OPERATIONS RESEARCH AND HEALTH CARE: AN OPPORTUNITY TO MAKE A DIFFERENCE

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The Road Map

- Where have we been?
- Where are we now?
- Where are we going?
- Where MUST we go!

Health Care

- Patients
- Treatment
- Quality of Life

Operations Research

- Models
- Algorithms
- Data

Common Ground?

Health Care

- Physicians are patient-focused
- Treatment is a resource
- Quality versus quantity

Operations Research

- Resource allocation
- Efficiency
- Optimality

Is there a conflict?

Operations Research: Early Successes

- Scheduling Problems
  - Nurses, Beds, ORs
- Queueing Analysis
  - Patient flow
- Operations Management
  - Inventory control

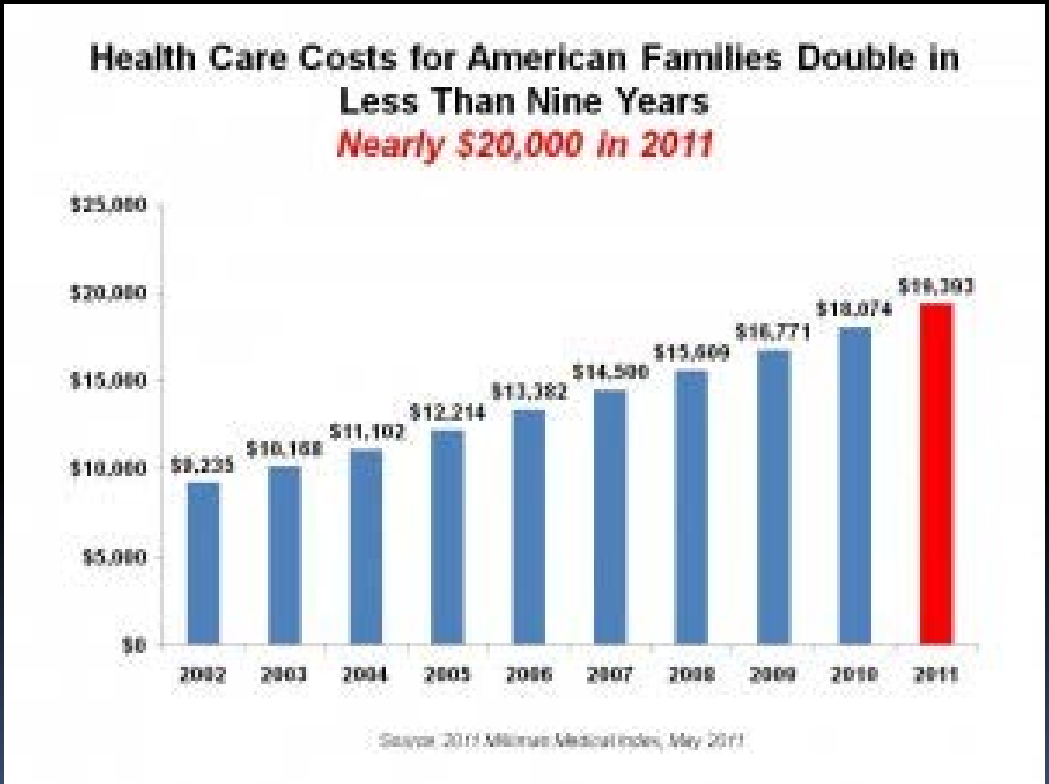
Operations Research: The Present

Explosion of interest (21st Century)

- Treatment Planning and Optimization
  - IMRT, Organ allocation
- Resource Management
  - Pharmaceuticals, stockpiling
- Public Health Policy Analysis
  - Immunization, HIV, pandemic response

Changing Landscape

Health care cost explosion!



Observation and Questions

Health care is about preserving / enhancing quality / quantity of life

Questions:

- How do people die? (mortality)
- How do people become disabled? (morbidity)

Leading Causes of Death -- 1920

Pneumonia (all forms) and influenza
Diseases of the heart
Tuberculosis (all forms)
Intracranial lesions of vascular origin
Nephritis (all forms)
Cancer and other malignant tumors
Accidents excluding motor-vehicle
Diarrhea, enteritis, and ulceration of the intestines
Premature birth

Leading Causes of Death -- 1960

Diseases of heart
Malignant neoplasms
Vascular lesions affecting central nervous system
Accidents
Certain diseases of early infancy
Influenza and pneumonia (excluding newborns)
General arteriosclerosis
Diabetes mellitus
Congenital malformations
Cirrhosis of liver
Other diseases of circulatory system
Suicide
Other hypertensive disease
Chronic and unspecified nephritis and other renal sclerosis
Ulcer of stomach and duodenum

Leading Causes of Death -- 2012

Heart disease
Cancer
Chronic lower respiratory diseases (e.g., emphysema)
Cerebrovascular disease (stroke)
Accidents
Alzheimer's
Diabetes
Nephritis (kidney disease)
Influenza/Pneumonia
Suicide
Septicemia (blood poisoning)
Chronic liver disease and cirrhosis
Hypertension
Parkinson's
Pneumonitis (inflammation of lungs)

Observations

Leading causes of death have shifted away from infections.

