Data-powered decision making:
One state’s approach to improving colorectal cancer screening in underserved populations

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Roadmap

• The rationale
• The approach
  – Defining target areas/regions for intervention
  – Selecting and adapting interventions
  – Quantifying the expected impact of interventions for specific areas/regions
  – Implementing interventions
  – Evaluating outcomes
The rationale for CRC screening

The 3 hot spots in the U.S. with the highest colon cancer death rates

Although the risk of death from colorectal cancer in the United States has dropped dramatically in recent decades, there are three "hot spots" in Appalachia and the rural South where death rates are "unnecessarily high," researchers said. By Lena H. Sun July 8, 2015

Translating Cancer Surveillance Data Into Effective Public Health Interventions

In this issue of JAMA, Mokdad and colleagues' report that cancer mortality has markedly decreased in the United States over the past 30 years. Based on data from the National...
The rationale for CRC screening

• Colorectal cancer (CRC) screening via colonoscopy or fecal testing (FOBT/FIT) is effective and saves lives.
• CRC screening is underused in both the U.S. (66% up to date) and N.C. (70% up to date)
• CRC screening is especially low among rural (& low income, uninsured, and minority) populations
• Decision makers need to know the most effective and efficient approach to close the gap in specific settings
  • Impact and efficiency of CRC screening interventions vary depending on local context
• How can healthcare systems be optimized to ensure that people receive CRC screening at the lowest cost?
• We know how to reduce CRC morbidity and mortality
• Yet, we are terrible at implementing what we know works

CDC Trends in CRC screening, 2010
Cancer Prevention and Control Research Network: 
A national effort funded by CDC and NCI to advance the science and practice of 
dissemination and implementation in cancer prevention and control

Putting Public Health Evidence in Action

Training Workshop Facilitator’s Guide
Cancer Prevention & Control Research Network
of the Prevention Research Center Program
www.cpcrn.org
Evidence-Based Intervention (EBI) Modeling Impact Workgroup

**Purpose:**
To inform cancer screening implementation planning at practice, health system, and policy levels by integrating best available evidence into decision support models and using these models to conduct virtual comparative effectiveness research.

**Example Works in Progress:**
- Estimate statewide effect of health insurance coverage (via Medicaid expansion and health insurance exchanges) on costs and benefits of CRC screening in vulnerable populations.
- Compare EBIs for improving CRC screening for Oregon’s counties and regional Coordinated Care Organizations.
Why simulate?

- Mathematical simulations offer a systematic method to:
  - Incorporate a range of diverse data sources into a complex “whole system” model
  - Quantify the expected uptake and health and economic impact of implementing specific EBIs
  - Forecast outcomes over a longer time period than observed in traditional epidemiologic or experimental data
  - Evaluate uncertainty
- Mathematical simulations can aid in:
  - Comparing specific EBIs to each other (selection and adaptation)
  - Evaluating implementation strategies
  - Selecting relevant implementation outcomes
  - Evaluating clinical/comparative effectiveness outcomes
Why simulate?

- **Underlying Population**
  - Census data: 2005-2010 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

- **Screening Patterns**
  - 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

- **Disease Progression**
  - RTI Model: Natural history of adenomas and cancer

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

- **Intervention Effects**
  - 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

**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
Unique linkages:
Cancer registry, multi-payer claims data (Medicare, Medicaid, private), SSI death index, BRFSS, other contextual data

Health Care Claims:
>6m persons since 2003

NC Cancer Registry:
100% of 2003-2013
>500,000 cases

Cases linked to claims
80% of NC cancers
450,000

Key collaborators
May Kuo
Anne Marie Meyer
Chris Baggett

Shared resources
4 Systems developers
6 Analysts
1 program coordinator

Funding
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Key pubs (>50)
Meyer et al, NCMJ, 2014
Wheeler et al, H&P, 2014
Wheeler et al, Medical Care, 2013
OHSU Center for Health Systems Effectiveness

Unique linkages:
Oregon All Payer All Claims database (Medicare, Medicaid, private insurers), other contextual data

Health Care Claims:
From 2007 for Medicare and Medicaid; 2010 for private

Key collaborators
John McConnell
Melinda Davis
Stephanie Renfro

Shared resources
3 Health economists
5 Statisticians
3 Research assistants
1 program coordinator

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Key pubs (>52)
McConnell et al, Health Affairs, 2017
Davis et al, J of Rural Health, 2016
Charlesworth et al, JAMA IM, 2016
Defining target areas for intervention

Hotspots of Age-Adjusted Colorectal Cancer Mortality Rate in North Carolina*

* The significance test was computed by including Virginia and North Carolina counties.
## Selecting and adapting evidence based interventions for local implementation

