Analyzing Clusters of Disease and Populations to Simplify and Improve Care Delivery

July 28, 2016
2 Part Presentation

1. What is Clustering?

2. Using Clusters to Improve Care Delivery
What is a Cluster?

1. a number of things of the same kind, growing or held together; a bunch.
2. a group of persons or things close together.
3. a small metal embellishment affixed to a military decoration to indicate its having been awarded again.
4. a succession of two or more contiguous consonant sounds within a syllable, as str- in strap.
5. a group of stars, similar in age and composition, held together by gravitation.
6. a group of classes or subjects administered or taught together.
Cluster analysis is the grouping of a set of objects in such a way that objects in the same group (called a cluster) are more similar to each other than those in other groups (clusters).

Pattern recognition when there is no dependent variable.
The Process

1. Select Sample
2. Characterize
3. Association Measures
4. Clustering Algorithm
5. Groups
Define Attributions for Clustering

Chronic Conditions
- Elixhauser (31)
- Charlson (3)
- CCS (4)
27 Chronic Conditions

- Congestive Heart Failure
- Cardiac Arrhythmia
- Valvular Disease
- Pulmonary Circulation Disorders
- Vascular Complications (PVD, CAD, MI, CVD)
- Hypertension (with or without complications)
- Diabetes (with or without complications)
- Paralysis
- Other Neurological Disorders
- Chronic Pulmonary Disease (including asthma)
- Hypothyroidism
- Renal Failure
- Liver Disease
- Peptic Ulcer
- AIDS/HIV
- Cancer (Lymphoma, Metastatic, Solid Tumor)
- Coagulopathy
- Obesity
- Weight Loss
- Fluid & Electrolyte Disorders
- Blood Loss Anemia
- Deficiency Anemia
- Mental Health (Depression, Psychoses, Drug or Alcohol Abuse)
- Dementia
- Lipid Metabolism Disorders
- Osteoarthritis
- Rheumatoid Arthritis/collagen vascular diseases
Association Measures

When data are not coordinates in an Euclidean space, we use an association measure to describe the similarity between observations (patients)

Clusters are formed based on similarity measures
Hierarchical Method

- Agglomerative Approach (bottom-up)
- Start with each patient in a separate group
- Merges patients that are ‘close’
- Keeps merging groups that are ‘close’
- Continues until all groups are merged into one
- Creates a tree or dendogram
Clustering in Medicare Patients

> 50,000 patients

11 Most frequent conditions

- 72% Hypertension
- 69% Lipid Metabolism Disorders
- 39% Vascular Complications
- 38% Obesity
- 35% Osteoarthritis
- 29% Mental Health (Depression, Abuse)
- 28% COPD
- 28% Diabetes
- 15% Cancer
- 14% Renal Failure
- 12% Congestive Heart Failure
Example: Cont’d

Randomly divided group into 3 sets

First data set used to develop clusters
  – Computed Jaccard’s coefficient
  – Used Ward’s linkage method
  – Resulted in 12 clusters

Confirmed clustering solution in the remaining 2 datasets
# Clustering Results

<table>
<thead>
<tr>
<th>Cluster</th>
<th>N</th>
<th>Predominant Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1170 (2.3%)</td>
<td>Hyperlipidemia</td>
</tr>
<tr>
<td>2</td>
<td>2706 (5.3%)</td>
<td>Hypertension</td>
</tr>
<tr>
<td>3</td>
<td>2007 (4.0%)</td>
<td>Osteoarthritis</td>
</tr>
<tr>
<td>4</td>
<td>4183 (8.3%)</td>
<td>Obesity</td>
</tr>
<tr>
<td>5</td>
<td>5383 (10.6%)</td>
<td>Cancer</td>
</tr>
<tr>
<td>6</td>
<td>6237 (12.3%)</td>
<td>Congestive Heart Failure</td>
</tr>
<tr>
<td>7</td>
<td>5226 (10.3%)</td>
<td>COPD / Asthma</td>
</tr>
<tr>
<td>8</td>
<td>6581 (13.0%)</td>
<td>Diabetes</td>
</tr>
<tr>
<td>9</td>
<td>3532 (7.0%)</td>
<td>Behavioral Health</td>
</tr>
<tr>
<td>10</td>
<td>4351 (8.6%)</td>
<td>Renal</td>
</tr>
<tr>
<td>11</td>
<td>5509 (10.9%)</td>
<td>Vascular</td>
</tr>
<tr>
<td>12</td>
<td>3742 (7.4%)</td>
<td>“Healthy”</td>
</tr>
</tbody>
</table>
Clustering Results: Summary

