Precision Medicine Cluster

• The goal of precision medicine is to make optimal treatment decisions for an individual patient based on all information available thus allowing the tailoring of treatment to the patient.

• A partnership of faculty from the Statistics, Mathematics and ISE departments

• What we can bring: the development and implementation of quantitative methods toward this goal

“the right treatment for the right person, at the right time”
My Research Interests

• Modeling, analyzing and optimizing service systems under uncertainty and with heterogeneous consumers

• Goal is to use Operations Research to make recommendations that have a broad impact, inform policy level decisions and reduce inequality

• Focus on the human condition can be divided into two main streams:
  – Predictive models of health and economic outcomes
  – Resource allocation in emergency and disaster situations
Predictive Models of Health Outcomes

• Use multiple sources of secondary and observational data and a mixed methods approach to enable predictions of health outcomes at levels for which it is difficult to conduct studies in practice.
THE IMPACT OF INSURANCE EXPANSION ON COLORECTAL CANCER SCREENING
The Team

Stephanie Wheeler,

Kristen Hassmiller

Melinda Davis,

Meghan O’Leary
Leah Frerichs

Stephanie Renfro
Bonnie Lind
Yifan Gu

Rachel Townsley

Sid Nambiar
Background on Colorectal Cancer

- CRC screening is recommended for adults ages 50-75 (USPSTF)
- Effectively reduces CRC incidence and mortality
- Is cost-effective
CRC screening

• Is underutilized, 62% up to date (in 2015)
• 27% had never screened (in 2012)
• Lower screening rates
  – 58% for younger adults (50-64)
  – 52% for Latinos
  – 48% for those living in poverty
  – 45% for those without HS graduation
  – 27-47% for those living in rural areas

* Sources: Behavioral Risk Factor Surveillance System (BRFSS), ACS
Setting the Stage

• High differential in screening rates associated with Insurance
  – proportion that had never been screened was greater among those without insurance (55.0% vs. 24%) and without a regular care provider (61.0% vs. 23.5%)
  – Up-to-date among younger adults, 25% for uninsured, 57% for publically insured (vs. 62% for privately insured)

• Patient Protection Affordable Care Act (ACA)
  – Signed into law March 23 2010
  – Health insurance exchange rolled out Oct 1 2013
  – Bulk of provisions rolled out 2013 and 2014
  – “No cost sharing on essential preventative care”
  – Medicaid Expansion
Research Questions

What is the impact of Medicaid expansion and ACA on colorectal cancer screening?

What is the potential impact of changes in screening on long term outcomes?
NC-CRC Simulation Model

- Developed a geo-spatially explicit, population-based, individual-level, discrete event simulation model of the natural history of CRC progression and of screening behavior
- Accounts for heterogeneous compliance with screening and choice of modality
- Used synthetic population and cancer registries in North Carolina
- Analyzed cost-effectiveness of interventions being considered by CDC and North Carolina
- Partnered with Oregon to expand model beyond NC
NC-CRC Inputs

Demography
- Census data
  2006-2010 American Community Survey/Public Use Microdata Sample
  Project from sample to population

Synthetic population
- Realistic population of all individuals who will be eligible for CRC screening over the 10-year policy window

Natural History
- RTI Model
  Natural history of adenomas and cancer

Cancer Registry
- Population-based data on incident CRC cases (counts, patient demographics, stage at diagnosis)
  Calibration of CRC natural history parameters
  Parameter estimates

Screening and Testing
- Claims data
  Medicare, Medicaid, Blue Cross Blue Shield and linked community data such as the Area Resource File
  Statistical model development and testing
  Statistical models
  Logistic regression models predicting individuals' preferred screening modality and likelihood of compliance
  Predicted probabilities

Literature Review
- Evidence on interventions to increase CRC screening, existing CRC simulation models, and cost studies
  Interventions to consider; intervention effects and costs

Intervention scenarios
- Approaches for improving population-level screening compliance
  Structural assumptions and parameter values used to simulate each intervention and scenario

NC-CRC Simulation Model
- Geo-spatially explicit, population-based, individual-level discrete-event simulation model of the natural history of CRC progression and screening behaviors
NC-CRC Inputs

Demography

- Census data
  2006-2010 American Community Survey/Public Use Microdata Sample
  Project from sample to population
- Synthetic population
  Realistic population of all individuals who will be eligible for CRC screening over the 10-year policy window

