfaction mediates pain-related emotional distress

Fatigue is:

- Common in chronic pain
- Understudied as a target of intervention
- Likely a confluence of physical and psychological factors
- A significant barrier to physical functioning, likely mediating effects of pain on physical dysfunction
Single Session Pain Catastrophizing Class to Reduce Pain

N=57 with chronic pain
Single session class
PCS = Pain Catastrophizing Scale

<table>
<thead>
<tr>
<th>Time Point</th>
<th>PCS Mean (SD)</th>
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</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>26.1 (10.8)</td>
</tr>
<tr>
<td>Post-Treatment Week 2</td>
<td>16.5 (9.9)</td>
</tr>
<tr>
<td>Post-Treatment Week 4</td>
<td>13.8 (9.5)</td>
</tr>
</tbody>
</table>

Characterizing Presurgical Factors that Predict Chronic Pain or Opioid Use
Imagine four patients whose pain or opioid use resolves...

<table>
<thead>
<tr>
<th>Proportion of Patients with Pain or taking Opioids</th>
<th>Time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jim</td>
<td></td>
</tr>
<tr>
<td>Sue</td>
<td></td>
</tr>
<tr>
<td>Jill</td>
<td></td>
</tr>
<tr>
<td>Billy-Bob</td>
<td></td>
</tr>
</tbody>
</table>
Factors Predicting Prolonged Opioid Use After Surgery

Reduction in rate of opioid cessation
Preoperative opioid use: 73% reduction
Self-perceived risk of addiction: 53% reduction
Beck Depression Inventory, each 10-point increase: 42% reduction

Many surgeries associated with increased risk of chronic opioid use in opioid naïve patients

641,941 patients undergoing one of 11 surgeries

Factors Associated with Chronic Opioid Use:
- Male sex
- Age > 50 years
- Preoperative history of drug abuse, alcohol abuse, depression, benzodiazepine use, or antidepressant use

Sun EC, Jena AB, Kao MC, Darnall BD, Baker LC, Mackey SC. Incidence of and Risk Factors for Chronic Opioid Use Among Opioid Naïve Patients in the Perioperative Period. JAMA Internal Medicine 2016
Characterizing Presurgical Factors that Predict Chronic Pain or Opioid Use
Estimating hospital Length of Stay (LOS)

- LOS is the main driver of in-hospital healthcare cost
- Heritage Foundation
  - $3M cash prize
  - *Outcome variable*: total hospital + ED LOS over the next year for individual patients
  - *Predictor variables*: comprehensive administrative dataset
  - Contest ran for 2 years, 2011-13

Results

- While there are clear leaders in the final leaderboard, no single variable proved to be the main driver
- General opinion:
  - Even the best performing model was unsatisfactory
  - No small subset of administrative variables percolated as the main driver
- Our opinion:
  - This data is plagued by high-dimensionality, epidemiologic concerns, and inherent problems with administrative data (3 of the 6 Vs of Big Data)
Peri-Operative CHOIR: Predicting LOS

- Of the 2,073 patients seen at APEC, 991 have LOS at least 1 day
- Incorporated into generalized additive model and quantile regression
  - Race and ethnicity
  - Pre-op PROMIS measurements

**Result**
- Age, Gender, & Physical Function together significant
- LOS linearly increases as a function of worsening Physical Function effect despite adjusting for Age
- LOS significantly increases when Age is above 60
**SHC Pre-Anesthetic Questionnaire**

**Test Patient13**

- **MRN:** 10013-1
- **DOB:** 05/05/1975
- **Age:** 40
- **Height:** 5’6”
- **Weight:** 175 lbs
- **Gender:** M

**Contact Information**
- Best contact phone number to reach you before surgery?: 555-1234
- If this is not your phone, please indicate whose phone number it is: My brothers

**Pre-Anesthesia Questionnaire**
- Anesthesia Pre-op Clinic visit in the last 12 months: No
- Have had surgery at Stanford: Yes

**Past Surgeries**
- Type of operation: Appendix removed
- Year of surgery: 1992
- Anesthetic given: General anesthesia
- Problems or side effects?: Yes
- Explain: Nausea and dizziness when I woke up
- Type of operation: Broken ankle
- Year of surgery: 2001
- Anesthetic given: General anesthesia
- Problems or side effects?: Yes
- Explain: Same as before

**Health Conditions**
- Allergic to: foods, I get hives if I eat strawberries
- Type of reaction: Hives
- Corticosteroid use in last 6 months: No
- Personal or family history of anesthesia complications: No
- Past medical history / Problems not already documented in EMR: High blood pressure, palpitations, irregular heart beats, anide swelling, difficulty walking, acid reflex symptoms
- Acute illness in last 2 weeks: Yes
- No hospitalization in the past 6 months: Yes

**Smoking, Alcohol and Drugs**
- Smoked 1 pack(s) per day 12 years: Quit 2006
- Do drink alcohol: More than 10 drinks per week. Every day.
- Have not used recreational drugs in the last 5 years: 3 drinks per day

**Questions**
- Questions for the anesthesiologist: No

**Pain Intensity:** 0=No Pain, 10=Worst Pain Imaginable

<table>
<thead>
<tr>
<th>Worst</th>
<th>Average</th>
<th>Now</th>
<th>Least</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

**PROMIS Physical Function**

<table>
<thead>
<tr>
<th>PROMIS Outcomes Measures</th>
<th>Score</th>
<th>%ile</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Function *</td>
<td>62</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Pain Interference</td>
<td>61</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td>46</td>
<td>34</td>
<td>None/Minimal</td>
</tr>
<tr>
<td>Anxiety</td>
<td>53</td>
<td>62</td>
<td>Mild</td>
</tr>
<tr>
<td>Anger</td>
<td>48</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Fatigue</td>
<td>42</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Sleep Disturbance</td>
<td>31</td>
<td>3</td>
<td>None to Slight</td>
</tr>
</tbody>
</table>

9 areas selected on the most recent body map.
Pediatric-Collaborative Health Outcomes Information Registry (Peds-CHOIR): a learning health system to guide pediatric pain research and treatment

Rashmi P. Bhandari, Amanda B. Feinstein, Samantha E. Huestis, Elliot J. Krane, Ashley L. Dunn, Lindsey L. Cohen, Ming C. Kao, Beth D. Darnall, Sean C. Mackey
Press-Ganey Patient Satisfaction and the Challenges of Chronic Pain
An unmet need

- Comprehensive capture of patient experience touchpoints
- Concise item stems
- Actionable results
- Integrated into CHOIR
- Open source and free

Covers, and extends, all the domains of existing patient satisfaction surveys, including:

- Press Ganey
- Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS)
- TOPS
Pain Clinic orientation video improves patient satisfaction

Impact of Orientation Video on Likelihood

- Seen video (n=313)
- Completed video (n=...
The Present and Future

- Implemented in multiple clinics and academic sites nationally and internationally
- Genetics: Stanford GenePool
- National pain data repository across sites with governance
- Software based decision support
- Mobile device integration for daily experiential sampling
- Quantitative sensory testing
- Adaptive randomization for pragmatic trials
- Open source (free) licensing with minimal restrictions
• NIH Pain Consortium
• Redlich Pain Research Endowment
• Stanford Center for Clinical Informatics
  • Michael Halaas
  • Susan Weber
  • Garrick Olson
  • Teresa Pacht
• Northwestern/PROMIS
  • Karon Cook, PhD
• Stanford Systems Neuroscience and Pain Lab (SNAPL)
• All our collaborators!!!!!!