<table>
<thead>
<tr>
<th>Level</th>
<th>Approaches</th>
</tr>
</thead>
</table>
| Policy         | Payment model reforms (e.g., Medicaid and private insurance expansion)  
Access to care for uninsured (e.g., CDC-funded CRC control program)  |
| System         | Care coordination (e.g., through medical homes, ACOs)  
Improving health IT infrastructure  
- Population identification  
- Visit-based reminders  
- Tracking systems/registries  |
| Provider       | Provider outreach, education  
Quality reporting and incentives to meet screening goals  |
| Patient/Person | Decision aids delivered at visit  
Patient navigation support  
Community outreach, education, media campaigns  
Client reminders  |
## Selecting and adapting evidence based interventions for local implementation

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Effect Size</th>
<th>Base ($)</th>
<th>Cost Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicaid Mailed Reminder</td>
<td>5% age point increase in p(screen)</td>
<td>$10,000</td>
<td>Develop registry &amp; content (one-time)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$200 / year</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Programming time</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$0.71 / reminder</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Materials (postage, paper, ink)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$3,850 / year</td>
<td>Mail reminders</td>
</tr>
<tr>
<td>Endoscopy Expansion</td>
<td>Individually-specific predicted p(screen) based upon claims-based statistical models</td>
<td>$500,000 / facility</td>
<td>Financial incentive to locate facility in 6 underserved areas</td>
</tr>
<tr>
<td>Targeted Mass Media</td>
<td>Will reach 80% of blacks, 2% age point increase in p(screen)</td>
<td>$368,000 / year</td>
<td>Content development (one-time)</td>
</tr>
<tr>
<td></td>
<td>Will reach 40% of non-blacks, 1% age point increase in p(screen)</td>
<td>$332,000 / year</td>
<td>Advertising for one month</td>
</tr>
<tr>
<td>Voucher for uninsured</td>
<td>500 uninsured individuals turning 50 will receive colonoscopies</td>
<td>$750 / person</td>
<td>Voucher for colonoscopy</td>
</tr>
</tbody>
</table>
Endoscopy proximity does not predict CRC screening in publicly insured populations. But sending reminders to Medicaid enrollees has the potential to greatly increase screening, at low cost.

Quantifying the expected impact of interventions for specific areas/regions.

Cost-Effectiveness Analysis of Four Simulated Colorectal Cancer Screening Interventions, North Carolina

Kristen Hassmiller Lich, PhD¹; David A. Cornejo²; Maria E. Mayorga, PhD²; Michael Pignone, MD, MPH³,⁴,⁵,⁶; Florence K.L. Tangka, PhD⁷; Lisa C. Richardson, MD, MPH⁷; Tzy-Mey Kuo, PhD, MPH³; Anne-Marie Meyer, PhD³,⁸; Ingrid J. Hall, PhD, MPH⁷; Judith Lee Smith, PhD⁷; Todd A. Durham, MS¹; Steven A. Chall, MS⁹; Trisha M. Crutchfield, MHA, MSIS⁴,⁶; Stephanie B. Wheeler, PhD, MPH¹,³,⁴

Additional persons screened for CRC: 0, 100,000, 200,000, 300,000, 400,000.
Impact of Medicaid expansion: Expected change in disparity gap between White and African American males in the percent up-to-date with colorectal cancer screening from baseline to 2023 by NC region.
Impact of Medicaid expansion: Differences in cumulative CRC screening and treatment cost savings per person between policy scenarios.

ACA and Medicaid Expansion result in substantial long-term cost savings, especially for African American males.
Implementing interventions and evaluating outcomes

Pragmatic trial of mailed reminders +/- FIT kits in NC Medicaid populations

Medicaid Beneficiaries N = 2144

Randomization

Excluded = 355
Bad Address = 204
Previous COLO = 68
Previous FOBT/FIT = 10
Previous Other = 8
Opted Out = 65

Reminder + FIT N = 1071

Included 716

Returned FIT 151 (21%)

Positive 11

Negative 136

Reminder ONLY N = 1073

Included 655

Requested FIT 147

Returned FIT 85 (13%)

Positive 6

Negative 79

Excluded = 418
Bad Address = 224
Previous COLO = 92
Previous FOBT = 10
Previous Other = 10
Opted Out = 82

Difference 8% (4%, 12%; p<0.01)
What’s next for the Modeling EBI workgroup?

• What would it take to get to 80% by 2018 in NC? In OR?
• How can we best integrate decision support modeling with implementation science for CRC screening?
  – To inform implementation of specific CRC screening EBIs in geographically distinct areas and populations:
    • Urban, publicly insured populations
    • Federally qualified health centers (FQHCs)
    • Coordinated Care Organizations (CCOs) in OR
    • Eastern NC
  – To develop best practices for using simulation in stakeholder implementation decision support
Realizing impact

- Outcomes/Products
  - Increased CRC screening
  - Evidence to inform value
  - Publications, policy briefs, white papers, presentations, etc.

