Database & Methods Cyberseminar Series

Applying Comorbidity Measures-A Deeper Dive
This session is dedicated to

*James F. Burgess, Jr., PhD*
Today’s objectives

At the end of this session, the participant will be able to:

• Distinguish terms: disease burden, multimorbidity, and comorbidity
• Describe how the CCI and the ECM measures are applied
• Name and understand the steps in SAS to apply comorbidity measures with clinical administrative data
• Find resources to support application of the CCI and ECM and adaptations of these comorbidity measures
Session roadmap

• Concept Review
• Understanding & Applying Two Methods
  • Charlson Comorbidity Index (CCI) and adaptations
  • Elixhauser Comorbidity Method (ECM)
• Examples Comparing CCI & ECM
• Summary
• Additional Resources
Poll Question #1: What is your role in applying comorbidity measures?

• I am leading/designing a study that requires risk adjustment
• I am/will be extracting the data to construct the measure
• I am adapting existing measures or developing new measures
• All of the above
• Other – please describe via the Q&A function
Session roadmap

- Concept Review
- Understanding & Applying Two Methods
  - Charlson Comorbidity Index (CCI) and adaptations
  - Elixhauser Comorbidity Method (ECM)
- Examples Comparing CCI & ECM
- Summary
- Additional Resources
Concept Review

Comorbidity

• A concomitant but unrelated pathological or disease process (Am Heritage Medical Dictionary)

• Assuming focal condition, comorbidities are unrelated and specific, separate from health status

• Measures may be simple ‘flags’ or composite measures and may be validated and tested in relation to a particular outcome

(Valderas, JM, Starfield, B, Sibbald, B, et al., 2009; Austin et al. 2015)
Other Terms to Distinguish

Multi-morbidity

• Co-occurrence of diseases (acute or chronic) within one person at one point in time

Frailty

• Focuses on a physiologic state of vulnerability to stress, be they physical or mental

Functional status

• Ability to perform daily tasks

Disease Burden

• May focus on a single disease or multiple/more population focused

• Example: Disability-adjusted life years (DALYs) incorporates mortality and the burden of living from the Global Burden of Disease Study
While there may be associations among these different concepts/measures they are considered separate entities, and may have independent effects on outcomes…

Questions to ask yourself…

What are your outcome measures? Are you interested in comorbidities in relation to a focal condition? General or specific risk adjustment? What type of study data?
Commonly Used Comorbidity Measures Using Clinical Administrative Data

- Charlson (CCI)
  - Deyo-Romano-Klabunde-VIReC adaptations
- Elixhauser Comorbidity Method (ECM) & adaptations
- Quan (CCI & ECM)
- HCC/DCG
- RxRisk
- Nosos
- ACG
- Functional Comorbidity Index
- Others
CCI & ECM and Adaptations Developed to Predict Specific Outcomes

- In-hospital mortality
- One-year mortality
- Hospital readmissions
- Length of stay and charges (ECM)

- Many have applied these measures and reported associations with costs and health care use
Poll # 2: What level of experience do you have with the CCI or ECM with VA data?

- **Very experienced with CCI/ECM**—I have applied one of these measures using VA data in my research
- **Experience with CCI/ECM & non-VA**—I have applied these measures with non-VA data (e.g. HCUP)
- **Experience only with other Comorbidity Measures & VA**—I have applied other measures using VA data (e.g. NOSOS, CAN scores)
- **Beginner**—learning about it!
Session roadmap

- Concept Review
- Understanding & Applying Two Methods
  - Charlson Comorbidity Index (CCI) and adaptations
  - Elixhauser Comorbidity Method (ECM)
- Examples Comparing CCI & ECM
- Summary
- Additional Resources
Charlson Comorbidity Index (CCI)

- Developed to predict mortality
  - Constructed based on the mortality rates of 607 patients admitted to the general internal medicine service
- Now includes 19 chronic conditions
  - Each has a weight from 1-6
- CCI Score = Sum of weights
- Extended/adapted by Deyo, Romano, Klabunde, VIReC, and others independently for use with clinical administrative data
- Commonly used as a general risk adjustment tool
VIReC Adaptation of CCI for Use with VA Data

