MICHIGAN ENGINEERING
UNIVERSITY OF MICHIGAN

Evaluating Screening and Care of Diabetic Retinopathy in Veterans Using Mixed-Integer Programming and Simulation

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INFORMS Annual Meeting

October 21, 2019

CENTER FOR
HEALTHCARE ENGINEERING & PATIENT SAFETY
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Rx

A prescription to address system complexity in healthcare

INNOVATING HEALTHCARE DELIVERY

FOSTERING LEARNING

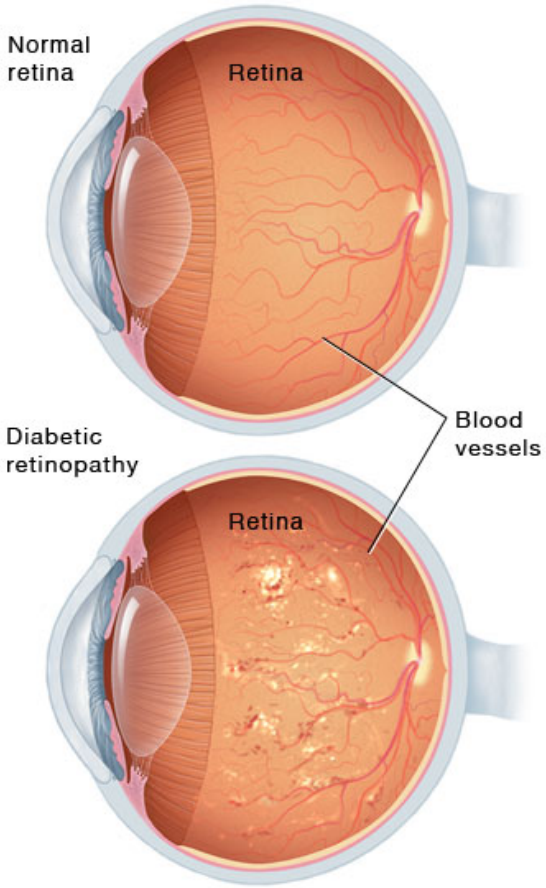
BUILDING COMMUNITY

POSITIVE IMPACT THROUGH...

Research
Education
Implementation
Outreach
Dissemination

Background

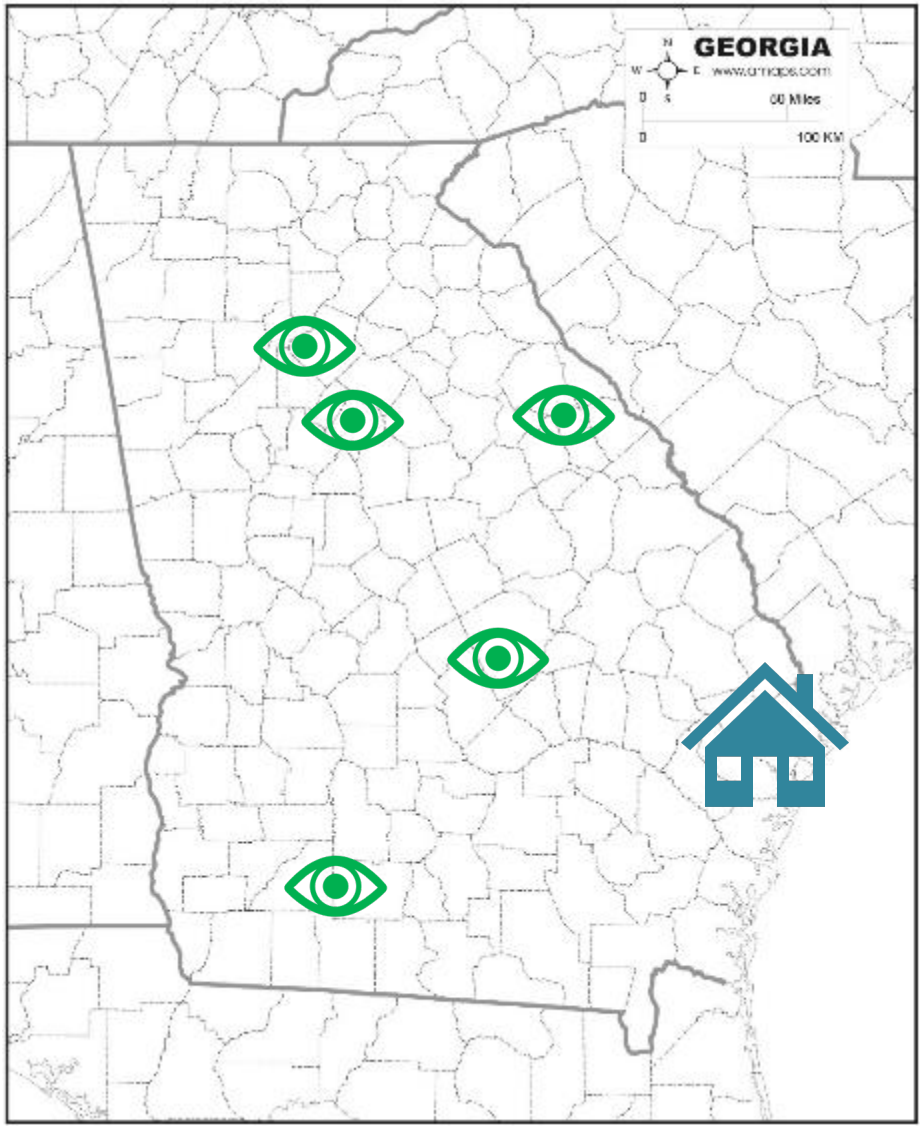
- Diabetes and diabetic retinopathy (DR)
  - Diabetes → blood sugar → retinal eye vessels weakened /weak new vessels → damage to vision
- DR diagnosed by an eye care specialist
  - Early retinopathy = monitoring, diabetes management
  - Advanced retinopathy = photocoagulation, vitrectomy, medical injection
    - Even after treatment, DR can reemerge