- Dissemination/Implementation
  - National level: CDC, NCI, Moonshot, National CRC Roundtable
  - Provider or State level: Medicaid, CCNC, DPH, NC Roundtable
Relationships, Data, and Quality Improvement Infrastructure

Critical Factors when Accountable Care Organizations and Primary Care Practices Collaborate to Increase Colorectal Cancer Screening in Medicaid Members
Background

• Health system stakeholders are increasingly aligning as Accountable Care Organizations (ACOs) to support improved quality, experience, and controlled costs.

• Context:
  
  — Oregon’s Coordinated Care Organizations (CCOs, Medicaid ACOs) are the single point of accountability for health care access, quality, and outcomes of Medicaid members.
  
  — Colorectal cancer screening is one of 18 CCO quality incentive metrics.

• **Research Questions:** How are clinics and ACOs/CCOs working together to improve care (colorectal cancer screening)? What interventions are they implementing?
Community Health Advocacy and Research Alliance (CHARA)

- Location: Columbia River Gorge (PacificSource CCO Region)

- Established with funding from the PCORI Pipeline to Proposal Award Series (2014 – 2017)

- **Goal:** Network of community members, local health leaders and researchers who can “identify, develop, and conduct health research to answer questions that matter here.”

For more information: davismel@ohsu.edu  
http://www.communityresearchalliance.org/
Controlling for age, beneficiaries had greater odds of receiving CRC testing if they were female (OR 1.04, 95% CI 1.01-1.08), commercially insured, or urban residents (OR 1.14, 95% CI 1.07-1.21).

Accessing primary care (OR 2.47, 95% CI 2.37-2.57), but not distance to endoscopy (OR 0.98, 95% CI 0.92-1.03) was associated with testing.
CRC Screening in Oregon’s CCOs

Thirteen CCOs achieved benchmark or improvement target for colorectal cancer screening between 2014 & 2015.

- Columbia Pacific
- AllCare Health Plan
- Primary/Health of Josephine County
- Yamhill CCO
- Willamette Valley Community Health
- FamilyCare
- Umpqua Health Alliance
- Jackson Care Connect
- Eastern Oregon
- PacificSource - Gorge
- Health Share of Oregon
- Intercommunity Health Network
- Western Oregon Advanced Health
- PacificSource - Central
- Trillium
- Cascade Health Alliance

Benchmark: 47.0%
Point Prevalence of CRC Testing in Oregon CCO Medicaid Members

Results displayed where number of cases (denominator) > 10.
Methods

• Design & Setting: Observational cross case comparative study among Oregon’s 16 CCOs

• Data Collection & Participant Sample:
  – CRC technical assistance consults with CCOs between June – July 2016
  – Semi-structured interviews with key stakeholders between February – August 2016

• Analysis: Fieldnotes & interview transcripts transferred to Atlas.ti and analyzed using data-driven, emergent approach
Results - Participants

• Data gathered from 14 of 16 CCOs
  – 10 CCO consultations
  – 26 key informants: state innovator agents (n=4), CCO leadership (n=16) and primary care practice members (n=6)

• Over 30% of the informants (n=8) worked with more than 1 CCO.
Results

• CCOs developed their strategies and infrastructure to work with clinics over time

• CCOs often started very lean: “for over a year and a half, [the CCO] didn't lease a physical office space... They held meetings in their partners’ offices.” (P12)

• CCOs implemented multicomponent interventions to improve CRC screening

<table>
<thead>
<tr>
<th>CRC Intervention Strategy</th>
<th>Component</th>
<th>Evidence-based?*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase community demand</td>
<td>Client reminders</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Client incentives</td>
<td>Insufficient</td>
</tr>
<tr>
<td></td>
<td>Small media</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Mass media</td>
<td>Insufficient</td>
</tr>
<tr>
<td></td>
<td>One-on-one education</td>
<td>Yes</td>
</tr>
<tr>
<td>Interventions to increase community access</td>
<td>Reducing structural barriers</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Reducing client out-of-pocket costs</td>
<td>Insufficient</td>
</tr>
<tr>
<td>Interventions to increase provider delivery</td>
<td>Provider assessment &amp; feedback</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Provider reminder &amp; recall</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Provider incentives</td>
<td>Insufficient</td>
</tr>
</tbody>
</table>

* Based on the Guide to Community Preventive Services
CCO Case Examples

Regional efforts have focused on implementing incentive programs for members ($20 Walmart gift card for returning a fecal test) and providers ($50-$100 when a patient completes screening). The CCO has improvement staff who leverage relationships with practices to provide education on their alternative payment method (APM) strategies, help create pop-up reminders in clinic EHRs, and provide patient gap lists. Additionally, CCO receptionists make reminder calls to patients that are due for screening.

