Embedded Research in an Integrated Health Care Delivery System

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Department of Research and Evaluation
Kaiser Permanente Southern California
Preview

- Describe the KPSC Care Improvement Research Team
- Provide overview of portfolio of internally focused and externally funded research projects
- Share results of ongoing projects
  - Hospital-associated venous thromboembolism
  - Surveillance of small pulmonary nodules
- Discuss opportunities and challenges for research embedded in health systems
KPSC

- Pre-paid, capitated health plan (KFH/HP)
- Independent medical group (SCPMG)
- Integrated delivery system
- Comprehensive electronic health records

Values:
- Quality
- Affordability
- Physician autonomy
- Small “m” managed care
KP Southern California

>4.2 Million Members

209 Medical Offices

14 Hospitals

6,035 Physicians

20,393 Nurses

61,897 Employees
Department of Research and Evaluation

- >30 full-time research scientists
- About 300 support staff
- Located in Pasadena, CA
- Employed by SCPMG
  - Report to Medical Director for Quality and Clinical Analysis
- Data resources: RDW, VDW, PCORnet CDM
- Researchers embedded in health system
Care Improvement Research Team

- Created by KPSC leadership in 2013
- Help improve care and increase affordability for members
- Weave research into existing fabric of clinical care and quality improvement
- Create and share generalizable knowledge about improvement
- Foster a culture of inquiry and evaluation
- Help to realize the potential of the learning health care system
CIRT Vision and Mission

Vision
• To be the model for embedded research within a learning health care system.

Mission
• To enhance the health of individuals and populations through systematic study of ways to improve health care delivery.

We collaborate with clinicians, patients, operational leaders, and other stakeholders to identify gaps in care delivery and apply rigorous research methods to understand and close these gaps within the KPSC system.
The Learning Health Care System

Clinical trials, comparative effectiveness research, molecular and biologic data

Information-rich, patient-focused data

Evaluation of outcomes

Patient

Transformation of subsequent care delivery

Data aggregation, evidence generation

CIRT Sponsors

Kaiser Foundation Hospitals & Health Plan
- Benjamin K. Chu, MD, MPH, MACP
- Nirav R. Shah, MD, MPH
- Angela Coron, MPH

Southern California Permanente Medical Group
- Michael H. Kanter, MD
- Steven J. Jacobsen, MD, PhD
Key Contributions of Leadership

- Made hard-money investment in program development
- Provide researchers with unprecedented access to operational decision-makers
- Facilitate relationships with operational work groups
  - VTE Regional Steering Committee
  - Regional Readmissions Group
  - LAMC Cancer Care Redesign
- Help to translate findings back into practice
CIRT Members

**Scientists**
- Michael Gould, MD, MS
- Erin Hahn, PhD, MPH
- Brian Mittman, PhD
- Huong Nguyen, PhD, RN
- Adam Sharp, MD, MS
- Shayna Henry, PhD (post-doc)
- Anna Davis (UCLA doctoral student)

**Project Managers**
- Danielle Altman, MA
- Angel Alem, MS, MPH
- Tania Tang, PhD, MPH

**Research Support**
- Fernando Barreda
- Erika Estrada, MS
- Mayra Macias, MS
- Leah Maddock, MPH
- Corrine Munoz-Plaza, MPH
- Ellen Rippberger, MPH
- Su Wu, MS

**Biostatistics**
- Brian Huang, MPH (UCLA doctoral student)
- Alice Kwan, MPH
- Janet Lee, MS
- Amy Liu, MS
- Ernest Shen, PhD
- David Yi, MPH
- Jianjin Wang, MS
- Yi-Lin Wu, MS
CIRT Research Themes: The Health System as a Laboratory for Improvement

- Facilitating chronic disease management and self-care
- Reducing use of unnecessary, low-value care
- Using decision support to improve emergency and acute care
- Exploring social determinants of health and health disparities
- Improving cancer care and survivorship
CIRT Strategy and Tactics