12 Clusters
1. “Healthy”
2. Lipid
3. Hypertension
4. Osteoarthritis
5. Obesity
6. Cancer
7. Congestive Heart Failure
8. COPD
9. Diabetes
10. Mental Health
11. Renal
12. Vascular

External Validity Check
- Age
- Race
- Gender
- Number Out-patient visits
- Number Medications
- Blood Pressure
Take Away Points

Purpose of Clustering is to discover structure in data that is not readily apparent

Different clustering methods can generate different solutions for the same data

"Everything should be made as simple as possible but not simpler."
Why Discuss Multiple Chronic Conditions?
An Overview

25% of Americans have ≥2 or more chronic conditions and account for ~2/3 of U.S. healthcare spending

• 2001: IOM Report: Crossing the Quality Chasm, recommended developing guidelines to address multiple chronic diseases

• 2011: CDC, Nat’l Center for Chronic Disease Prevention, and US DHHS expanded upon the IOM 2001 with 4 priority areas

• 2012: US DHHS and IOM identified 11 principles in 3 categories to improve guidelines for multiple chronic conditions:
  1. improve the technical process for developing guidelines
  2. strengthen guideline content on multiple chronic conditions
  3. increase focus on patient-centered care.
Jobs allowed his wife to convene a meeting of his doctors. He was facing the type of problem he never permitted at Apple. His treatment was fragmented rather than integrated. Each of his myriad maladies was being treated by different specialists in oncology, pain, nutrition, hepatology, hematology, etc., but his care was not coordinated.

Jobs’ physicians and consultants on care coordination were invited to the Jobs’ home where they agreed on an integrated plan to manage his pain and other health conditions.

A few people with MCC have the knowledge and resources to obtain an integrated care plan, while most patients with MCC do not.

Question: Is it possible to re-design healthcare for greater efficiency and better outcomes for most patients with MCC?
Why Focus on MCC & Cluster-Based Care?

Costs in Medicare Fee-for-Service Participants.

Chronic health conditions (CHCs) increase as a function of age and costs are strongly related to # of CHCs in Medicare FFS.

If there are a limited number of well-defined MCC clusters, this knowledge could result in better integrated guidelines, patient-centered care strategies, clinical outcomes and costs.

Average spending for Medicare FFS beneficiaries: $9,738

- $2,025
- $5,698
- $12,174
- $32,658

Number of Chronic Conditions:
- 0 to 1
- 2 to 3
- 4 to 5
- 6+
**Medicare Beneficiaries in CCI Database: Patterns of Chronic Disease**

<table>
<thead>
<tr>
<th>Diagnosis 1</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipid, 100%</td>
<td>HBP, 100%</td>
<td>OA, 100%</td>
<td>Obesity, 100%</td>
<td></td>
</tr>
<tr>
<td>Diagnosis 2</td>
<td>Lipid, 65%</td>
<td>Lipid, 60%</td>
<td>HBP, 59%</td>
<td></td>
</tr>
<tr>
<td>Diagnosis 3</td>
<td>HBP, 56%</td>
<td>Lipid, 54%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnosis 4</td>
<td>OA, 36%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