...the CCO elected to implement a direct mail program modeled after Kaiser. CCO leadership worked with 4-5 clinics to pilot test the intervention and work out the kinks in the first year; this included learning to have clinics review member lists in advance. The program has expanded over time and recently transitioned from implementation by CCO staff to a contract with a vendor who supports material prep and distribution. The CCO also distributes money from the quality metric pool back to clinics that meet their CRC performance targets.
Results

CCOs addressed three key dimensions as they sought to improve CRC screening with regional clinics:

1) Establishing and building relationships
2) Producing and sharing data
3) Developing a process and infrastructure to support quality improvement (QI)
1) Establishing Relationships

Relationships and physical proximity were critical in building trust, buy-in, and shared decision making for improvement activities by CCO and clinic partners.

“...[CCO A] did not exist as an entity on the ground before...for us in [rural] Oregon, Portland can sometimes be a million miles away...Versus [CCO B] that has a physician led organization and the community...you knew the players from that one [from the start].” (P15)
“I think that's the way we've been able to achieve anything [is by building and leveraging relationships]. It has to be a partnership with the clinic, because we really are a guest in their clinics, so you can't just go in there and tell them what to do.”

- CCO Staff, P9
2) Producing and Sharing Data

Multiple CCOs focused on generating and producing actionable data to inform improvement efforts

- Some CCOs routinely, and strategically, shared data with member clinics
- Others were refining their approach

Clinics varied in their interest and ability to respond to performance data
“We have really good reporting… We have gap lists that we can produce by clinic, by provider, by measure. We know who's got the most members and clients…so that we know where to target.”

—CCO Staff, P10

“…the reports that we had gotten from the CCO were not very helpful … we would get reams of paper and about the fourth or fifth page in when three-quarters…weren't assigned to us we sort of saw them as unuseful and put them aside…..

- Clinic Member, P8
3) Developing a Process and Infrastructure to Support QI

Some CCOs led regional learning collaboratives and supported improvement staff

- Clinic-based panel managers and QI leads
- CCO-level improvement staff

“[The CCO improvement staff] actually come [out here to] the clinic and say, “What do you guys need as a clinic? What can we do to help you?”…they do a lot of support for [clinic] management …for implementation of metrics… They are really there to help operationalize [what] we need to do to show that we’re giving good care….They help with data collection…They're fabulous. I couldn't ask for anything more.” (P11)
Conclusions

• CCOs used multicomponent strategies to increase CRC screening

• Not all interventions had sufficient evidence, according to the Community Guide

• CCOs needed to address relationships, data, and QI infrastructure when working with clinics to increase CRC screening

→ similar steps for other quality metrics?
Implications & Recommendations

• Health system and policy leaders must consider relationships, data, and QI infrastructure when implementing population health initiatives across diverse settings
  — Understand/assess/respond to local context
  — Allow prior history and experience to inform partnership goals
  — Set realistic improvement targets based on local capacity

• Use and equity-based participatory implementation science approach

• Monitor for unintended consequence: increasing disparities because of focus on “larger” clinics/systems

See also, Wheeler & Davis (In Press). “Taking the Bull by the Horns”: Four Principals to Align Public Health, Primary Care, and Community Efforts to Improve Rural Cancer Control. *Journal of Rural Health.*
Acknowledgements

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Thank You

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Community Health Advocacy and Research Alliance (CHARA) Timeline

2011: ACO rules released by DHS & Oregon HB 3650 authorized CCOs

2012: Oregon CCOs launched, including Pacific Source Columbia Gorge CCO

2013: Drs. Davis and Dillon brainstorm at NAPCRG


2015: PCORI P2P Tier II awarded. CHARA named.

2016: PCORI P2P Tier III awarded. PCORI and NIH proposals submitted

2017: Sustainability Transition

Gorge employees Collective Impact Health Specialist

Columbia Gorge CCO region receives RWJF Culture of Health Prize.
CRC Screening in Oregon’s CCOs

Percentage of adult members who had appropriate screening for colorectal cancer in 2015 and 2016, by CCO.