- Develop sustainable partnerships between researchers, clinicians and operational leaders
  - Embed researchers within existing work groups

- Create virtuous cycle of internally focused and externally funded research
  - Goal: ~50-50 distribution

- Use variety of research methods and select efficient designs to improve feasibility of practice-based research
  - Observational studies to identify gaps in care
  - Qualitative approaches to understand barriers and facilitators to change
  - Quasi-experimental studies to evaluate new interventions
  - Pragmatic trials to use health system as laboratory
Internally-Focused Projects

- Understanding high-need, high-cost patients
- Addressing members’ unmet social needs
- Evaluation of the online personal action plan
- Evaluation of Open Notes
- Reducing readmissions for COPD
- Improving prophylaxis for VTE
- Reducing use of biomarker testing in breast cancer survivors
- Implementation of lung cancer screening
  - Evaluation of pulmonary nodules
- Decision support for triage of pneumonia and use of head CT in ED
- Reducing antibiotic prescribing for acute sinusitis
- Embedded PCP to improve care for cancer survivors
- Improving adherence with CPAP in sleep apnea
- Improving outcomes for patients with CKD and ESRD
Externally Funded Projects

- Home-based physical activity coaching for COPD (PCORI)
- Care transitions for chronic disease (PCORI)
- Early palliative care for lung cancer (NINR)
- Distress screening for breast cancer (CBCF)
- Sleep apnea, PAP and kidney disease (NIDDK)
- Improving palliative care for chronic disease (PORTAL)
- Kidney transplant education and living donation (HRSA)
- Watch the Spot Trial (PCORI)
- Lung cancer comorbidities, treatments and outcomes (NCI)
- Research Networks: PCORnet (PORTAL), NCOPR CCDR, HCSRN/CRN
The Learning Health Care System

Improving VTE Prophylaxis: Methods

- Retrospective, observational study of VTE prophylaxis and outcomes
- Assembled cohort of ~250,000 adult members of KPSC with hospital admission for medical illness
  - July 2010 through June 2014
- Collected data from electronic health records
  - VTE risk factors, e.g. age, cancer, prior VTE
  - VTE prophylaxis, including chemical and mechanical methods
  - VTE events (in hospital or within 90 days of discharge)
  - Validated VTE outcome definitions
- Compared accuracy of 4 VTE risk prediction models
### Validation of VTE Outcomes

<table>
<thead>
<tr>
<th>Validation of VTE Outcome Definitions</th>
<th>Sens</th>
<th>Spec</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 1 VTE diagnosis code</td>
<td>100</td>
<td>47</td>
<td>68</td>
<td>100</td>
</tr>
<tr>
<td>≥ 1 diagnosis code AND (≥1 procedure code OR ≥1 pharmacy code)*</td>
<td>94</td>
<td>72</td>
<td>79</td>
<td>92</td>
</tr>
<tr>
<td>≥ 1 diagnosis code AND ≥1 pharmacy code</td>
<td>82</td>
<td>81</td>
<td>83</td>
<td>80</td>
</tr>
<tr>
<td>≥ 1 diagnosis code AND ≥1 procedure code</td>
<td>76</td>
<td>84</td>
<td>84</td>
<td>76</td>
</tr>
<tr>
<td>≥ 1 diagnosis code AND (≥1 procedure code AND ≥1 pharmacy code)</td>
<td>64</td>
<td>93</td>
<td>92</td>
<td>70</td>
</tr>
</tbody>
</table>
Accuracy of Existing Risk Models

- Existing risk assessment models perform similarly in our patient population at KPSC, but have only fair accuracy for predicting VTE.
- 7-variable IMPROVE-2 model may represent best tradeoff between accuracy and simplicity.
All Risk Models Well-Calibrated

Expected and Observed VTE Events (Improve Model)

Expected and Observed VTE Events (Improve Associated Model)

Expected and Observed VTE Events (Padua Model)