- Adapted existing Charlson-based macro code that resulted in a new comorbidity index that:
  - Updates and combines approaches for use with mixed inpatient and outpatient data
  - Adds VA and Medicare outpatient procedures to achieve greater ascertainment of conditions
  - Replaces previous VA data sources with the VA data from the VA Corporate Data warehouse (CDW)
  - Incorporates the ICD10 and ICD9 coding schema
- Caveat: Needs validation

Reference see: VIReC. Calculating a Comorbidity Index for Risk Adjustment Using VA or Medicare Data. Available at: https://vaww.virec.research.va.gov/Tutorials/CALC-CCI/Tutorial-CALC-CCI.pdf
Constructing the Measure in Three Steps

• Step 1: Construct Input Dataset
• Step 2: Screen Input Dataset
• Step 3: Calculate Comorbidity Index Weights & Score
**VIReC CCI -- Step 1: Construct Input Dataset**

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Download the Zip file containing comorbidity tutorial programs from the “Tutorials” page on VIReC’s website: (see Appendix B for URL).</td>
</tr>
<tr>
<td>2</td>
<td>Download the most current version of the Alpha-Numeric HCPCS File from the “Alpha-Numeric HCPCS” page on the CMS website (see COMORBIDITY file for URL).</td>
</tr>
<tr>
<td>3</td>
<td>Unzip these files and save them in a SAS library.</td>
</tr>
<tr>
<td>4</td>
<td>Open the spreadsheet within the Alpha-Numeric HCPCS File and create a BETOS crosswalk file as a tab-delimited text file containing the HCPCS and BETOS code variables only.</td>
</tr>
<tr>
<td>5</td>
<td>Open the COMORBIDITY.sas file.</td>
</tr>
<tr>
<td>6</td>
<td>Associate a SAS library with each libref.</td>
</tr>
<tr>
<td>7</td>
<td>Replace unique identifier and anchor date variables with those relevant to the study cohort dataset.</td>
</tr>
<tr>
<td>8</td>
<td>Customize the COMORBIDITY program by modifying data sources and years so they are relevant to the study.</td>
</tr>
<tr>
<td>9</td>
<td>Run COMORBIDITY to create the input dataset.</td>
</tr>
<tr>
<td>Step</td>
<td>Action</td>
</tr>
<tr>
<td>------</td>
<td>--------</td>
</tr>
<tr>
<td>1</td>
<td>Review Variables and Variable Values in Healthcare System Datasets to Screen for Non-Clinician Assigned Diagnoses to determine the appropriate variables and variable values for removing non-clinician assigned records.</td>
</tr>
<tr>
<td>2</td>
<td>Determine the maximum number of diagnosis code variables (or fields) in the input dataset.</td>
</tr>
<tr>
<td>3</td>
<td>Open the CALL_REMOVE_RULEOUT_MACRO.sas file.</td>
</tr>
<tr>
<td>4</td>
<td>Associate a SAS library with each libref.</td>
</tr>
<tr>
<td>5</td>
<td>Customize the program to include or exclude any necessary variables and variable values for removing non-clinician assigned records.</td>
</tr>
<tr>
<td>6</td>
<td>Customize the program by entering the maximum number of diagnosis code variables (or fields).</td>
</tr>
<tr>
<td>7</td>
<td>Run CALL_REMOVE_RULEOUT_MACRO to create the rule-out dataset.</td>
</tr>
</tbody>
</table>
Klabunde et al “Rule-Out” MACRO -- Selecting records to exclude

This MACRO returns the dataset "&OUTDATA" which contains records within the specified window from which the unreliable ICD-9/ICD10 diagnosis codes have been excluded.
### VIReC CCI -- Step 3: Calculate Comorbidity Index Weights & Score