- Primary Health of Josephine County
- Cascade Health Alliance
- Intercommunity Health Network
- Willamette Valley Community Health
- Eastern Oregon
- AllCare Health Plan
- PacificSource - Gorge
- FamilyCare
- Trillium
- PacificSource - Central
- Columbia Pacific
- Health Share of Oregon
- Jackson Care Connect
- Yamhill Community Care
- Western Oregon Advanced Health
- Umpqua Health Alliance

Benchmark 47.0%

2016 Final Performance Report

Oregon Health Authority
Technical Considerations: the past, present and future of simulation modeling of colorectal cancer

Siddhartha Nambiar, Rachel Townsley, Maria Mayorga
North Carolina State University

Kristen Hassmiller Lich, Stephanie Wheeler
University of North Carolina-Chapel Hill
• In 2012 only about 65% of individuals were up-to-date with screening
• 27% had never screened
• Improving screening rates is a priority
Example Cancer Evolution Model

- Preclinical screen-detectable polyp phase
  - No lesion
  - Adenoma ≤ 5mm
  - Adenoma 6-9mm
  - Adenoma ≥ 10mm

- Preclinical screen-detectable cancer phase
  - Preclinical stage I
  - Preclinical stage II
  - Preclinical stage III
  - Preclinical stage IV

- Clinical cancer phase
  - Clinical stage I
  - Clinical stage II
  - Clinical stage III
  - Clinical stage IV

- Death: colorectal cancer
CRC Simulation Model Paradigms

Discrete Event Simulation Models
- Support for Individual Patient Simulation (IPS).
- Flexibility for patient-patient, patient-environment interaction.

Markov Models
- Enumerate health states a person will experience during the course of the disease.
- The changes in state are described using transition diagrams very similar to flow charts.

Stochastic Microsimulation Models
- “Stochastic” - Models simulate sequences of events by drawing from distributions of probabilities or durations.
- “Microsimulation” - persons are moved through the model one at a time.
CRC Simulation Model - Development History

Simulation Models

- Markov Models
  - Harvard Model
  - UCSF Model
  - Michigan Model

- Stochastic Micro-simulation Models
  - Microsimulation Screening Analysis (MISCAN)
  - RTI Model
  - NC CRC Model

- CRC Simulated Population Model for Incidence and Natural History (CRC-SPIN)

Discrete Event Simulation Models

- CISNET Models
  - Simulation CRC (SimCRC)
  - Vanderbilt Model
  - V-NC Model
• UCSF (University of California, San Francisco) Model - a cohort based Markov model from age 50 until death.
• Monte Carlo simulation that runs through the model 3500 times to determine approximate values for the percent of people in each state at a given time.
• Has a small probability for cancer to develop without developing from an adenoma.
V-NC Model

- Primary Simulation Objects
  - Employs an **OOS** (Object Oriented System), driven by a model-independent database.

  - Allows for convenient modeling of causal and treatment pathways.

  - The primary object in the CRC simulation is the **person**.

  - The replication will be terminated when the person dies or when statistics collection ends.
MIconosimulation SCreening ANalysis (MISCAN)

- MISCAN–Colon is a micro–simulation program, generating individual life histories.
- Uses the Monte Carlo method to simulate all events in the program.
- Possible events are birth and death of a person, adenoma incidence and transitions from one state of disease to another.
North Carolina Colorectal Cancer (NC-CRC) model

Outline-

• Designed to support decision making regarding population screening for colorectal cancer within the state of North Carolina.
• Simulates cancer incidence and mortality by stage, age and calendar year.
• The model can be used to test the effects of various interventions on life-years and costs by increasing an individual’s probability of being screened for CRC.

History-

• Based significantly on the MISCAN-COLON model (Loeve et al. 1999) and the work of Subramanian and colleagues. (2005)
Expansion on other simulation models

– **Applying statistical models** from administrative claims data to predict the preferred screening modality of individuals and compliance with screening.

– **Calibrating natural history parameters** so that the incidence, age and stage of CRC diagnosis closely match registry data specific to the state of NC.

– **Models insurance** and allows status to change over time.

– Incorporating the effects of **population-level interventions** to increase compliance with CRC screening recommendations.
Model Structure

Input
- Demography: Synthetic population of NC
- Natural History: Development and incidence of CRC
- Screening and Testing: Screening compliance and preferred modality

Model
- Micro-simulation: implemented using AnyLogic®

Output
- CRC screening: Up to date by age and race
- CRC cases and deaths: By age, race and stage of diagnosis
- Costs: Screening for CRC and treatment for CRC

Summary Results
- Life-years up-to-date, life-years, costs, life-years/cost
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

- % of the population up-to-date with CRC testing
- Relative impact of alternate intervention approaches on % up-to-date with CRC testing (overall, and by subgroup)
- Cost-effectiveness (efficiency) of alternate intervention approaches
- Disparities in % up-to-date with CRC testing (by sex, race, insurance, and geography)
- Estimated maximum impact of aggressive (i.e., all) intervention on % up-to-date with CRC testing
Object Based Model Structure

Model Structure

Collection of Person objects.
Compute event probabilities and population rates
Reads input population data.
Checks if people are due for routine tests.