Natural History

- RTI Model
  Natural history of adenomas and cancer

- Cancer Registry
  Population-based data on incident CRC cases (counts, patient demographics, stage at diagnosis)

Screening and Testing

- Claims data
  Medicare, Medicaid, Blue Cross Blue Shield and linked community data such as the Area Resource File

- Literature Review
  Evidence on interventions to increase CRC screening, existing CRC simulation models, and cost studies

- Statistical models
  Logistic regression models predicting individuals' preferred screening modality and likelihood of compliance

- Intervention scenarios
  Approaches for improving population-level screening compliance

Calibration of CRC natural history parameters

Parameter estimates

Population input file

Predicted probabilities

NC-CRC Simulation Model

Geo-spatially explicit, population-based, individual-level discrete-event simulation model of the natural history of CRC progression and screening behaviors
Demography and Synthetic Population

- We use a synthetic population that is designed to be realistic (useful!) but not real (a pain!)
- The population was created using the American Community Survey (ACS) of the U.S. Census Bureau from 2005-2009
  - Four variables were used to de-identify households by intelligently “shuffling”: age, race, income and household size
  - There is no health insurance indicator in the ACS, so we used the four ACS variables to estimate predicted probabilities of each insurance type for each individual based on 2010 ACS sample data using multinomial logit model
NC-CRC Inputs

Demography
- Census data
  2006-2010 American Community Survey/Public Use Microdata Sample
  Project from sample to population
- Synthetic population
  Realistic population of all individuals who will be eligible for CRC screening over the 10-year policy window

Natural History
- RTI Model
  Natural history of adenomas and cancer
- Cancer Registry
  Population-based data on incident CRC cases (counts, patient demographics, stage at diagnosis)
  Calibration of CRC natural history parameters
  Parameter estimates

Screening and Testing
- Claims data
  Medicare, Medicaid, Blue Cross Blue Shield and linked community data such as the Area Resource File
- Literature Review
  Evidence on interventions to increase CRC screening, existing CRC simulation models, and cost studies
- Statistical models
  Logistic regression models predicting individuals' preferred screening modality and likelihood of compliance
  Structural assumptions and parameter values used to simulate each intervention and scenario
- Intervention scenarios
  Approaches for improving population-level screening compliance

NC-CRC Simulation Model
Geo-spatially explicit, population-based, individual-level discrete-event simulation model of the natural history of CRC progression and screening behaviors
Natural History Model

- Polyp-adenoma process modeled
- Multiple polyps possible that appear and progress independently
- Generation and progression of polyps differentiated by age, race, and gender.
- Polyps detectable through screening tests
- Disease stage and detection time affect survival rates.
- When cancer causes death, compared to predicted cancer free life to determine lost life.
Model Structure

Main

Population
- Starts the model and controls progression of time (years).
- Collects Statistics and writes to external files.

Collection of Person objects.
- Computes event probabilities and population rates
- Reads input population data.

Person
- Defines parameters for each person.
  - Parameters are read from synthetic pop.
  - Track individual disease/health states.
  - Modality Choice via Statistical Model
  - Compliance Choice via Statistical Model
  - Creates events for each person.

Screening:
- Compliance Choice
- Modality Choice

Disease

Lesion
- Lesion Development
- Lesion Source

Test
- Collection of tests.
- Defines number of tests and what tests are offered.

Test Set
- Defines parameters of each test (name, specificity, sensitivity, etc.)

Legend:
- Java Objects: Building blocks of the model.
  - Includes variables, parameters, functions, timers and statecharts.
- Statecharts: Part of some objects.
  - Define states and when transitions between states are made.