~27% of Medicare Beneficiaries in this analysis had a limited burden of chronic diseases in the Elixhauser - Charlson Comorbidity Indices
## Clustering Results, cont’d

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Cluster 5</th>
<th>Cluster 6</th>
<th>Cluster 7</th>
<th>Cluster 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>5383 (10.6%)</td>
<td>6237 (12.3%)</td>
<td>5226 (10.3%)</td>
<td>6581 (13.0%)</td>
</tr>
<tr>
<td>Diagnosis 1</td>
<td><strong>Cancer, 100%</strong></td>
<td>CHF, 95%</td>
<td><strong>COPD, 100%</strong></td>
<td><strong>DM, 100%</strong></td>
</tr>
<tr>
<td>Diagnosis 2</td>
<td>HBP, 74%</td>
<td>HBP, 94%</td>
<td>HBP, 71%</td>
<td>HBP, 88%</td>
</tr>
<tr>
<td>Diagnosis 3</td>
<td>Lipid, 73%</td>
<td>Lipid, 83%</td>
<td>Lipid, 66%</td>
<td>Lipid, 85%</td>
</tr>
<tr>
<td>Diagnosis 4</td>
<td>Vascular, 39%</td>
<td>Vascular, 76%</td>
<td>Obesity, 37%</td>
<td>Obesity, 56%</td>
</tr>
<tr>
<td>Diagnosis 5</td>
<td>OA, 36%</td>
<td>COPD, 59%</td>
<td>Vascular, 32%</td>
<td>OA, 44%</td>
</tr>
<tr>
<td>Diagnosis 6</td>
<td>Obesity, 33%</td>
<td>DM, 50%</td>
<td>OA, 30%</td>
<td>Vascular, 37%</td>
</tr>
<tr>
<td>Diagnosis 7</td>
<td>COPD, 28%</td>
<td>Mental, 42%</td>
<td>Mental, 21%</td>
<td>Mental, 36%</td>
</tr>
<tr>
<td>Diagnosis 8</td>
<td>Mental, 27%</td>
<td>Renal, 42%</td>
<td>DM, 15%</td>
<td>COPD, 19%</td>
</tr>
<tr>
<td>Diagnosis 9</td>
<td>DM, 22%</td>
<td>Cancer, 20%</td>
<td>Cancer, 1%</td>
<td>Cancer, 1%</td>
</tr>
<tr>
<td>Diagnosis 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Why Initial Focus on CHF ‘Cluster’ in Medicare Beneficiaries?
~12% of patients, high burden of comorbid disease and cost

<table>
<thead>
<tr>
<th>Chronic Dz</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. CHF</td>
<td>100%</td>
</tr>
<tr>
<td>2. Hypertension</td>
<td>94%</td>
</tr>
<tr>
<td>3. Hyperlipidemia</td>
<td>83%</td>
</tr>
<tr>
<td>4. Vascular Dz</td>
<td>76%</td>
</tr>
<tr>
<td>5. Arrhythmias</td>
<td>64%</td>
</tr>
<tr>
<td>6. Chronic lung dz</td>
<td>56%</td>
</tr>
<tr>
<td>7. Fluid &amp; Lytes</td>
<td>48%</td>
</tr>
<tr>
<td>8. Diabetes</td>
<td>48%</td>
</tr>
<tr>
<td>9. Obesity</td>
<td>45%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chronic Dz</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. Valve ♥ Dz</td>
<td>45%</td>
</tr>
<tr>
<td>11. Osteoarthritis</td>
<td>44%</td>
</tr>
<tr>
<td>12. ESRD / CKD</td>
<td>42%</td>
</tr>
<tr>
<td>13. Mental Health</td>
<td>41%</td>
</tr>
<tr>
<td>15. Anemia</td>
<td>31%</td>
</tr>
<tr>
<td>15. Hypothyroid</td>
<td>31%</td>
</tr>
<tr>
<td>16. Pulmon Circ</td>
<td>26%</td>
</tr>
<tr>
<td>17. Other neuro</td>
<td>20%</td>
</tr>
<tr>
<td>18. Cancer</td>
<td>20%</td>
</tr>
</tbody>
</table>
## Claims-Based Chronic Conditions in Medicare Beneficiaries