Defines parameters for each person.
Defines how health of a person progresses.
Defines screening procedure.
Creates events for each person.

Person

Disease
Screening

Lesion
Lesion Development
Lesion Source

Test

Collection of tests.
Defines number of tests, and what tests are offered.

Main

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

Collection of tests.
Defines number of tests, and what tests are offered.

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.
Limitations and Challenges

• Model is highly data intensive.

• Meant to inform population guidelines and is based on general population trends.

• Model can end up requiring extensive computational resources.
Future of CRC Simulation Models

• Optimization algorithms to generate candidate follow-up strategies for specific patient subgroups.

Questions/Discussions/Comments?
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• NC Translational and Clinical Sciences Institute Pilot Grant “Using systems science methods to improve colorectal cancer screening in North Carolina” (PI: Lich)

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Additional Slides
Assumptions (MISCAN)

• Demography Assumptions
  – The life table differs per birth cohort.
  – Death from colorectal cancer and death from other causes are considered independent from each other.

• Natural History Assumptions
  – Focus on the initiation, progression and response to treatment of colorectal cancer in the model.

• Screening Assumptions
  – Focus on all aspects of screening, including compliance and operational characteristics of the screening process.
Statistical Model Description

$logit(\pi_{ij}) = Y_{ij} = \beta_{0j} + \sum_{k} \beta_{k}X_{ik} + \sum_{l} \beta_{l}X_{jk} + \epsilon_{ij}$

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

$\pi_{ij}$ - Probability of binary outcome (CRC Screening vs No Screen or Colonoscopy vs FOBT) for person i at county j

$\beta_{0j}$ - County level intercept

$X_{ik}$ - Person level attributes (race, gender, etc)

$X_{jk}$ - County level attributes (distance to endoscopy facility)
Age Cohorts Included In Model

- Age;
- Sex;
- Race (white, black, Hispanic, other);
- Smoking status (current, former, never);
- Household income (<$25,000, $25,000-<$50,000, ≥$50,000);
- Insurance status (none, private, Medicare, Medicaid, dual Medicare and Medicaid);
- Education (not complete college, completed college);
- Residential location (zip code).
- State health insurance program participation (SHEP, not a participant, participant);
- Marital status for privately insured individuals (married, unmarried, unknown)
Process flow of lesion progression
USING INDIVIDUAL-BASED SIMULATION MODELING TO INTEGRATE BIG DATA AND INTERVENTION EVIDENCE TO INFORM INTERVENTION SELECTION, ADAPTATION, AND EVALUATION: AN EXAMPLE ON COLORECTAL CANCER SCREENING

PRESENTED BY: KRISTEN HASSMILLER LICH, PHD MHSA ASSISTANT PROFESSOR, UNIV OF NORTH CAROLINA AT CHAPEL HILL
HOW DO WE TYPICALLY SELECT EVIDENCE-BASED PRACTICES?
SO... HOW DO WE TYPICALLY SELECT EVIDENCE-BASED PRACTICES?

HTTP://GUIDES.LIBRARY.UWM.EDU/EBPTUTORIAL
SO... HOW DO WE TYPICALLY SELECT EVIDENCE-BASED PRACTICES?

HTTPS://WWW.CDC.GOV/PCD/ISSUES/2013/12_0275.HTM
SO... HOW DO WE TYPICALLY SELECT EVIDENCE-BASED PRACTICES?

(SOURCE: COMMUNITY GUIDE AND USPSTF REPORTS)
SO... HOW DO WE TYPICALLY SELECT EVIDENCE-BASED PRACTICES?

REF: HASSMILLER LICH ET AL., PREVENTING CHRONIC DISEASE
SO... HOW DO WE TYPICALLY SELECT EVIDENCE-BASED PRACTICES?

HTTPS://WWW.CDC.GOV/PCD/ISSUES/2007/OCT/07_0025.HTM
SO... HOW DO WE TYPICALLY SELECT EVIDENCE-BASED PRACTICES?

HTTP://AZHIN.ORG/CUMMINGS/RE-AIM
HOW COULD WE LEVERAGE SIMULATION?
THE PUZZLE OF LOCAL DECISION MAKING

ENGAGING DECISION MAKERS WITH SIMULATION CAN HELP!
THE PUZZLE OF LOCAL DECISION MAKING

ENGAGING DECISION MAKERS WITH SIMULATION CAN HELP!

Know what works (evidence)
Know your population
Know what it takes to implement
Know what is already in place
Know system capacity and strengths
Know what is coming...
Engaging decision makers with simulation can help!