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Determine the maximum number of diagnosis and procedure code variables (or fields) in the rule-out dataset.</td>
</tr>
<tr>
<td>2</td>
<td>Open the CALL_COMORBIDITY_MACRO.sas file.</td>
</tr>
<tr>
<td>3</td>
<td>Associate a SAS library with each libref.</td>
</tr>
<tr>
<td>4</td>
<td>Customize COMORBIDITY_MACRO and CALL_COMORBIDITY_MACRO by removing any comorbidity that is the condition of study.</td>
</tr>
<tr>
<td>5</td>
<td>Customize CALL_COMORBIDITY_MACRO by entering the maximum number of diagnosis and procedure code variables (or fields).</td>
</tr>
<tr>
<td>6</td>
<td>Run CALL_COMORBIDITY_MACRO to create the comorbidity output file dataset.</td>
</tr>
</tbody>
</table>
Example of Output to Calculate CCI

CCI Theoretical Range: 1-29

For related conditions, the scoring algorithm for the CCI summary measure only counts the more severe one.

For this patient Liver1, Diabetes1 and Cancer flags were superseded by the more severe DX in calculating the CCI=27.
Session roadmap

• Concept Review
• Understanding & Applying Two Methods
  • Charlson Comorbidity Index (CCI) and adaptations
  • Elixhauser Comorbidity Method (ECM)
• Example Comparing CCI & ECM
• Summary
• Additional Resources
Elixhauser Comorbidity Method

- Developed to provide a comprehensive set of comorbidity measures for use with large administrative inpatient datasets
- Construction based on adult, nonmaternal inpatients from 438 acute care hospitals in California in 1992 ($n = 1,779,167$).
- Outcome measures: length of stay, hospital charges, and in-hospital death
  - Includes 29/30 chronic conditions
- ECM Summary Indices now include Readmission and Mortality score = Sum of weights
- Commonly used as a general risk adjustment tool
<table>
<thead>
<tr>
<th>Var Name</th>
<th>Description</th>
<th>Var Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHF</td>
<td>Congestive Heart Failure</td>
<td>LYPH</td>
<td>Lymphoma</td>
</tr>
<tr>
<td>VALVE</td>
<td>Valvular disease</td>
<td>METS</td>
<td>Metastatic cancer</td>
</tr>
<tr>
<td>Pulmcirc</td>
<td>Pulmonary circulation disorders</td>
<td>TUMOR</td>
<td>Solid tumor wo mets</td>
</tr>
<tr>
<td>Perivasc</td>
<td>Peripheral vascular disease</td>
<td>ARTH</td>
<td>Rheumatoid arthritis/ collagen vascular diseases</td>
</tr>
<tr>
<td>Htn_c</td>
<td>Hypertension (combine un-and complicated)</td>
<td>COAG</td>
<td>Coagulation deficiency</td>
</tr>
<tr>
<td>PARA</td>
<td>Paralysis</td>
<td>OBESE</td>
<td>Obesity</td>
</tr>
<tr>
<td>NEURO</td>
<td>Other neurological disorders</td>
<td>WGHTLOSS</td>
<td>Weight loss</td>
</tr>
<tr>
<td>CHRNLUNG</td>
<td>Chronic pulmonary disease</td>
<td>LYTESS</td>
<td>Fluid and electrolyte disorders</td>
</tr>
<tr>
<td>DM</td>
<td>Diabetes wo complications</td>
<td>BLDLOSS</td>
<td>Blood loss anemia</td>
</tr>
<tr>
<td>DMCX</td>
<td>Diabetes w complications</td>
<td>ANEMDEF</td>
<td>Deficiency anemias</td>
</tr>
<tr>
<td>HYPOTHY</td>
<td>Hypothyroidism</td>
<td>ALCOHOL</td>
<td>Alcohol abuse</td>
</tr>
<tr>
<td>RENLFAIL</td>
<td>Renal failure</td>
<td>DRUG</td>
<td>Drug abuse</td>
</tr>
<tr>
<td>LIVER</td>
<td>Liver disease</td>
<td>PSYCH</td>
<td>Psychoses</td>
</tr>
<tr>
<td>ULCER</td>
<td>Chronic peptic ulcer disease</td>
<td>DEPESS</td>
<td>Depression</td>
</tr>
<tr>
<td>AIDS</td>
<td>HIV and AIDS</td>
<td>(Elixhauser et al, Med Care 1998)</td>
<td></td>
</tr>
</tbody>
</table>
AHRQ HCUP Revision of the ECM