Leading causes of death have shifted towards age-related diseases and lifestyle choices.

Most Common causes of deaths are tradeoffs based on lifestyle choices and research advances to address chronic/acute conditions.

More Observations

Medical research advances drive higher health care costs (e.g., Hepatitis C, 1989)

Efficiency (alone) will not stop the surge in health care costs.

Need to rethink how medical advances are measured and used (comparative effectiveness).

Tough Choices for the Future

National debate on healthcare

Medicare insolvence?

Private versus public?

Can Operations Research Save the Day?

Operations Research

Strengths: Efficiency, optimality, allocation

Health Care

Needs: Safety, efficacy, access

Lesson #1

If OR is a hammer,

not all health care challenges are nails.

Lesson #2

Learn the language!

Health care immersion

(Turing Test)

Health Care Priorities

Patient safety

Patient outcomes

Patient access

OR Capabilities

Efficiency

Optimality

Robustness

Lesson #3

Learn the culture!

Collaborate

Integrate

Disseminate

Health Care Needs

Better patient care

Enhanced quality of life

Comparative Effectiveness

OR Capabilities

Modeling

Analysis

Algorithms

Operations Research: A Call to Arms

Optimal solutions to the wrong problems

vs

Good solutions to the right problems

What are the Objectives?

Patient Outcomes: QALY

Patient safety

Access of care

vs

Cost Reduction

Resource Efficiency

Optimal Utilization

Operations Research: A Call to Arms

Elegant Mathematics

versus

Effective Medicine

Comparative Effectiveness

Overall goal …. is the generation and synthesis of evidence that compares the benefits and harms of alternative methods to prevent, diagnose, treat, and monitor a clinical condition, or to improve the delivery of care

Ref: IOM 2009

Comparative Effectiveness

The purpose …. is to assist consumers, clinicians, purchasers, and policy makers to make **informed decisions** that will improve health care at both the individual and population levels.

Ref: IOM 2009

Comparative Effectiveness

The “new and improved”
evidence-based medicine

What are the best treatments for a patient, producing the optimal results, with a minimal risk of harm, that will result in additional quality and quantity of life?

InfORmed Decision Making

OR Methodologies

Stochastic / Deterministic Optimization
Markov Decision Processes
Game Theory
Decision Analysis
Simulation

An Illustrative Example

Designing Clinical Trials

Randomized Control Trials
(Double Blind)

What works best?
For whom?
Side Effects?

Observational Studies

Used when randomized studies are infeasible

Data is non-random

May contain sources of bias that confound treatment effect estimate

Dealing with Bias

Covariates are measured attributes that potentially influence treatment response

Reduce bias in estimate of treatment by removing bias in covariates between treatment and control groups

Matching

Most common way to remove covariate bias is to only compare similar (w.r.t. covariates) treatment and control individuals

Match (similar) treatment and control units

Use resulting groups to estimate average treatment response

Matching Limitations

Exact matches not likely for all individuals, which means that inexact matches must be used

How does one assess the quality of the inexact matches found?

Covariate Imbalance

A measure of residual bias that exists between the selected treatment and control groups

Covariate imbalance should be minimized to reduce bias in treatment effect estimate

Is Matching Necessary?

Matching is used to find groups with covariate balance

If balanced groups are the goal, why not search for this directly?

The BOSS Model: An OR Solution

Find groups (not matched pairs) that minimize a measure of covariate imbalance

Balance **O**ptimization **S**ubset **S**election

The BOSS Model

Find groups (not matched pairs) that minimize some measure of covariate imbalance

T is set of treatment individuals
C is set of control individuals

Balance Optimization Subset Selection:
Find $C' \subseteq C$ that optimizes balance measure *M(T, C')*

Math Programming Formulation

Represent C' using a binary vector x of dimension $|C|$

$f(x) = M(T, C'(x))$, where $C'(x) = \{c \in C : x_c = 1\}$

Let $\boldsymbol{X}$ be the set of covariates

Let $\mu_i(S)$ be mean value of covariate $i \in \boldsymbol{X}$ for individuals in any set S

An Example: Mean-Matching

$$\min \quad f(x) = \sum_{i \in \mathbf{X}} \left| \mu_i(C'(x)) - \mu_i(T) \right|$$

$$\text{s.t.} \quad \sum_{c \in C} x_c = |T|$$

$$x_c \in \{0, 1\} \quad \forall\ c \in C$$

How OR Can Make a Difference

Mean-Matching is an Integer LP

BOSS is NP-Hard in general

OR techniques can solve this problem

- Exact Algorithms
- Approximation Algorithms
- Heuristics

Message to Share

The opportunities for OR are great

OR must focus on the right HC problems

OR is a means, not the ends, in HC

Thank you!

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