The puzzle of local decision making

Know your population
Know what works (evidence)
Know what it takes to implement
Know what is already in place
Know system capacity and strengths
Know what is coming...

- Differences in the population targeted can change impact!
  - What if my population is older?
  - More racially diverse?
  - Less likely to stay insured?
  - More rural?

- What if our state is doing a great job with a subpopulation already?
  - Medicaid screening rates are high
  - Just had a big colonoscopy initiative

- What if an intervention requires something that isn’t in place?
  - Mass media encouraging colonoscopy... but no access?

- We address this by:
  - Projecting screening to the local population (census data is key)
  - Basing current screening estimates on local data (claims, administrative)

The puzzle of local decision making
SIMULATION ALLOWS DECISION MAKERS TO PROJECT CURRENT SCREENING PATTERNS TO THE LOCAL POPULATION
SIMULATION ALLOWS DECISION MAKERS TO PROJECT **CURRENT SCREENING PATTERNS** TO THE LOCAL POPULATION

### Table: Impact on % Up-to-Date in 10th Year of Policy Window

<table>
<thead>
<tr>
<th></th>
<th>Testing as usual</th>
<th>Mailed Reminder</th>
<th>Endoscopy Expansion</th>
<th>Mass Media</th>
<th>Voucher for Uninsured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>53.6%</td>
<td>+0.3%</td>
<td>+0.0%</td>
<td>+0.4%</td>
<td>+0.1%</td>
</tr>
<tr>
<td>By sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>54.7%</td>
<td>+0.3%</td>
<td>+0.0%</td>
<td>+0.6%</td>
<td>+0.2%</td>
</tr>
<tr>
<td>Females</td>
<td>52.4%</td>
<td>+0.5%</td>
<td>+0.0%</td>
<td>+0.5%</td>
<td>+0.1%</td>
</tr>
<tr>
<td>By race</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whites</td>
<td>54.7%</td>
<td>+0.3%</td>
<td>+0.0%</td>
<td>+0.4%</td>
<td>+0.1%</td>
</tr>
<tr>
<td>Blacks</td>
<td>51.4%</td>
<td>+0.9%</td>
<td>+0.0%</td>
<td>+1.4%</td>
<td>+0.2%</td>
</tr>
<tr>
<td>Others</td>
<td>47.5%</td>
<td>+0.5%</td>
<td>+0.0%</td>
<td>+0.4%</td>
<td>+0.4%</td>
</tr>
<tr>
<td>By insurance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private</td>
<td>56.2%</td>
<td>+0.0%</td>
<td>+0.0%</td>
<td>+0.5%</td>
<td>+0.0%</td>
</tr>
<tr>
<td>Medicaid</td>
<td>50.3%</td>
<td>+4.6%</td>
<td>+0.2%</td>
<td>+0.8%</td>
<td>+0.0%</td>
</tr>
<tr>
<td>Medicare</td>
<td>51.3%</td>
<td>+0.0%</td>
<td>+0.0%</td>
<td>+0.4%</td>
<td>+0.0%</td>
</tr>
<tr>
<td>Dual</td>
<td>44.8%</td>
<td>+3.5%</td>
<td>+0.1%</td>
<td>+0.7%</td>
<td>+0.0%</td>
</tr>
<tr>
<td>Uninsured</td>
<td>14.6%</td>
<td>+0.0%</td>
<td>+0.0%</td>
<td>+0.6%</td>
<td>+1.1%</td>
</tr>
</tbody>
</table>
THE PUZZLE OF LOCAL DECISION MAKING

ENGAGING DECISION MAKERS WITH SIMULATION CAN HELP!

- Challenges:
  - The “system” is big!
  - ... and constantly changing
  - Micro costing is difficult
  - Uncertainty in evidence

- Know your population
- Know what works (evidence)
- Know what it takes to implement
- Know what is already in place
- Know system capacity and strengths
- Know what is coming...
Many practical and systematic ways for groups to document current systems

- **Process flow diagramming** to describe current or proposed practices
- **Whole system mapping** to document current programs, services, initiatives
- **Asset mapping** or **system support mapping** to elicit resources, strengths, needs
WE TYPICALLY ESTIMATE COST/IMPACT AND COMPARE