Veteran Eye Care

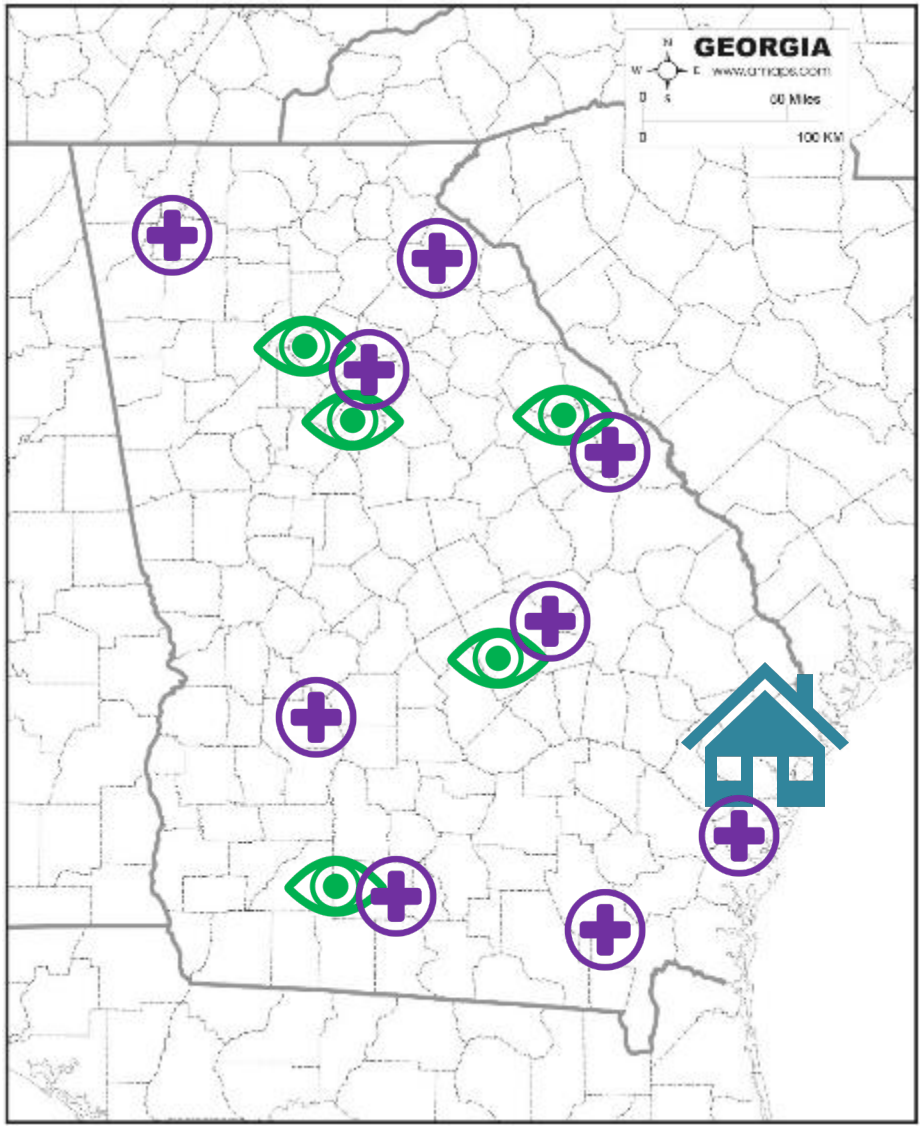
- Veterans face barriers accessing eye care
  - Access big challenge for rural veterans
  - Veterans report greater delays in seeking care than non-veterans
  - Eye care is 3rd most utilized service in VA (after primary care and mental health)
- Diabetes prevalence: VA patients (11.4%) > general US population (7.2%)
- Why VA research?
  - VA is cost-incentivized to reduce barriers to accessing care
  - Patient utilization of care is relatively consistent
  - Care coordination in VA: primary care/ophthalmology/endocrinology