Lesion
- Adds lesion to a person.
Natural History Model

**ADENOMA**
Preclinical screen-detectable adenoma phase

- No lesion
- Small < 5mm
  - Medium 6 – 9mm
    - Large > 10mm

**PRECLINICAL CANCER**
Screen-detectable cancer phase

- Pre Stage I
  - Pre Stage II
  - Pre Stage III
  - Pre Stage IV

**CLINICAL CANCER**
Phase

- Clin Stage I
  - Clin Stage II
  - Clin Stage III
  - Clin Stage IV

Death colorectal cancer
## Calibration – Cancer Incidence Counts

<table>
<thead>
<tr>
<th>Year</th>
<th>Localized CRC Cases</th>
<th>Total CRC Cases</th>
<th>CRC cases for age group 32-44</th>
<th>CRC cases for age group 45-64</th>
<th>CRC cases for age group 65-92</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>1608</td>
<td>3968</td>
<td>207</td>
<td>1507</td>
<td>2254</td>
</tr>
<tr>
<td>2009</td>
<td>1546</td>
<td>3890</td>
<td>230</td>
<td>1497</td>
<td>2163</td>
</tr>
<tr>
<td>2010</td>
<td>1433</td>
<td>3810</td>
<td>216</td>
<td>1454</td>
<td>2140</td>
</tr>
<tr>
<td>2011</td>
<td>1409</td>
<td>3822</td>
<td>205</td>
<td>1469</td>
<td>2148</td>
</tr>
<tr>
<td>2012</td>
<td>1371</td>
<td>3755</td>
<td>211</td>
<td>1487</td>
<td>2057</td>
</tr>
<tr>
<td>2013</td>
<td>1384</td>
<td>3870</td>
<td>231</td>
<td>1526</td>
<td>2113</td>
</tr>
<tr>
<td>2014</td>
<td>1364</td>
<td>3930</td>
<td>218</td>
<td>1555</td>
<td>2157</td>
</tr>
</tbody>
</table>

## Calibration – Cancer Incidence Rates

<table>
<thead>
<tr>
<th>Year</th>
<th>Localized CRC Cases</th>
<th>Total CRC Cases</th>
<th>CRC cases for age group 32-44</th>
<th>CRC cases for age group 45-64</th>
<th>CRC cases for age group 65-92</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>30.67</td>
<td>75.69</td>
<td>12.16</td>
<td>62.88</td>
<td>197.14</td>
</tr>
<tr>
<td>2009</td>
<td>28.94</td>
<td>72.81</td>
<td>13.54</td>
<td>60.82</td>
<td>182.83</td>
</tr>
<tr>
<td>2010</td>
<td>26.55</td>
<td>70.60</td>
<td>13.06</td>
<td>57.69</td>
<td>175.03</td>
</tr>
<tr>
<td>2011</td>
<td>25.56</td>
<td>69.34</td>
<td>12.09</td>
<td>57.54</td>
<td>170.03</td>
</tr>
<tr>
<td>2012</td>
<td>24.64</td>
<td>67.48</td>
<td>12.56</td>
<td>58.00</td>
<td>155.78</td>
</tr>
<tr>
<td>2013</td>
<td>24.44</td>
<td>68.33</td>
<td>13.52</td>
<td>59.19</td>
<td>153.51</td>
</tr>
<tr>
<td>2014</td>
<td>23.75</td>
<td>68.43</td>
<td>12.73</td>
<td>59.77</td>
<td>151.00</td>
</tr>
</tbody>
</table>

Calibration – Cancer Incidence

- Calibrate to cancer incidence rates per year, distribution by type and age.
- Calibration error is computed as RMS error between the simulated and actual values for localized cases ($loc_{rms}$), total cases ($tot_{rms}$), and cases by age group ($age_{rms}$).
- An iterative algorithm is performed in four successive stages by varying each of four parameters one at a time.
  - $w$: Polyp to preclinical cancer,
  - $x_1$: Preclinical 1 to preclinical 2,
  - $x_2$: Preclinical 2 to preclinical 3,
  - $x_3$: Preclinical 3 to preclinical 4.
- In each stage, the parameter value chosen for the next stage is one that corresponds to the smallest value of $((loc_{rms} + tot_{rms} + age_{rms})/3)$.
- Achieve average RMS of about 9 cases per 100,000.
Calibration – Cancer Incidence

\[
\frac{1}{x_1} + \frac{1}{y_1} = \frac{2}{2.5}
\]

\[
\frac{1}{x_2} + \frac{1}{y_2} = \frac{2}{2.5}
\]

\[
\frac{1}{x_3} + \frac{1}{y_3} = \frac{2}{3.7}
\]

\[x_4 = 1.5\]
NC-CRC Inputs

Demography
- Census data (2006-2010 American Community Survey/Public Use Microdata Sample)
  - Project from sample to population
- Synthetic population (Realistic population of all individuals who will be eligible for CRC screening over the 10-year policy window)