**Obj:**
To develop 2 indices, based on the ECM to predict in-hospital mortality and 30-day readmission

**Data:**
HCUP Inpatient 2011-2012
ICD9 Only

**Methods:**
Bootstrapped replications on each outcome
Produced Odds ratios and index weights for each Elixhauser comorbidity to create a single index score per record

Model validation with C-statistics

---

Moore, et al Med Care, 2017
Moore et al 2017 Revision of the ECM

**Mortality index:**

- **Weight range:**
  - 7 (drug abuse) to +14 (metastatic cancer)
  - 9 of the 29 comorbidities had a negative weight

- **C statistic range:**
  - 0.66-0.81

**Readmission index:**

- **Weight range:**
  - 3 (obesity) to 21 (metastatic cancer)
  - 2 of the 29 comorbidities had negative weights

- **C statistic range:**
  - 0.57-0.65

**Limitations**

- Only ICD9 so needs validation for ICD10
- Need to adapt for VA data, which lacks DRGs
Beta Elixhauser Comorbidity Software for ICD-10-CM

The Elixhauser Comorbidity Software for ICD-10-CM is one of the HCUP tools that can be applied to HCUP and other similar databases. These were created by AHRQ through a Federal-State-Industry partnership.

Caution: These ICD-10-CM/PCS tools were created prior to the availability of ICD-10-CM/PCS-coded data. AHRQ is concerned about unexpected discontinuities between the tools based on ICD-9-CM and those based on ICD-10-CM/PCS. See this page for details on how to correct for these issues.

Beta Elixhauser Comorbidity Software for ICD-10-CM

The Elixhauser Comorbidity Software is one in a family of databases and software tools developed as part of the Healthcare Cost and Utilization Project (HCUP). HCUP databases, tools, and software inform decision making at the national, State, and community levels.

Contents:
- Overview of the Elixhauser Comorbidity Software for ICD-10-CM Tool
- Description of the Elixhauser Comorbidity Software for ICD-10-CM Tool
- Technical Guidance for the Elixhauser Comorbidity Software for ICD-10-CM Tool
- Downloading Information for the Elixhauser Comorbidity Software for ICD-10-CM Tool
- Publications Using the Elixhauser Comorbidity Software for ICD-10-CM Tool
- For More Information, Comments, or Questions About the Elixhauser Comorbidity Software for ICD-10-CM Tool

Overview of the Elixhauser Comorbidity Software for ICD-10-CM Tool

The Elixhauser Comorbidity Software for ICD-10-CM assigns variables that identify comorbidities in hospital discharge records using original ICD-9-CM comorbidity measures reported by Elixhauser et al.¹

The Elixhauser Comorbidity Software for ICD-10-CM consists of two SAS computer programs for personal computers. Although these are written in SAS, they can be adapted to other programming languages.

The first program, Creation of Format Library for Elixhauser Comorbidity Groups, creates a SAS format library that maps diagnosis codes to complications or that may be related to the principal diagnosis.

- ConformatYYYY_N.txt is designed for files that include fiscal year (FY) YYYY ICD-10-CM codes and corresponding MS-DRG. This file is included with the software.