<table>
<thead>
<tr>
<th>Comorbidity</th>
<th>CHD</th>
<th>CHF</th>
<th>A-Fib</th>
<th>Stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number Pts</td>
<td>8,678,060</td>
<td>4,366,489</td>
<td>2,556,839</td>
<td>1,145,719</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1 (81%)</td>
<td>1 (86%)</td>
<td>1 (84%)</td>
<td>1 (89%)</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>2 (69%)</td>
<td>3 (63%)</td>
<td>2 (64%)</td>
<td>2 (70%)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>3 (42%)</td>
<td>5 (47%)</td>
<td>7 (37%)</td>
<td>6 (42%)</td>
</tr>
<tr>
<td>Arthritis</td>
<td>4 (41%)</td>
<td>6 (46%)</td>
<td>6 (42%)</td>
<td>5 (44%)</td>
</tr>
<tr>
<td>Anemia</td>
<td>5 (39%)</td>
<td>4 (51%)</td>
<td>5 (43%)</td>
<td>4 (47%)</td>
</tr>
<tr>
<td>HF</td>
<td>6 (36%)</td>
<td>Index</td>
<td>4 (51%)</td>
<td>7 (37%)</td>
</tr>
<tr>
<td>CHD</td>
<td>Index</td>
<td>2 (72%)</td>
<td>3 (64%)</td>
<td>3 (58%)</td>
</tr>
<tr>
<td>CKD</td>
<td>7 (30%)</td>
<td>4 (44%)</td>
<td>8 (34%)</td>
<td>8 (35%)</td>
</tr>
<tr>
<td>COPD</td>
<td>9 (21%)</td>
<td>8 (31%)</td>
<td>9 (24%)</td>
<td>†</td>
</tr>
<tr>
<td>AF</td>
<td>10 (19%)</td>
<td>9 (29%)</td>
<td>Index</td>
<td>†</td>
</tr>
<tr>
<td>Alzheimer’s</td>
<td>†</td>
<td>10 (26%)</td>
<td>†</td>
<td>9 (34%)</td>
</tr>
</tbody>
</table>

Why Focus on MCC & Cluster-Based Care? Costs in Medicare Fee-for-Service Participants.

- If there are a limited number of well-defined MCC clusters, this knowledge could result in better integrated guidelines, patient-centered care strategies, clinical outcomes and costs.

- The integrated strategy may overcome some limitations of a focus on individual disease management guidelines.
Chronic Conditions & Categories of Medicare Costs

Total Medicare Spending: $141,772,441,945

- 6+ Chronic Conditions: 41%
- 4 to 5 Chronic Conditions: 34%
- 2 to 3 Chronic Conditions: 26%
- 0 to 1 Chronic Conditions: 19%

Percentage Breakdown:
- Inpatient: 24%
- PAC: 2%
- Hospice: 10%
- Outpatient: 8%
- Evaluation & Management: 4%
- Procedures: 4%
- Imaging & Testing: 7%
- DME & other Prosthetics: 7%

CMS Chartbook 2012
Why Discuss Multiple Chronic Conditions? An Overview

25% of Americans have ≥2 or more chronic conditions and account for ~2/3 of U.S. healthcare spending

• The U.S. healthcare system historically has NOT been designed to care for these individuals mainly related to service silos

• Individual disease focus produces less benefit than expected

The trend to PCMH, ACOs and integrated, rapid-learning health systems provides exciting opportunities for improving the experience and outcomes of care at affordable costs for the growing number of individuals with MCC
Brent Egan, MD
Chief Science Officer

Susan Sutherland, Ph.D.
Senior Biostatistician

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