Veteran Eye Care in Georgia



VA Eye Care

Add Screening Options



VA Eye Care
VA Primary Care

What kind of problem is this?

- Combinatorial matching problem
  - Deciding locations to offer eye care and how to staff those locations
- Constrained resources
- Multi-criteria decision
  - Consider cost, distance traveled, number of patients seen, etc.

Problem Statement

- Goal: Evaluate **which locations** to offer eye care screenings and **what provider type(s)** to staff each eye care location
- Assumptions:
  - Patients go to "assigned" clinic for eye care screening
  - One-year time frame
  - Patients have homogeneous screening need (one screening every other year)
- Limitations:
  - Considering eye care screening only (follow-up care not included)
  - No consideration for patients' provider preferences

General modeling approach

Possible eye care locations

- 28 VA locations in Georgia

Decide

- At which locations do we offer eye care?
- What kind(s) of provider(s) should staff each location?

"Assign" patients

- Patients from a given zip code assigned to clinic location(s)

Model Overview: Feasibility Constraints

- Patient Capacity

$$\sum_{z \in Z} x_{zc}^t \leq v^t * y_c^t \qquad \forall\, c \in C,\ \forall t \in T$$

- Demand

$$\sum_{t \in T} \sum_{c \in C} x_{zc}^t \geq n_l * p_z \qquad \forall\, z \in Z$$

$$\sum_{t \in T} \sum_{c \in C} x_{zc}^t \leq n_u * p_z \qquad \forall\, z \in Z$$

- Provider Capacity

$$y_c^t \leq g_c^t \qquad \forall t \in T, \forall c \in C$$

$$\sum_{t \in T} y_c^t \leq g_c \qquad \forall c \in C$$

Model Overview: Two objective functions

I. Maximize patients assigned

+ constraints: budget, distance

$$Maximize \sum_{z \in Z} \sum_{c \in C} \sum_{t \in T} x_{zc}^{t}$$

II. Minimize overall costs

+ constraints: patients, distance

$$Minimize \left[\sum_{c \in C} \sum_{z \in Z} \sum_{t \in T} (a_c^t * x_{zc}^t + (d_{zc} * x_{zc}^t) * r + f_c^t * y_c^t) \right] + h * \sum_{z \in Z} (n_u * p_z - \sum_{t \in T} \sum_{c \in C} x_{zc}^t)$$