Expected and Observed VTE Events (Premier Model)
### VTE Incidence by IMPROVE Risk Score

<table>
<thead>
<tr>
<th>VTE Risk Score</th>
<th>% of Sample (n=246,822)</th>
<th>VTE Risk (%)</th>
<th>% of All VTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (0-1)</td>
<td>73</td>
<td>0.3</td>
<td>40</td>
</tr>
<tr>
<td>Moderate (2-3)</td>
<td>21</td>
<td>1.0</td>
<td>37</td>
</tr>
<tr>
<td>High (4-5)</td>
<td>5</td>
<td>1.9</td>
<td>16</td>
</tr>
<tr>
<td>Very High (6+)</td>
<td>1</td>
<td>3.5</td>
<td>6</td>
</tr>
</tbody>
</table>
## Timing of VTE Outcomes

<table>
<thead>
<tr>
<th>Time Period</th>
<th>LOS ≤48h Absolute risk per 1,000</th>
<th>LOS ≤48h % of total</th>
<th>LOS &gt;48h Absolute risk per 1,000</th>
<th>LOS &gt;48h % of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-hospital</td>
<td>0.1</td>
<td>2</td>
<td>2.3</td>
<td>27</td>
</tr>
<tr>
<td>≤30 days</td>
<td>1.9</td>
<td>59</td>
<td>4.2</td>
<td>50</td>
</tr>
<tr>
<td>31 to 90 days</td>
<td>1.2</td>
<td>39</td>
<td>2.0</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>3.2</td>
<td>100</td>
<td>8.4</td>
<td>100</td>
</tr>
<tr>
<td>33% of all VTE</td>
<td></td>
<td></td>
<td>67% of all VTE</td>
<td></td>
</tr>
</tbody>
</table>
Trends in VTE

VTE Outcome by Quarter

\[ y = 0.0384x + 5.1508 \]
\[ R^2 = 0.1237 \]
VTE: Ongoing Activities and Next Steps

- Presented results to health system leaders at Regional VTE Summit
- Working with local and national leaders (CDC) to implement computerized decision support
- Encourage adherence with mechanical prophylaxis
- Act on modifiable risk factors
  - Early ambulation, in-hospital and at home
  - Remove (or do not place) central lines and urinary catheters
  - Consider extended duration prophylaxis in high-risk patients
The Learning Health Care System

How Common are Pulmonary Nodules?

- Pulmonary nodules are commonly seen in primary care and specialty practice
  - 150,000 cases per year in the 1980s, but recent estimates of incidence not available

- Slow uptake of lung cancer screening with LDCT will further exacerbate the problem

- Most small nodules are benign and harmless, but ~3% represent a potentially curable form of lung cancer
# Rate of Chest CT Scanning

<table>
<thead>
<tr>
<th>Year</th>
<th>Members (millions)</th>
<th>Unique Members with ≥1 CT scan (thousands)</th>
<th>Rate per 1,000 Person-Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>2.62</td>
<td>34.9</td>
<td>15.4</td>
</tr>
<tr>
<td>2007</td>
<td>2.67</td>
<td>37.3</td>
<td>16.1</td>
</tr>
<tr>
<td>2008</td>
<td>2.67</td>
<td>41.1</td>
<td>17.5</td>
</tr>
<tr>
<td>2009</td>
<td>2.66</td>
<td>45.4</td>
<td>19.3</td>
</tr>
<tr>
<td>2010</td>
<td>2.70</td>
<td>47.8</td>
<td>20.0</td>
</tr>
<tr>
<td>2011</td>
<td>2.82</td>
<td>51.5</td>
<td>20.5</td>
</tr>
<tr>
<td>2012</td>
<td>2.92</td>
<td>53.9</td>
<td>20.7</td>
</tr>
<tr>
<td>All years</td>
<td>4.61</td>
<td>218.1 (4.7%)</td>
<td>18.6</td>
</tr>
<tr>
<td>Increase</td>
<td>11%</td>
<td>55%</td>
<td>(18.5 to 18.6)</td>
</tr>
</tbody>
</table>
## Rate of Positive Chest CT Scans

