Strategies for Improving Chronic Disease Care

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Pradyumna (Autri) Dutta
Greg Ramsey
Ryan McCabe
Background

- Past Work

- Knowledge for Practice
  - Intervention Research
  - Translational Research

- Knowledge for Science and Practice
  - Interdisciplinary Framework
“It can be said with complete confidence that any scientist of any age who wants to make important discoveries must study important problems. Dull or piffling problems yield dull or piffling answers. It is not enough that a problem should be ‘interesting’—almost any problem is interesting if it is studied in sufficient depth. A problem must be such that it matters what the answer is—whether to science generally or to mankind.

P.B. Medawar
Nobel Laureate in Medicine and Physiology
1979
The Problem

• 18.2 million people – 6.3% of the population – have diabetes.

• Diabetes is the 5th leading cause of death by disease.

• Direct medical and indirect expenditures attributable to diabetes in 2002 were estimated at $132 billion.

- American Diabetes Association
More Diabetes Facts

• Approximately 65% of deaths among people with diabetes are due to heart disease and stroke.

• Diabetes is the leading cause of new cases of blindness among adults 20-74 years old.

• In most practice settings, only a minority of adults with diabetes have achieved evidence-based goals.

- American Diabetes Association
... the acute care paradigm is no longer adequate for a world, in which chronic illness is a major health challenge facing all countries. In the U.S. alone, the Centers for Disease Control and Prevention has recently estimated that chronic illness is responsible for 70 percent of all health-related deaths and 75 percent of all health care costs. The aging of the U.S. population and increases in risk factors such as obesity ensures that chronic illness will be an even greater problem in future years.

Innovative Care for Chronic Conditions
World Health Organization, 2002
Strategies for More Effective Diabetes Care

- Question – Science / Practice
- Data – Lab / Field
- Simulation Tools
- Testing – Practice / Policy
Issues for Theory and Practice

A = Expert
B = Experienced Non-Expert
B¹ = Redesigned Non-Expert
C = Consensus Guidelines
D = RCT

Role of Theory

• Medicine – Understanding the Task

• Decision Science and Organization Theory – Decision Making and Policy Practices

• Cognitive Science – Explanation for Success and Failure / Methodology for Investigation
The Task

- Select evidence-based clinical goals
- Initiate therapy
- Titrate therapy to achieve goals
- Assess and manage co-morbid conditions
Background of Empirical Work

• Modify Physician Decisions Through Case Based Learning-(SimCare Project- AHRQ)

• Personalized Information for Physicians and Patients - (Project MOVES - NIH)

• Modify Physician Decisions Through Personalized Case Based Learning and Real Time Decision Support- (Clinical Inertia Project-NIH)
Success and Failure in Chronic Disease Care

• Limited Experience (Lack of Expertise)
• Delay of Feedback
• Cognitive Bias / “First Do No Harm”
• Clinical Inertia
• Nature’s Solution – A. Clark, 1998
Knowledge in a Low Base-Rate World

• Knowledge Production Problem

• Knowledge Transfer Problem

• Arbitrage: The Alternative Solution
Information Arbitrage

• “The Lexus and the Olive Tree”
  - Thomas Friedman

• A Strategy of Knowledge Production
  - Gibbons et al

• A Strategy for Usable/Actionable Knowledge
  - Lindbloom & Cohen
Arbitrage for the Personalization of Care
# The Personalization of Care Problem

## Patients

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<tr>
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## Treatments

### Outcomes:

- a = optimal
- b = moderate
- c = weak
### Ashby’s Law of Requisite Variety*

#### Treatments

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<th>Patient Types</th>
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<tr>
<td>C</td>
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<td>b</td>
<td>a</td>
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#### Outcomes:
- a = optimal
- b = moderate
- c = weak

---

Some Example Patient Types (categories) for Type II Diabetes

“Don’t Worry Be Happy”

“Walking Time Bomb”

“Train Wreck”
Decision Policies for a Low Base-Rate World
Record of Problem Solving Activity with Panel of Real Patient Cases

Physician Problem Solver
Physician Problem Solver

Record of Problem Solving Activity with Panel of Real Patient Cases

Record of Problem Solving Activity with Sample of Synthetic Patient Cases
Record of Problem Solving Activity with Panel of Real Patient Cases

Record of Problem Solving Activity with Sample of Synthetic Patient Cases

Models of Physician Problem Solvers

Record of Problem Solving Activity on Population of Synthetic Patient Data

Physician Problem Solver
Record of Problem Solving Activity with Population of Real Patient Cases

Physician Problem Solver

Record of Problem Solving Activity with Sample of Synthetic Patient Cases

Models of Physician Problem Solvers

Record of Problem Solving Activity on Population of Synthetic Patient Data

Development of Prediction Tools
Patient Model
- SimCare Patient Simulation -
SimCare’s Core Functions