Natural History
- RTI Model (Natural history of adenomas and cancer)
- Cancer Registry (Population-based data on incident CRC cases (counts, patient demographics, stage at diagnosis))
  - Calibration of CRC natural history parameters
  - Parameter estimates

Screening and Testing
- Claims data (Medicare, Medicaid, Blue Cross Blue Shield and linked community data such as the Area Resource File)
  - Statistical model development and testing
  - Statistical models (Logistic regression models predicting individuals' preferred screening modality and likelihood of compliance)
    - Structural assumptions and parameter values used to simulate each intervention and scenario
- Literature Review (Evidence on interventions to increase CRC screening, existing CRC simulation models, and costs studies)
  - Interventions to consider; intervention effects and costs
- Intervention scenarios (Approaches for improving population-level screening compliance)

NC-CRC Simulation Model
- Geo-spatially explicit, population-based, individual-level discrete-event simulation model of the natural history of CRC progression and screening behaviors
Screening and Testing

• Screening compliance, as well as an individual’s choice of test modality are based on a probabilistic distribution of choices.

• The compliance and modality choice models are comprised of a statistical analysis based on observational **claims data** of individuals enrolled in either a state-sponsored health plan or private insurance.

• The multi-level, random effects logistic regression allows for individual attributes (e.g. sex, income) to have varying impacts between county level attributes (e.g. percent below poverty line).
Claims Data

Total unique linked records in Medicaid and Commercial personal summary files: 3,248,568

Unique Medicaid members: 1,020,373
- Turned 50 during study period (2010-2013): 20,567
- Continuously enrolled 11/12 months each year of study period: 7,240
- Alive at end of the study period: 7,150
- Resident of no more than 2 counties during study period: 7,112
- Not dual eligible for Medicaid/Medicare: 4,545
- No history of CRC/total colectomy: 4,531
- No history of ESRD: 4,516

Unique Commercial members: 2,228,595
- Turned 50 during study period (2010-2013): 110,408
- Continuously enrolled 11/12 months each year of study period: 60,321
- Alive at end of the study period: 60,321
- Resident of no more than 2 counties during study period: 60,301
- No history of CRC/total colectomy: 60,231
- No history of ESRD: 60,195
Statistical Analysis

• Primary Outcome- whether the beneficiary received any type of CRC screening test procedure, consistent with USPSTF guidelines, during the study period

• Services identified using ICD-9, CPT, and HCPCS codes

• Independent variables
  – Individual level: gender, race/ethnicity, insurance type, observed years, geographic location, use of PC, distance to nearest facility
  – County level characteristics from AHRF data

• Multilevel mutivariable logistic regression models by insurance type
• included a county-level random effect to account for additional unmeasurable, county specific regional differences across the state
Screening and Testing

• The specifications of the multi-level model are provided below

• $i$ indexes over individuals, $j$ indexes over counties (100 counties in NC), $k$ is the number of person level characteristics in the model, $l$ is the number of county level characteristics.

• The linear formulation of the logistic regression value function is converted into a probability as follows.

$$\logit(\pi_{ij}) = Y_{ij} = \beta_{0j} + \sum_{k} \beta_k X_{ik} + \sum_{l} \beta_l X_{jl} + \varepsilon_{ij}$$

$$\pi_{ij} = \frac{e^{Y_{ij}}}{1 + e^{Y_{ij}}}$$

• Where $\pi_{ij}$ is the probability for the binary outcome (CRC Screening vs. No Screen or Colonoscopy Choice vs. FOBT) for person $i$ at county $j$.

• $\beta_{0j}$ is the county level intercept $X_{ik}$ and $X_{jl}$ represent the person level (e.g. race, gender) and county level (e.g. distance to endoscopy facility).
## Screening and Testing