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Effect Size</th>
<th>Base ($)</th>
<th>Cost Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicaid Mailed Reminder</td>
<td>5% age point increase in p(screen)</td>
<td>$10,000</td>
<td>Develop registry &amp; content (one-time)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$200 / year</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Programming time</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$0.71 / reminder</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Materials (postage, paper, ink)</td>
</tr>
<tr>
<td>Endoscopy Expansion</td>
<td>Individually-specific predicted p(screen) based upon claims-based statistical models</td>
<td>$500,000 / facility</td>
<td>Financial incentive to locate facility in 6 underserved areas</td>
</tr>
<tr>
<td>Targeted Mass Media</td>
<td>Will reach 80% of blacks, 2% age point increase in p(screen)</td>
<td>$368,000 / year</td>
<td>Content development (one-time)</td>
</tr>
<tr>
<td></td>
<td>Will reach 40% of non-blacks, 1% age point increase in p(screen)</td>
<td>$332,000 / year</td>
<td>Advertising for month</td>
</tr>
<tr>
<td>Voucher for uninsured</td>
<td>500 uninsured individuals turning 50 will receive colonoscopies</td>
<td>$750 / person</td>
<td>Voucher for colonoscopy</td>
</tr>
</tbody>
</table>

COST-EFFECTIVENESS EFFICIENCY FRONTIER: INTERVENTION COST VERSUS ADDITIONAL LIFEYEARS UP-TO-DATE

- Testing as usual
- Mailed Reminder
- Endoscopy Expansion
- Mass Media
- Voucher for Uninsured
- Mailed reminder + Mass media
- Mailed reminder + Mass media + Voucher
- All interventions

Cost of intervention over 10 years
Number of additional life-years up-to-date over 20 years
INSTEAD, WE CAN DISCUSS…

**What Combination of Cost Multipliers & Effect Multipliers are fundable for a given willingness to pay level?**

<table>
<thead>
<tr>
<th>Mass Media Intervention Cost</th>
<th>$3,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willingness to pay (WTP)</td>
<td>WTP $10</td>
</tr>
</tbody>
</table>

**Mass Media:**

Fundable Cost/Effect Multiplier Combinations (below the curve)

- **Cost Multiplier**
  - 3.5
  - 3
  - 2.5
  - 2
  - 1.5
  - 1
  - 0.5
  - 0

- **Minimum Effect Multiplier**
  - 0
  - 0.5
  - 1
  - 1.5
  - 2
  - 2.5
  - 3
  - 3.5
  - 4
  - 4.5
  - 5
INSTEAD, WE CAN DISCUSS...

Mailed Reminder Intervention Cost
Willingness to pay (WTP) $1,619,578
WTP $10

Mailed Reminder:
Fundable Cost/Effect Multiplier Combinations
(below the curve)
### Recommendation based on most Life Years UTD

<table>
<thead>
<tr>
<th>Mass Media Cost</th>
<th>Mailed Reminder Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3,000,000</td>
<td>1,679,578</td>
</tr>
</tbody>
</table>

#### Willingness to pay

| Effect | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1   | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2   | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3   |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| $54,350|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $125,050|   5,435|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $221,050| 12,505|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $350,030| 35,037|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $507,620| 50,762|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $609,530| 68,953|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $901,850| 90,195|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $1,136,140| 113,614|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $1,399,600| 139,960|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $1,694,950| 169,495|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $2,024,030| 202,403|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $2,331,030| 233,103|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $2,606,950| 260,695|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $2,839,460| 283,946|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $3,210,460| 321,046|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $3,513,470| 351,347|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $3,849,570| 384,857|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $4,200,200| 420,026|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $4,554,260| 455,426|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $4,931,800| 493,180|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $5,324,040| 532,404|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $5,733,080| 573,308|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $6,155,260| 615,526|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $6,581,640| 658,164|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $6,846,500| 684,250|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $7,094,760| 709,476|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $7,348,660| 734,666|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $7,593,340| 759,334|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| $7,842,640| 784,264|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

#### Mass Media

- $3,000,000
- $1,679,578
THE PUZZLE OF LOCAL DECISION MAKING

ENGAGING DECISION MAKERS WITH SIMULATION CAN HELP!
TARGET AUDIENCES

• **State or local public health leaders and policy makers** who want to know the benefits and trade-offs of public health interventions

• **Organizations responsible for specifying clinical and public health practice guidelines** (e.g., the US Preventive Services Task Force, the American Cancer Society, and the Centers for Disease Control and Prevention);

• State systems such as **health plans, accountable care organizations, or coalitions**

• Local systems such as **healthcare and hospital systems, large employers, Federally Qualified Health Centers, AHEC regions**

• **Clinician and/or public health researchers**

• **Patients and patient advocates** in the community
THANK YOU!

klich@unc.edu
Simulation model components & data sources

Underlying Population

- **Census data**
  - 2005-2010 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

Screening Patterns

- **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

Disease Progression

- **RTI Model**
  - Natural history of adenomas and cancer
  - Parameter estimates

Cancer Outcomes

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

Intervention Effects

- **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

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

CPCRN
Cancer Prevention and Control Research Network