Current SimCare/Clinical Inertia in DM Care Model - Functional Overview

- Therapeutic Goals
- Clinical Encounters
- Observable Patient States
  - Smoking
  - Aspirin Status
  - HgbA1c
  - BG
  - BP
  - LDL
- Lifestyle Recommendations
- Physician Actions
- Medications
- Dose Response and Time Effect Curves
- Medication Effects
The SimCare Study

40 Physicians

3 Simulated Patients
SimCare Patient Cases

• Case 1: Initiate & titrate oral medications to reach evidence-based goals

• Case 2: Detect & treat depression, stop contraindicated metformin, adjust insulin once depression is treated

• Case 3: Recognize that metformin & glipizide are contraindicated, initiate & titrate insulin to reach evidence-based goal
Errors in the Treatment of Chronic Disease

• **Omission**
  - Failure to collect information
  - Failure to start medication
  - Failure to titrate to goal

• **Commission**
  - Contra indications
Health Outcome (A1c) vs. Cost vs. Frequency of Errors (Total) for Selected Physicians on Synthetic Patient 15 (Case 1)

Total Cost = Pharmacy + Referral + Lab Test

- 7.0: 91 days, 8 enctrs
- 7.3: 120 days, 8 enctrs
- 7.5: 126 days, 4 enctrs
- 7.5: 309 days, 9 enctrs
- 8.2: 42 days, 5 enctrs
- 8.3: 360 days, 6 enctrs
Physician Decision Making Methods

Non-Expert Physician

**Process**

(Feedback)

Current A1c – *Previous* A1c

Less Frequent
Less Intensive
Titration

Expert Physician

**Process**

(Feedforward)

Current A1c – *Expected* A1c

More Frequent
More Intensive
Titration
Decision Making as Process Control

• Series of Decisions

• Decisions are Interdependent

• The environment changes, both autonomously and as a consequence of previous decisions
Process Control for Type 2 Diabetes

Goal

Patient Model

Rx

0 0
5 -1%
10 -2%
20 etc.

Patient Response

Inverse Problem

Treatment

Estimated Response

Patient Model

Rx | \( \Delta A_1c \)
---|---
0  | 0
5  | -1%
10 | -2%
20 | etc.

Error

+
Solving the Inverse Problem

- Reasoning From Effects to Causes
- The Default Strategy
- What the Expert Does
Expert’s Solution: Solving the Inverse Problem

Current Treatment:
- No treatment
- Oral Medication
- Insulin

Distance to Goal \( \times \) Current Treatment

Treatment Move

Treatment needed to get the desired effect

<table>
<thead>
<tr>
<th>Distance to Goal</th>
<th>Current Medications</th>
<th>Treatment Move</th>
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<tr>
<td>3</td>
<td>No treatment</td>
<td>Start 2 oral medications</td>
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<tr>
<td>3</td>
<td>Oral med</td>
<td>Increase dose, introduce 2\textsuperscript{nd} oral medication</td>
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<tr>
<td>3</td>
<td>Oral - max dose</td>
<td>Start Insulin, adjust quickly</td>
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Explaining Success

• Process Control
• The Patient Model
• Solving the Inverse Problem
Explaining Failure

• Slips and Mistakes
• Lack of Knowledge
• Inert Knowledge
• Mind Bugs
Decision Making as Process Control

Feed Forward

\[
\text{D} \rightarrow \text{T} \rightarrow \text{E}
\]

Feedback

\[
\text{D} \rightarrow \text{T} \rightarrow \text{E}
\]

W.R. Ashby (1956). Introduction to Cybernetics
Feedback Strategy
(Anchoring & Adjustment)

- Determine Anchor (Goal or Desired Decrease in A1c)
- Determine Distance to Goal
- Select Move (Medication & Dose)
- Compare Observed A1c with Anchor
- Iterate to Goal
Feed Forward Strategy

• Determine Distance and Time to Achieve Goal

• Determine Rate of Change (Slope) Needed to Achieve Goal

• Select Move (Medication & Dose)

• Compare Observed & Expected A1c

• Iterate to Goal
Expert’s Strategy

- Determine Distance & Time to Achieve Goal
- Determine Rate of Change (Slope) Needed to Achieve Goal
- Select Move (Medication & Dose)
- Compare Observed & Expected A1c
- Determine Adjustments in Slope Needed to Achieve Goal
- Iterate to Goal
Comparison of Expert and Expert’s Method on Synthetic Patient 15
Performance of Physician Models on 13 Synthetic Patients

<table>
<thead>
<tr>
<th>Patient Characteristics (A1c)</th>
<th>Feedback Physician</th>
<th>Feedforward Physician</th>
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<tr>
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<td>4018</td>
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<tr>
<td>7 &lt; A1c &lt; 12 (13 total)</td>
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<tr>
<td>A1c &gt; 9 (6 total)</td>
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<td>0</td>
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<tr>
<td>A1c ≤ 9 (7 total)</td>
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<td>3</td>
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Effect of Physician Treatment Strategies on Populations of Simulated Patients
Target Population of Simulated Patients