- A summary of the independent variables is defined in the table below

<table>
<thead>
<tr>
<th>Gender</th>
<th>Female vs. Male</th>
<th>Regional % Non-White</th>
<th>Low-Medium vs Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Race</td>
<td>Black vs. white</td>
<td>Regional Unemployment Rate</td>
<td>Medium-High vs Low</td>
</tr>
<tr>
<td></td>
<td>Other vs. white</td>
<td></td>
<td>High vs Low</td>
</tr>
<tr>
<td>Year turned 50</td>
<td>2003 vs 2008</td>
<td>Regional Unemployment Rate</td>
<td>Low-Medium vs Low</td>
</tr>
<tr>
<td>Distance</td>
<td>5-10 vs &lt; 5 miles</td>
<td></td>
<td>Medium-High vs Low</td>
</tr>
<tr>
<td></td>
<td>10-15 vs &lt; 5 miles</td>
<td></td>
<td>High vs Low</td>
</tr>
<tr>
<td></td>
<td>15-20 vs &lt; 5 miles</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20-25 vs &lt; 5 miles</td>
<td></td>
<td>Facility Test Volume (per 10,000)</td>
</tr>
<tr>
<td></td>
<td>25+ vs &lt; 5 miles</td>
<td>Facility Test Volume (per 10,000)</td>
<td>1-200 vs 0</td>
</tr>
<tr>
<td>Regional Uninsurance (40-64)</td>
<td>Low-Medium vs Low</td>
<td>Facility Test Volume (per 10,000)</td>
<td>200-400 vs 0</td>
</tr>
<tr>
<td></td>
<td>Medium-High vs Low</td>
<td>Facility Test Volume (per 10,000)</td>
<td>400-600 vs 0</td>
</tr>
<tr>
<td></td>
<td>High vs Low</td>
<td>Facility Test Volume (per 10,000)</td>
<td>600-800 vs 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>800+ vs 0</td>
</tr>
<tr>
<td></td>
<td>Generalist Count</td>
<td></td>
<td>Above median vs below median</td>
</tr>
</tbody>
</table>

*Note: The table above summarizes various independent variables and their respective comparisons.*
Screening and Testing

• The outcomes of the regression are compliance and modality within a 6 year window.

• Since FIT is recommended every year and colonoscopy every 5 years we convert these from 6 year probabilities (\(\pi\)) to the appropriate time interval.
  
  \[
  P_{FIT} = 1 - (1 - \pi)^{1/6}
  \]
  \[
  P_{col} = 1 - (1 - \pi)^{5/6}
  \]

• This is done assuming that the probability of screening in a single year is distributed as a Bernoulli random variable, thus the number of screens in a given time period are binomially distributed.
Screening and Testing
Increase in compliance for first time screeners

- First time screeners have an increased probability of being screened over a five-year-period.
- For colonoscopy screeners,
  - $\hat{P}_{col} = \min(P_{col} + p', 1)$.
- For FIT screeners,
  - $\hat{P}_{FIT} = P_{FIT} + x = 1 - \sqrt[5]{(1 - P_{FIT})^5 - p'}$. 

\[ \]
Calibration – Secular Trend

• We used data from BRFSS between 2002 and 2012 (conducted every 2 years) to estimate the proportion of NC residents aged 50-75 years who reported being up-to-date with CRC screening.
• The estimated proportions likely were overestimates of the true proportions of North Carolinians up-to-date with screening.
• We determined values by which the compliance probabilities of an individual are to be increased such that the % UTD obtained from the model matched the BRFSS data after adjustment for self-report.
• Calibration was performed in an iterative fashion by year.
Calibration – Secular Trend

<table>
<thead>
<tr>
<th>Secular trend values</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.15</td>
</tr>
</tbody>
</table>
NC-CRC Inputs

Demography
- Census data
  2006-2010 American Community Survey/Public Use Microdata Sample
  - Project from sample to population
- Synthetic population
  Realistic population of all individuals who will be eligible for CRC screening over the 10-year policy window

Natural History
- RTI Model
  Natural history of adenomas and cancer
- Cancer Registry
  Population-based data on incident CRC cases (counts, patient demographics, stage at diagnosis)
  - Calibration of CRC natural history parameters
  - Parameter estimates

Screening and Testing
- Claims data
  Medicare, Medicaid, Blue Cross Blue Shield and linked community data such as the Area Resource File
  - Statistical model development and testing
- Statistical models
  Logistic regression models predicting individuals' preferred screening modality and likelihood of compliance
  - Predicted probabilities

NC-CRC Simulation Model
Geo-spatially explicit, population-based, individual-level discrete-event simulation model of the natural history of CRC progression and screening behaviors
Policy Scenarios

• **Scenario 1 (Status Quo):** The development and use of the health insurance exchange under the ACA as implemented in North Carolina (i.e., without Medicaid expansion).