The second SAS program, Creation of Elixhauser Comorbidity Variables, applies the formats created above to a data set containing the following variables:

https://www.hcup-us.ahrq.gov/toolssoftware/comorbidityicd10/comorbidity_icd10.jsp

AHRQ HCUP Website provides:
- Software documentation
- Download instructions
- SAS programs
- Bibliography

09/2019
Example of Output to Calculate the ECM Mortality Index

**ECM Mortality Index Theoretical range: -32 to 99**

<table>
<thead>
<tr>
<th>Condition</th>
<th>289572919</th>
<th>672930457</th>
<th>734892027</th>
<th>782902496</th>
<th>293048209</th>
<th>109238490</th>
<th>523564184</th>
<th>238495792</th>
<th>489236709</th>
</tr>
</thead>
</table>
| Weighted sum of all conditions: 52
Session roadmap

- Concept Review
- Understanding & Applying Two Methods
  - Charlson Comorbidity Index (CCI) and adaptations
  - Elixhauser Comorbidity Method (ECM)
- Examples Comparing CCI & ECM
- Summary
- Additional Resources
Quan Revised & Compared Deyo-CCI & ECM
ICD9 & ICD10 Versions

Approach
- Developed ICD10 and enhanced ICD9 version of Deyo-CCI and ECM

Results
- Similar frequencies for 17 CCI and 30 ECM comorbidities—See Tables!
- Algorithms matched or outperformed original Deyo-CCI and ECM ICD9 algorithms in predicting in-hospital mortality

Quan et al, Med Care, 2005
Quan Revision—Limitations and Lessons

• ICD-9-CM and ICD-10 coding algorithms were assessed with different years of data (2001 & 2002) and before ICD was in practice in US
• Validity relative to a criterion standard not done
• Restricted the ICD-10 codes selected to the 4th digit

“The decision of whether to include or exclude specific codes or conditions from a coding algorithm depends to a large extent on a given study’s objectives.”

Quan et al. 2005
Example from an Ongoing VA Cohort Study

- **Cohort:** VA patients with a diagnostic sleep study during FY2016-2018
  - **Obj:** Identify comorbidities during a specific time period leading up to a procedure
    - 1 year ‘look-back’ prior to procedure
    - 2 year ‘look-back’ prior to procedure

- **Outcome Measures:**
  - Venue of care, care coordination needs, quality of care

- **Data:** VA CDW
  - Inpatient and Outpatient
  - VA, Community, and Fee basis, PIT
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Inpatient</td>
<td></td>
<td>ICD9SID ICD10SID</td>
<td></td>
</tr>
<tr>
<td>Inpatient Diagnosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient Discharge Diagnosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient Fee Diagnosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient Transfer Diagnosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present on Admission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specialty Transfer Diagnosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inpatient CD Procedure</td>
<td></td>
<td></td>
<td>CPTSID</td>
</tr>
<tr>
<td>Inpatient Surgical Procedure</td>
<td></td>
<td>ICD9ProcedureSID ICD10ProcedureSID</td>
<td></td>
</tr>
<tr>
<td>Inpatient CPT Procedure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workload V Diagnosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workload V Procedure Diagnosis</td>
<td></td>
<td>ICD9SID ICD10SID</td>
<td>CPTSID</td>
</tr>
<tr>
<td>Workload V Procedure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fee Inpatient Invoice CDD Diagnosis</td>
<td></td>
<td>ICD9SID ICD10SID</td>
<td></td>
</tr>
<tr>
<td>Fee Inpatient Invoice CDP Procedure</td>
<td></td>
<td>ICD9ProcedureSID ICD10ProcedureSID</td>
<td></td>
</tr>
<tr>
<td>Fee Service Provided</td>
<td></td>
<td>ICD9SID ICD10SID</td>
<td>ServiceProviderCPTSID</td>
</tr>
</tbody>
</table>

VA CDW Datasets: Diagnosis & Procedure Codes

09/2019
Example: Ongoing VA Sleep Study Cohort

Exploring VIReC CCI & ECM Measures with 1- & 2-Year ‘Look-backs’