(Number of Patients Per Cell Reflects Distribution in Real Patient Population)

<table>
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<th>Initial A1c</th>
<th>Adherence</th>
<th>Total</th>
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<tr>
<td></td>
<td>High</td>
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<td>A1c ≥ 10%</td>
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<td>153</td>
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<tr>
<td>8 ≤ A1c &lt; 10%</td>
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<td>284</td>
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<td>A1c &lt; 8%</td>
<td>6687</td>
<td>1024</td>
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<td>Total</td>
<td>8539</td>
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Treatment Strategies for Effective Diabetes Care

Feedback

Weak

Strong

Feedforward

Weak

Strong
Decision Rules
(Far From Goal)

> **Monitor A1c level**: increase meds when patient not at goal and A1c not decreasing

> **Monitor A1c level**: increase meds when patient not at goal

> **Monitor Rate of Change** (slope) in A1c level: increase meds and/or reduce time between visits to maintain minimum rate of reduction in A1c (e.g., 0.5% per month*)

> **Monitor Change in Slope**: increase meds and/or reduce time between visits to maintain minimum rate of reduction in A1c to meet time goal (e.g., 1 yr.)

*compute as monthly decrease in A1c required to reach goal within a specified period of time, e.g., 1 yr.*
Decision Rules
(Near Goal A1c = 7.5)

> Increase dose when A1c has stopped decreasing (Nature’s Solution)

> Increase dose when Avg. SMBG has stopped decreasing (Nature’s Solution)

> Increase dose when A1c above goal (Org. scaffolding)

> Increase dose when A1c above goal & prescribed meds estimated insufficient to reach goal (adding dose response curves)
Decision Rules
(Maintaining Goal)

> Increase med dose when A1c above “recidivism threshold”

> Increase med dose when A1c or avg. SMBG above “recidivism threshold”

> Increase dose when prior avg. SMBG above goal and avg. SMBG values have upward slope.

A1c Recidivism threshold = 7.5%
SMBG Recidivism threshold = 165 mg/dL
Effect of 1 Year of Treatment by Models, Physicians and Clinical Guidelines

Effect of 1 Year of Treatment
Initial A1c ≥ 10%

N= 611 for Models, N= 438 for Physicians

Average A1c (%) vs Years in Treatment

* Staged Diabetes Mgmt (SDM) Guidelines, 2005.
Effect of 1 Year of Treatment by Models, Physicians and Clinical Guidelines

Effect of 1 Year of Treatment
Initial A1c between 8% and 10%

N = 1687 for Models, N = 1207 for Physicians
Effect of Treatment Strategies over Time

N = 611

Average A1c
Initial A1c > 10%

Years in Treatment

Average A1c (%)

FBW
FBS
FFW
FFS
Guidelines
Treatment Strategies and Variation in Patient State

(Initial A1c Values $\geq$ 10%)
(Average A1c Value in Bars)

$N = 611$

![Graph showing standard deviation of A1c for different treatment strategies](image)
## Cost to Bring Patients to A1c Goal - Year 1

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Pt Type (# Pts)</th>
<th>% of Pts at Goal</th>
<th>$ PMPM</th>
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PMPM = Per Member Per Month
## Cost to Bring Patients to A1c Goal - Year 2

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PMPM = Per Member Per Month
# Cost to Reduce A1c by 0.5% - Year 1

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PMPM = Per Member Per Month
## Cost to Reduce A1c by 0.5% - Year 2

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PMPM = Per Member Per Month
Personalization: Exploiting Variety

• Use predictive models to match patients and physicians

• Types of predictive models
  • Statistical (e.g., UKPDS risk engine)
  • Machine Learning (e.g., decision tree)
Experiment: Switch Patients to Low Cost FBW Strategy for Maintenance

- Treat patients A1c > 10% and A1c < 8% with FBS, FFW, FFS, Expert strategies for 1 year

- For all patients that reached goal at end of 1 year:
  - maintain by using existing strategies
  - maintain by switching to FBW strategy
Experiment: Number of Patients at Goal by Year 1

<table>
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Experiment: Cost to Treat
Year 2