<table>
<thead>
<tr>
<th>Year</th>
<th>Members (millions)</th>
<th>Unique Members with ≥1 Positive CT Scan (thousands)</th>
<th>Rate per 1,000 Person-Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>2.62</td>
<td>9.0</td>
<td>3.9</td>
</tr>
<tr>
<td>2007</td>
<td>2.67</td>
<td>10.9</td>
<td>4.6</td>
</tr>
<tr>
<td>2008</td>
<td>2.67</td>
<td>12.1</td>
<td>5.1</td>
</tr>
<tr>
<td>2009</td>
<td>2.66</td>
<td>13.8</td>
<td>5.8</td>
</tr>
<tr>
<td>2010</td>
<td>2.70</td>
<td>15.6</td>
<td>6.5</td>
</tr>
<tr>
<td>2011</td>
<td>2.82</td>
<td>16.3</td>
<td>6.4</td>
</tr>
<tr>
<td>2012</td>
<td>2.92</td>
<td>17.4</td>
<td>6.6</td>
</tr>
<tr>
<td>All years</td>
<td>4.61</td>
<td>69.0 (1.5%)</td>
<td>5.6</td>
</tr>
<tr>
<td>Increase</td>
<td>11%</td>
<td>94%</td>
<td>(5.6 to 5.7)</td>
</tr>
</tbody>
</table>

# Standardized Rates and Estimates, 2010

<table>
<thead>
<tr>
<th></th>
<th>Rate (per 1,000)</th>
<th>Standardized Rate (per 1,000)</th>
<th>Extrapolated Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest CT scans</td>
<td>20.0</td>
<td>20.7</td>
<td>4.8 M</td>
</tr>
<tr>
<td>Positive scans</td>
<td>6.5</td>
<td>6.7</td>
<td>1.6 M</td>
</tr>
<tr>
<td>New positive scans</td>
<td>5.7</td>
<td>4.7</td>
<td>1.1 M</td>
</tr>
<tr>
<td>Lung cancer cases</td>
<td>0.34</td>
<td>0.26</td>
<td>62,000</td>
</tr>
</tbody>
</table>

*Adult population of U.S. in 2010: ~234 million*
Guidelines for Evaluation of Small Pulmonary Nodules

- For incidental nodules, frequency and duration guided by recommendations from the Fleischner Society (2005, 2013) and ACCP (2007, 2013)
- For nodules detected by screening, recommendations have been developed by ACR (Lung-RADS) and NCCN
- New guidelines recently published by BTS
- Optimal frequency and duration have not been determined
- Revised Fleischner guidelines expected in next few months