Data Overview

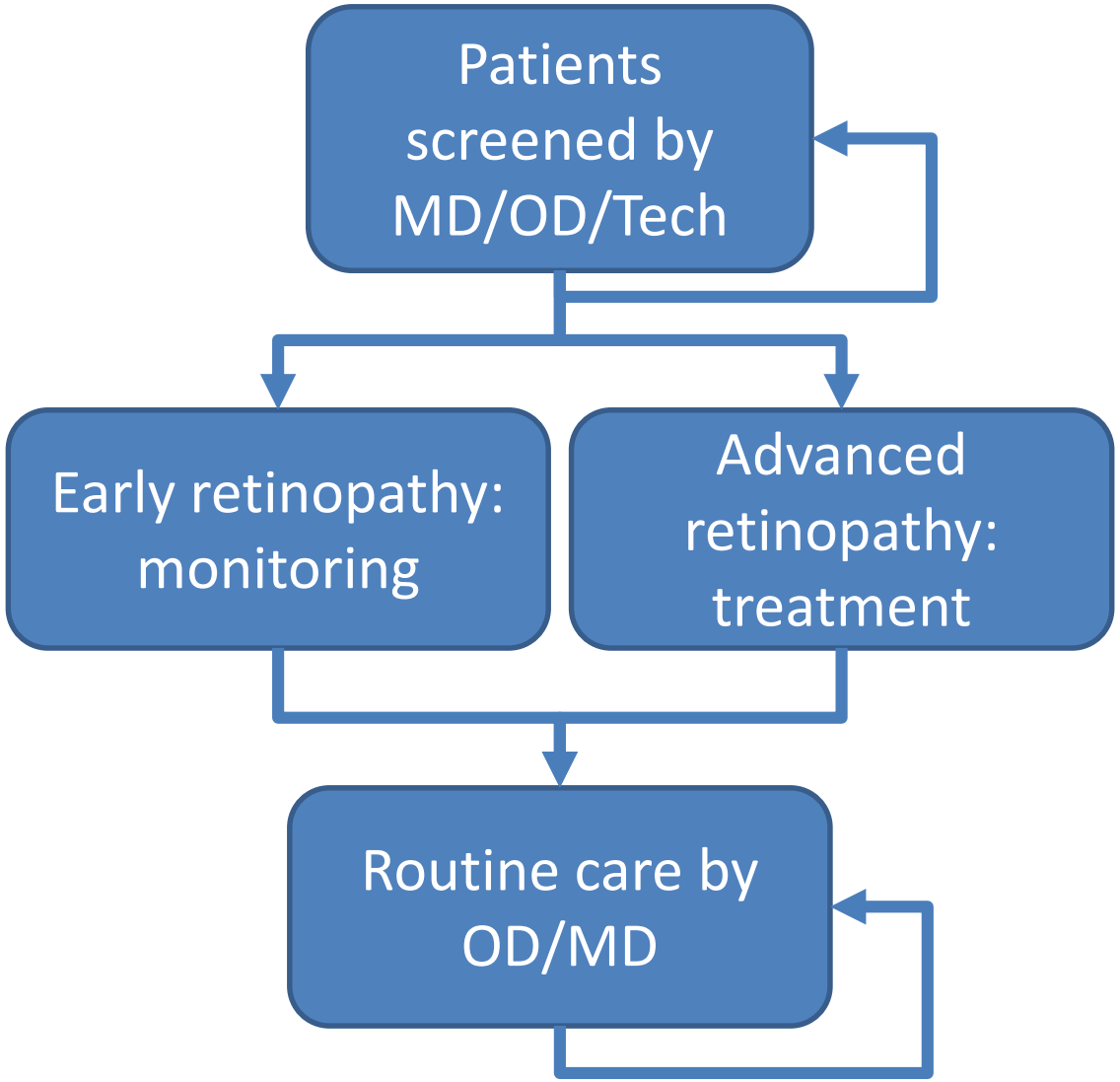
- Patients accessing Georgia VA for (any) care in 2017
  - Approx. 200,000 patients, grouped by zip code
- Clinic locations: 28 VA clinics in Georgia
- Driving distance from center of each zip code to each clinic location calculated via Google API
- Budget/costs, provider capacities, and other clinic-specific values obtained from VA
- Model implemented in CPLEX

Results

Metric	Model A: Maximize Patients Assigned		Model B: Minimize Cost	
	Baseline Providers	Start from Scratch	Baseline Providers	Start from Scratch
Patients Screened	86,340	91,577	20,371	20,160
Average driving distance (miles)	15.8	27.6	21.9	23.2
Total Cost	$24.0 M	$25.0 M	$7.0 M	$5.3 M
Per Patient Cost	$277	$273	$329	$266

Follow-up care for diabetic retinopathy

- We have considered DR screening, but what about longer term treatment?
- Use simulation to "follow" DR patients through treatment
  - Consider downstream effects of technician screenings
  - Determine best mix of MDs/ODs/technicians



Conclusions & next steps

- Each objective function inherently considers trade-offs, but access to diabetic retinopathy screening can be strategically implemented
- Tool can be used by VA when evaluating community care integration
- Next…
  - Further consider implications for follow-up care
  - Generalize beyond Georgia

Acknowledgements

VA HEALTH CARE

Seth Bonder Foundation

CHEPS

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Implementation Challenges

- We solve using CPLEX, not available for provider organizations like the VA
- Implement in Microsoft Excel OpenSolver