<table>
<thead>
<tr>
<th>Measure</th>
<th>One Yr Look-back</th>
<th>Two Yr Look-back</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td><strong>VIReC CCI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes 1</td>
<td>121,055</td>
<td>18.67</td>
</tr>
<tr>
<td>Diabetes 2</td>
<td>55,116</td>
<td>8.50</td>
</tr>
<tr>
<td>Overall CCI</td>
<td>1.0145 (Range 0-29)</td>
<td>1.3782 (Range 0-29)</td>
</tr>
<tr>
<td><strong>Elixhauser^</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>67,279</td>
<td>10.37</td>
</tr>
<tr>
<td>Diabetes w Complications</td>
<td>45,546</td>
<td>7.02</td>
</tr>
<tr>
<td>Overall ECM-Mortality</td>
<td>-0.3082 (Range -29 to 70)</td>
<td>-0.4928 (Range -29 to 79)</td>
</tr>
</tbody>
</table>


Session roadmap

- Concept Review
- Understanding & Applying Two Methods
  - Charlson Comorbidity Index (CCI) and adaptations
  - Elixhauser Comorbidity Method (ECM)
- Examples Comparing CCI & ECM
- Summary
- Additional Resources
Issues to Consider Using Either/Any Measure

- Individual disease flags or composite score
- Look-back periods
- Any coding changes during period of interest e.g., ICD9/ICD10 transition
- Validity relative to a standard
- Quality of your data

“…a summary measure may only be as good as the variables used to create it.”

Austin, et al, 2015
Other References on Comorbidity in General

Summary

• Selecting the right method always depends on the research questions and the type and quality of your study data

  • There is no one-size-fits-all approach!!!

• There are coding algorithms readily available, yet it is up to you to know where to go with these tools!
Session roadmap

- Concept Review
- Understanding & Applying Two Methods
  - Charlson Comorbidity Index (CCI) and adaptations
  - Elixhauser Comorbidity Method (ECM)
- Examples Comparing the CCI & ECM
- Summary
- Additional Resources
VIReC Comorbidity Measurement Resources

- Tutorial providing step-by-step guidance on constructing VIReC CCI (Updated in 2017)
- SAS Programs available as zip files (2015 and 2017 versions) here:
  https://vaww.virec.research.va.gov/Comorbidity/Overview.htm
  - Includes **5 SAS programs** that can be used with Medicare claims and/or VA CDW data for data extraction
  - Includes **3 Excel workbooks** describing details for:
    - ICD-9/ICD-10 codes used
    - All procedure and diagnosis code variables used
    - Explanation of the VA codes for non-clinician assigned dx

- VIReC Comorbidity Bibliography (Last updated in 2017)
AHRQ Resources for the ECM

- Software documentation for Elixhauser et al
  - ICD10 Version:
    https://www.hcup-us.ahrq.gov/toolssoftware/comorbidityicd10/comorbidity_icd10.jsp
  - ICD9 Version 3.7:
    https://www.hcup-us.ahrq.gov/toolssoftware/comorbidity/comorbidity.jsp
- Site also numerous updates for each year since 2011
- Bibliography of applications of the ECM
VIReC Options for Specific Questions

- Community knowledge sharing
- ~1,360 VA data users
- Researchers, operations, data stewards, managers
- Subscribe by visiting http://vaww.virec.research.va.gov/Support/HSRData-L.htm (VA Intranet)

- Individualized support
virec@va.gov
(708) 202-2413
Contact information

Denise M. Hynes, MPH, PhD, RN
Core Investigator
Center to Improve Veteran Involvement in Care (CIVIC)
Portland, OR

Denise.Hynes@va.gov
Hynesd@oregonstate.edu
Quick links for VA data resources

Quick Guide: Resources for Using VA Data

VIReC: http://vaww.virec.research.va.gov/Index.htm (VA Intranet)

VIReC Cyberseminars: http://www.virec.research.va.gov/Resources/Cyberseminars.asp


VINCI: http://vaww.vinci.med.va.gov/vincicentral/ (VA Intranet)

Health Economics Resource Center (HERC): http://vaww.herc.research.va.gov (VA Intranet)

CDW: https://vaww.cdw.va.gov/Pages/CDWHome.aspx (VA Intranet)
Selected References on Concepts