Gould et al. Chest 2013;143(suppl):e93S-e120S.
http://www.acr.org/Quality-Safety/Resources/LungRADS
Does This Nodule Require Follow-Up?
- Design: Large, simple, pragmatic trial with cluster randomization by hospital or health system
- Funding: Patient-Centered Outcomes Research Institute
- Patients: ~40,000 individuals with small (≤15 mm) lung nodules on chest CT, detected incidentally or by screening
- Intervention/comparator: recommendations for more versus less frequent CT surveillance embedded in radiology report
- Outcomes
  - Primary: Percent of cancer patients with stage >T1a N0 M0
  - Survival, time to diagnosis/treatment
  - Impact of Event scale, State Anxiety Scale, Short Form Health Survey (SF-36)
  - Resource use, procedure-related complications, radiation exposure
  - Adherence with recommended surveillance
<table>
<thead>
<tr>
<th>Health Care Organization</th>
<th>Type of Setting</th>
<th>Unique patients with chest CT during 20 months of enrollment</th>
<th>Estimated patients with nodules ≤15 mm</th>
<th>Estimated patients with lung cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boston Medical Center</td>
<td>Safety Net</td>
<td>7,840</td>
<td>1,250</td>
<td>37</td>
</tr>
<tr>
<td>Cleveland Clinic</td>
<td>Referral</td>
<td>26,670</td>
<td>5,330</td>
<td>160</td>
</tr>
<tr>
<td>Health Partners, MN</td>
<td>Integrated</td>
<td>4,920</td>
<td>780</td>
<td>23</td>
</tr>
<tr>
<td>Kaiser Colorado</td>
<td>Integrated</td>
<td>23,320</td>
<td>3,720</td>
<td>111</td>
</tr>
<tr>
<td>Kaiser Northwest</td>
<td>Integrated</td>
<td>12,680</td>
<td>2,020</td>
<td>61</td>
</tr>
<tr>
<td>Kaiser Southern California</td>
<td>Integrated</td>
<td>90,000</td>
<td>14,330</td>
<td>430</td>
</tr>
<tr>
<td>Marshfield Clinic</td>
<td>Integrated</td>
<td>6,160</td>
<td>980</td>
<td>29</td>
</tr>
<tr>
<td>Med. Univ. South Carolina</td>
<td>University</td>
<td>12,500</td>
<td>1,460</td>
<td>29</td>
</tr>
<tr>
<td>National Jewish Health</td>
<td>Referral</td>
<td>10,540</td>
<td>1,680</td>
<td>50</td>
</tr>
<tr>
<td>Portland VAMC</td>
<td>Veterans</td>
<td>8,790</td>
<td>1,120</td>
<td>34</td>
</tr>
<tr>
<td>UC Davis</td>
<td>University</td>
<td>11,640</td>
<td>780</td>
<td>16</td>
</tr>
<tr>
<td>UCLA</td>
<td>University</td>
<td>20,000</td>
<td>2,100</td>
<td>63</td>
</tr>
<tr>
<td>UC San Francisco</td>
<td>University</td>
<td>13,990</td>
<td>960</td>
<td>29</td>
</tr>
<tr>
<td>University of Pennsylvania</td>
<td>University</td>
<td>30,520</td>
<td>3,470</td>
<td>104</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>279,550</strong></td>
<td><strong>39,980</strong></td>
<td><strong>1,177</strong></td>
</tr>
</tbody>
</table>
Study Procedures: Pragmatic Design

- Goals of pragmatic design:
  - Integrate study procedures into existing clinical workflow
  - Few special assessments or visits outside of routine clinical care
  - Study data collected from readily available information in electronic health records

- Intervention targeted at the level of the radiology department

- Assigned protocol for CT surveillance applies to ALL patients with newly identified nodules at each site
  - Exclusions age <35, patients with known cancer, pregnant women
  - Radiologist’s discretion: multiple nodules; nodules with benign calcification or other reliable features of a benign etiology; accompanying findings that raise concern for cancer
Study Procedures: Human Subjects

- **Waiver of individual consent**
  - Risk of participating in study no greater (and no different) than risks commonly encountered in usual clinical care
  - Intervention delivered at the system level
  - Patients and providers permitted to deviate from recommended follow-up when indicated
  - Study not feasible or logistically possible without waiver

- **Respect for persons: all enrolled patients to be notified of study**
  - Patients permitted to opt out for data collection purposes
  - Consent to be obtained for participation in patient surveys
Novel Aspects of Methodology

- Pragmatic design
  - Integration into routine clinical practice
- Automated enrollment and data collection
- Cluster randomization
- Comparison of competing guidelines
- Waiver of consent
- Ambitious target for enrollment
The Learning Health Care System

Clinical trials, comparative effectiveness research, molecular and biologic data

Evaluation of outcomes

Information-rich, patient-focused data

Transformation of subsequent care delivery

Data aggregation, evidence generation

Implementation Science

- **Conceptual models**
  - Over 100 models from which to choose!
  - Extensions of simple Diffusion of Innovations Theory