• **Scenario 2:** The expansion of the state’s Medicaid program, increasing the threshold for Medicaid eligibility for all residents to 138% of the federal poverty level (FPL).

• **Scenario 3:** If insurance expansion did not happen under the ACA, i.e., insurance reduction or removal of ACA
How has ACA/Medicaid expansion changed insurance uptake in North Carolina and Oregon?
Trends in BRFSS, % Insured among all individuals 2011-2014

NC: Do you have any kind of health care coverage?

OR: Do you have any kind of health care coverage?
Insurance uptake between 2013 and 2014

- State specific data was extracted from BRFSS, combined 2013 and 2014 datasets
- Modeled health insurance (yes=1, no=0) using multivariable logistic regression with interactions
- Independent variables include:
  - Sex
  - Age category (18-24, 25-34, 35-44, 45-54, 55-64, 65+)
  - Race, 6 collapsed into 4 (Non-Hispanic White, Non-Hispanic Black, Hispanic, Other)
  - Marital Status, collapsed 6 into 2 (Married and Not-Married)
  - Year
- Significant two-way interactions included
  - Race and Age, Sex and Married, Race and Income, Income and Year

*imputed using monotone logistic regression in the PROC MI procedure in SAS
Modeling Insurance Uptake between 2013 and 2014

- For all subgroups, we estimate the predicted probabilities of having insurance in both 2013 and 2014.
- For each group we calculate the conditional probability that a person will become newly insured in 2014 given that they were not insured in 2013.
- We then apply this increase to each individual (probabilistically).
- Those who become newly insured will either get private insurance (e.g., through the exchange) or Medicaid (if they qualify).
How has/would CRC screening and outcomes changed following ACA/Medicaid expansion?
Hardware Specifications

• The simulation model run via AnyLogic software
• Runs performed on a
  – Dedicated 64-core machine,
  – 64-bit Windows Server 2008 r2 Datacenter,
  – 1TB of ram,
  – 2 GHz Intel Xeon X7550 processors,
  – 2 TB of disk storage.
• We run five replications with a total run time of approximately 150 minutes.
Simulation Runs

- Simulate the full life course of every NC resident between the ages of 50 and 75 intervention window (January 1, 2014 through December 31, 2023)
- This includes 3,918,469 people, as of January 1, 2009 when the synthetic population was created

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>2,852,111</td>
<td>100.0</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1,363,984</td>
<td>47.8</td>
</tr>
<tr>
<td>Female</td>
<td>1,488,127</td>
<td>52.2</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>2,187,959</td>
<td>76.7</td>
</tr>
<tr>
<td>Black</td>
<td>534,103</td>
<td>18.7</td>
</tr>
<tr>
<td>Other</td>
<td>130,049</td>
<td>4.6</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>84,217</td>
<td>3.0</td>
</tr>
<tr>
<td>Non-Hispanic</td>
<td>2,767,894</td>
<td>97.0</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-64</td>
<td>1,898,525</td>
<td>66.5</td>
</tr>
<tr>
<td>65-75</td>
<td>953,586</td>
<td>33.5</td>
</tr>
</tbody>
</table>
CRC incidence by stage and CRC mortality of full cohort projected for lifetime.

<table>
<thead>
<tr>
<th></th>
<th>No ACA</th>
<th>ACA</th>
<th>ACA + Medicaid Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CRC Cases</strong></td>
<td>140,837</td>
<td>139,432</td>
<td>137,918</td>
</tr>
<tr>
<td><strong>Stage 1</strong></td>
<td>47,911</td>
<td>47,544</td>
<td>47,164</td>
</tr>
<tr>
<td><strong>Stage 2</strong></td>
<td>42,665</td>
<td>42,170</td>
<td>41,752</td>
</tr>
<tr>
<td><strong>Stage 3</strong></td>
<td>28,507</td>
<td>28,194</td>
<td>27,834</td>
</tr>
<tr>
<td><strong>Stage 4</strong></td>
<td>21,754</td>
<td>21,524</td>
<td>21,168</td>
</tr>
<tr>
<td><strong>CRC Deaths</strong></td>
<td>56,561</td>
<td>55,967</td>
<td>55,244</td>
</tr>
</tbody>
</table>
### Simulated age-eligible NC population up to date with CRC screening on January 1, 2023