- **Implementation strategies**
  - Systematic intervention process to adopt and integrate innovations into routine care
  - At least 68 different approaches in 6 categories
  - Often take the form of complex, multi-component, multi-level social interventions
Implementation Strategies

- Planning: understanding needs, resources, local context
- Educational: lectures, conferences, KP Clinical Library
- Quality management: reminders, audit & feedback, PDSA cycles, improvement advisors, Collaboratives
- Restructuring: create teams, revise roles
- Financial: incentives (P4P) and penalties (readmissions)
- Policy: accreditation, credentialing, liability, public reporting

Embedded Research: Lessons Learned

- Health care is increasingly complex
  - Likely to become more so with move to precision medicine
  - Need for data-driven explanations and solutions

- Limited tolerance for disruption
  - “Don’t mess with my workflow”

- Operational imperative is to do something/anything and do it quickly
  - “Paralysis by Analysis” versus “Extinction by Instinct”
Embedded Research: Lessons Learned

- Stakeholder engagement is crucial
  - Never underestimate the value of a motivated clinical champion

- Hard money investment is helpful
  - Embedded research should be the R&D of health care systems

- Squeaky wheel gets the grease
  - Do we have the right measures?
  - What do we learn from measurement?
  - What are we not measuring?

- Physician behavior profoundly shaped by training and professional norms
Conclusions

- CIRT is a model for embedded research within a learning health care system
- Embedded research is the R&D of the health care industry
- Health systems must find ways to serve as laboratories for improvement without compromising work-flow or patient care
- “If we want more evidence-based practice, we need to create more practice-based evidence!”
# Relational Database for Mobile Devices

## Hopkins Procedures

<table>
<thead>
<tr>
<th>Name:</th>
<th>Date:</th>
<th>Procedure:</th>
<th>MR #:</th>
<th>Indication</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10/7/16</td>
<td>Bronchoscopy (flex),...</td>
<td></td>
<td>Infiltrate</td>
<td>Airway nodules,</td>
</tr>
<tr>
<td></td>
<td>10/6/16</td>
<td>Bronchoscopy (flex),...</td>
<td></td>
<td>Infiltrate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10/4/16</td>
<td>Bronchoscopy with...</td>
<td></td>
<td>Adenopathy 4R</td>
<td>Lymphs, Non diagnostic</td>
</tr>
<tr>
<td></td>
<td>9/30/16</td>
<td>Bronchoscopy (flex),...</td>
<td></td>
<td>Airway obstruction</td>
<td>Partial obstruction of s...</td>
</tr>
</tbody>
</table>

David Feller-Kopman, MD, personal communication
Thank You!

michael.k.gould@kp.org
In a learning health care system, research influences practice and practice influences research.

- **Evaluate**: Collect data and analyze results to show what does and does not work.
- **Implement**: Apply the plan in pilot and control settings.
- **Adjust**: Use evidence to influence continual improvement.
- **Design**: Design care and evaluation based on evidence generated here and elsewhere.
- **Disseminate**: Share results to improve care for everyone.

- **Internal and External Scan**: Identify problems and potentially innovative solutions.

CIRT has really advanced the way KP approaches learning and innovation in an evidence based fashion. This team has become mainstream operations in many areas of Kaiser Permanente.

CIRT represents the very best of the next generation of research. Fully integrated into operations, CIRT is helping create the "learning healthcare system" so many have spoken about for years, but no-one has seen until now.

With our new KP medical school, CIRT will play an important role in helping train the next generation of physicians -- exposing students from their first day in what is the "new normal" in practice-research partnership.
CIRT Partners: The Implementation Ecosystem

- CIRT
  - KFH/HP
    - Clinical Analysis
    - Complete Care
    - Readmission Reduction Team
    - EBM Services
    - Regional Chiefs (Emergency, Pulmonary, and Oncology Departments)
    - Systems Solutions & Deployment
    - VTE Improvement Collaborative
    - Health Education
    - LAMC Residents
    - Renal Business Group
  - Research Networks
    - Unmet Social Needs Initiative
    - Home Health Care
    - Vital Few: High Needs, High Utilizers
  - SCPMG
    - HCSRN, CRN
    - PORTAL, PCORnet
    - NCORP Cancer Care Delivery
    - KP CESR
KPSC Implementation Ecosystem: How to Weave Research into the Fabric?
“Even the smallest person can change the course of the future.”

J.R.R. Tolkien
Consolidated Framework for Implementation Research (CFIR)

Technical vs. Adaptive Challenges

**Technical**
- Easy to identify
- Quick and easy solutions
- Often solved by an authority or expert
- Require change in a few (contained) places
- People generally receptive
- Solutions can be implemented quickly

**Adaptive**
- Easy to deny
- Require changes in values, beliefs, roles, approaches to work
- Require change in numerous places that cross boundaries
- People often resist
- Solutions require experiments and new discoveries

Heifetz RA and Laurie DL. Harvard Business Rev 1997
Segmenting High-Needs High-Cost Patients

**Class 1: "End-Stage Renal Disease"**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialysis Status</td>
<td>100%</td>
</tr>
<tr>
<td>Other Significant Endocrine and Metabolic Disease</td>
<td>74%</td>
</tr>
<tr>
<td>Diabetes with Complications</td>
<td>57%</td>
</tr>
<tr>
<td>Vascular Disease &amp; Atherosclerosis</td>
<td>37%</td>
</tr>
<tr>
<td>Congestive Heart Failure</td>
<td>31%</td>
</tr>
<tr>
<td>Diabetic/Other Retinopathy</td>
<td>21%</td>
</tr>
<tr>
<td>Complications of Specified Heart Arrhythmias</td>
<td>16%</td>
</tr>
<tr>
<td>Specified Heart Arrhythmias</td>
<td>14%</td>
</tr>
<tr>
<td>Major Depressive, Bipolar, and Other Depressive</td>
<td>11%</td>
</tr>
<tr>
<td>Coronary Artery Disease</td>
<td>10%</td>
</tr>
<tr>
<td>Protein-Calorie Malnutrition</td>
<td>9%</td>
</tr>
<tr>
<td>Coagulation Defects &amp; Other Defects</td>
<td>8%</td>
</tr>
<tr>
<td>Chronic Obstructive Pulmonary Disease</td>
<td>7%</td>
</tr>
<tr>
<td>Solid Tumor</td>
<td>6%</td>
</tr>
<tr>
<td>Rheumatoid Arthritis &amp; Connective Tissue Injury</td>
<td>6%</td>
</tr>
</tbody>
</table>

**Class 2: "Neurologic and Catastrophic"**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>84%</td>
</tr>
<tr>
<td>Post-Stroke Paralysis</td>
<td>58%</td>
</tr>
<tr>
<td>Vascular Disease and Atherosclerosis</td>
<td>38%</td>
</tr>
<tr>
<td>Seizure Disorders and Convulsions</td>
<td>31%</td>
</tr>
<tr>
<td>Severe Head Injury or Burn</td>
<td>29%</td>
</tr>
<tr>
<td>Protein-Calorie Malnutrition</td>
<td>27%</td>
</tr>
<tr>
<td>Major Depressive, Bipolar, and Other Depressive</td>
<td>25%</td>
</tr>
<tr>
<td>Specified Heart Arrhythmias</td>
<td>22%</td>
</tr>
<tr>
<td>Diabetes with Complications</td>
<td>21%</td>
</tr>
<tr>
<td>Paralysis and Coma</td>
<td>18%</td>
</tr>
<tr>
<td>Artificial Openings for Feeding or Wasting</td>
<td>16%</td>
</tr>
<tr>
<td>Lung Infection</td>
<td>15%</td>
</tr>
<tr>
<td>Substance Use</td>
<td>13%</td>
</tr>
<tr>
<td>Cardio-Respiratory Failure or Arrest</td>
<td>13%</td>
</tr>
<tr>
<td>Congestive Heart Failure</td>
<td>12%</td>
</tr>
</tbody>
</table>