<table>
<thead>
<tr>
<th>Variable</th>
<th>No ACA</th>
<th>Percentage-point change in percent up to date on CRC screening compared with the No ACA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ACA</td>
<td>ACA + Medicaid Expansion</td>
</tr>
<tr>
<td>Overall</td>
<td>48.65%</td>
<td>+1.03%</td>
</tr>
<tr>
<td></td>
<td>+1.74%</td>
<td></td>
</tr>
<tr>
<td>By sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>46.13%</td>
<td>+0.94%</td>
</tr>
<tr>
<td></td>
<td>+1.55%</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>51.00%</td>
<td>+1.11%</td>
</tr>
<tr>
<td></td>
<td>+1.92%</td>
<td></td>
</tr>
<tr>
<td>By race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>49.92%</td>
<td>+0.73%</td>
</tr>
<tr>
<td></td>
<td>+1.29%</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>45.92%</td>
<td>+2.01%</td>
</tr>
<tr>
<td></td>
<td>+2.88%</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>42.22%</td>
<td>+0.05%</td>
</tr>
<tr>
<td></td>
<td>+2.90%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>42.36%</td>
<td>+1.40%</td>
</tr>
<tr>
<td></td>
<td>+3.40%</td>
<td></td>
</tr>
<tr>
<td>By insurance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private</td>
<td>53.87%</td>
<td>+0.01%</td>
</tr>
<tr>
<td></td>
<td>+0.03%</td>
<td></td>
</tr>
<tr>
<td>Dual</td>
<td>58.02%</td>
<td>+0.02%</td>
</tr>
<tr>
<td></td>
<td>+0.99%</td>
<td></td>
</tr>
<tr>
<td>Medicare</td>
<td>59.85%</td>
<td>+0.09%</td>
</tr>
<tr>
<td></td>
<td>+0.15%</td>
<td></td>
</tr>
<tr>
<td>Medicaid</td>
<td>42.63%</td>
<td>+0.07%</td>
</tr>
<tr>
<td></td>
<td>+0.02%</td>
<td></td>
</tr>
<tr>
<td>Uninsured</td>
<td>17.84%</td>
<td>-0.04%</td>
</tr>
<tr>
<td></td>
<td>-0.04%</td>
<td></td>
</tr>
</tbody>
</table>
Results

• Reduce cancers, deaths
• Increase % up-to-date
• Model total cost of treating CRC from the state’s perspective
• Costs include routine and diagnostic screenings, treating complications arising from a colonoscopy and the lifetime treatment costs
Difference in all CRC costs by year, compared to the No ACA scenario, 2013+
Discussion

• Both ACA and ACA + Medicaid scenarios provided lower total CRC treatment costs when compared to the removal of ACA scenario.
• ACA scenario resulted in increasing the percentage of the NC population screened, resulting in fewer CRC cases, decreased severity of CRC cases, and reduced mortality.
• Increased health care coverage was also found to reduce racial disparities in screening.
• Although the changes in outcomes are somewhat modest they are commensurate with other state-wide interventions.
CRC Model Conclusions

• NC-CRC model is intended to be used as a “virtual world” in which to simulate the effects of alternate scenarios about population demographics, disease determinants, clinical interventions, or policies on CRC screening, incidence, treatment, and mortality.
• The object oriented structure of the model allows us to easily compartmentalize the components that make up the core of the model.
• The model can simulate realistic cohorts (e.g., for comparative effectiveness research) or the entire population of NC.
• The real power of the model becomes more evident when estimating the impact of future policies.
“TO ACHIEVE 80% BY 2018, YOU HAVE TO DO IT ALL.”

Richard Wender, MD – American Cancer Society
Oregon CRC Roundtable – April 22, 2016
Future work

• The simulation need not be restricted to North Carolina’s populations and policies.
• We simulate Oregon, in addition to insurance expansion, testing Evidence Based Interventions (e.g. Direct Mail, patient navigators, etc.)
• Other models of patient choice to take into account past behavior
The problem is complex
Conclusions

• Operations research & systems engineering provides a powerful tool
• I hope to use OR to make recommendations that inform public and health policy
• Focus on implementable results that consider issues of fairness- thereby improving the human condition.
patients

Thank you!

Questions?