**Class 3: "Cardio-Vascular and Pulmonary"**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congestive Heart Failure</td>
<td>76%</td>
</tr>
<tr>
<td>Vascular Disease and Atherosclerosis</td>
<td>59%</td>
</tr>
<tr>
<td>Specified Heart Arrhythmias</td>
<td>59%</td>
</tr>
<tr>
<td>Coronary Artery Disease</td>
<td>53%</td>
</tr>
<tr>
<td>Diabetes with Complications</td>
<td>43%</td>
</tr>
<tr>
<td>Chronic Obstructive Pulmonary Disease</td>
<td>33%</td>
</tr>
<tr>
<td>Acute Renal Failure</td>
<td>27%</td>
</tr>
<tr>
<td>Cardio-Respiratory Failure or Arrest</td>
<td>26%</td>
</tr>
<tr>
<td>Protein-Calorie Malnutrition</td>
<td>19%</td>
</tr>
<tr>
<td>Major Depressive, Bipolar, and Other Depressive</td>
<td>18%</td>
</tr>
<tr>
<td>Morbid Obesity</td>
<td>12%</td>
</tr>
<tr>
<td>Coagulation Defects and Other Defects</td>
<td>12%</td>
</tr>
<tr>
<td>Solid Tumor</td>
<td>11%</td>
</tr>
<tr>
<td>Other Significant Endocrine and Metabolic Disease</td>
<td>8%</td>
</tr>
<tr>
<td>Substance Use</td>
<td>8%</td>
</tr>
</tbody>
</table>

**Class 4: "Diabetes with Multiple Comorbid Conditions"**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes with Complications</td>
<td>99%</td>
</tr>
<tr>
<td>Vascular Disease and Atherosclerosis</td>
<td>89%</td>
</tr>
<tr>
<td>Dialysis Status</td>
<td>71%</td>
</tr>
<tr>
<td>Congestive Heart Failure</td>
<td>65%</td>
</tr>
<tr>
<td>Other Significant Endocrine and Metabolic Disease</td>
<td>55%</td>
</tr>
<tr>
<td>Diabetic/Other Retinopathy</td>
<td>44%</td>
</tr>
<tr>
<td>Protein-Calorie Malnutrition</td>
<td>34%</td>
</tr>
<tr>
<td>Coronary Artery Disease</td>
<td>32%</td>
</tr>
<tr>
<td>Chronic Ulcer of Skin, Except Conjunctive Tissue</td>
<td>31%</td>
</tr>
<tr>
<td>Amputation Status and Related Conditions</td>
<td>31%</td>
</tr>
<tr>
<td>Specified Heart Arrhythmias</td>
<td>30%</td>
</tr>
<tr>
<td>Major Depressive, Bipolar, and Other Depressive</td>
<td>26%</td>
</tr>
<tr>
<td>Septicemia, Sepsis, Shock</td>
<td>24%</td>
</tr>
<tr>
<td>Complications of Specified Heart Arrhythmias</td>
<td>22%</td>
</tr>
<tr>
<td>Bone/Joint/Muscle Injury</td>
<td>20%</td>
</tr>
</tbody>
</table>
Spending Patterns by Class

Total Aggregate Spending

Millions

Class 1  Class 2  Class 3  Class 4  Class 5  Class 6  Class 7

Average Per Patient Spending

Thousands

Class 1  Class 2  Class 3  Class 4  Class 5  Class 6  Class 7  All Other Adults
Within-KPSC Variation in Serum Biomarker Testing in Breast Cancer
Qualitative interviews with high and low using oncologists

- Factors associated with high use:
  - Perceived patient anxiety
  - Oncologist anxiety
  - Concern about patient satisfaction
  - Peer use

- Factors associated with low use:
  - Beliefs about consequences (e.g., causes harms)
  - Medical center culture (e.g., collective decision to follow guidelines).