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Pt Type (# pts)</th>
<th>Avg Monthly Cost to Maintain Tracked Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Maintained by Initiating Strategy ($)</td>
</tr>
<tr>
<td>FBS</td>
<td>LH (6687)</td>
<td>312</td>
</tr>
<tr>
<td>FFW</td>
<td></td>
<td>331</td>
</tr>
<tr>
<td>FFS</td>
<td></td>
<td>354</td>
</tr>
<tr>
<td>EXP</td>
<td></td>
<td>355</td>
</tr>
<tr>
<td>FBS</td>
<td>HH (458)</td>
<td>1083</td>
</tr>
<tr>
<td>FFW</td>
<td></td>
<td>1097</td>
</tr>
<tr>
<td>FFS</td>
<td></td>
<td>1234</td>
</tr>
<tr>
<td>EXP</td>
<td></td>
<td>1443</td>
</tr>
</tbody>
</table>
Cost Savings Associated with Switching Treatment Strategies in Year 2

<table>
<thead>
<tr>
<th>Initial Strategy (# pts at goal)</th>
<th>Pt Type (# pts)</th>
<th>Cost* Savings per Year ($) when switched to FBW Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>FBS (6344)</td>
<td></td>
<td>837,408</td>
</tr>
<tr>
<td>FFW (6666)</td>
<td>LH (6687)</td>
<td>479,952</td>
</tr>
<tr>
<td>FFS (6682)</td>
<td></td>
<td>1,202,760</td>
</tr>
<tr>
<td>EXP (6686)</td>
<td></td>
<td>1,203,480</td>
</tr>
<tr>
<td>FBS (13)</td>
<td>HH (458)</td>
<td>780</td>
</tr>
<tr>
<td>FFW (69)</td>
<td></td>
<td>1,656</td>
</tr>
<tr>
<td>FFS (299)</td>
<td></td>
<td>7,176</td>
</tr>
<tr>
<td>EXP (428)</td>
<td></td>
<td>(25,680)</td>
</tr>
</tbody>
</table>

*Cost = Cost of year 2 treatment for tracked patients minus cost of year 2 treatments for those same pts when tested in year 2 with FBW strategy.
The Problem of Risk
The UKPDS (Prospective Diabetes Study) Risk Engine*

- Model for predicting absolute risk of CHD
- Based on RCT of 4540 newly diagnosed Type 2 diabetes patients followed for 10 years.
- Independent variables: age, gender, ethnicity, smoking, A1c, SBP, cholesterol
- Statistical model composed of survival probability equations

## Risk of Coronary Heart Disease (CHD): 1 Year of Treatment

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Pt. Type (# pts)</th>
<th>% Risk of Adverse Event within 10 Yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CHD Event</td>
</tr>
<tr>
<td>Untreated</td>
<td>LT (6687)</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>FBW</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>FBS</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>FFW</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>FFS</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>EXP</td>
<td>19</td>
</tr>
<tr>
<td>Untreated</td>
<td>HT (1394)</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>FBW</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>FBS</td>
<td>21</td>
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<tr>
<td></td>
<td>FFW</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>FFS</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>EXP</td>
<td>18</td>
</tr>
<tr>
<td>Untreated</td>
<td>HT (458)</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>FBW</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>FBS</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>FFW</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>FFS</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>EXP</td>
<td>19</td>
</tr>
</tbody>
</table>
Best Practice Strategies: Low Risk (of CHD) and Lowest (PMPM) Cost

- A1c < 8% – Expert
- A1c between 8% and 10% – Feedforward Weak
- A1c > 10% – Feedback Strong
Explaining Best Practice Strategies

- A1c < 8%: *Expert* – makes more moves than other strategies, identifies patients for moves via slope and level of average SMBG.

- A1c between 8% and 10%: *Feedforward Weak* – Makes more moves than feedback models because of scheduling practices (higher # patients with 0.5% decrease) and fewer than other feedforward models (lower cost than these models) because of smooth landing rule.

- A1c > 10%: *Feedback Strong* – This strategy has lower costs because it starts fewer patients on insulin (compared to oral meds insulin is costly)
Issues for Requisite Variety in the Treatment of Chronic Illness

• Regulation (with Respect Patient Categories)

• Personalization (with Respect to outcome, cost, risk)

• Converting Theory into Practice
Issues for Theory and Practice

A = Expert
B = Experienced Non-Expert
B₁ = Redesigned Non-Expert
C = Consensus Guidelines
D = RCT

Power (Performance)

Generality

P₅

P₄

P₃

P₂

P₁

G₁

G₂

G₃
Summary and Conclusions

• Modeling for Decision Making & Treatment Outcomes
  • Comparative Effectiveness Studies
  • Prioritization of Care
  • Policy Development

• Personalization of Care
  • Explanatory vs Predictive Modeling
  • Changing Practice- Training vs Decision Support
  • Redesign of Treatment Policies

• Unsolved Problems
The Way Forward

… To address the rising rates of chronic conditions, an evolution in health care systems is imperative. Acute care will always be necessary (even chronic conditions have acute episodes), but at the same time health care systems must embrace the concept of caring for long-term health problems.

Patients, health care organizations and decision-makers have to recognize the need to expand systems to include new concepts…

Innovative Care for Chronic Conditions
World Health Organization, 2002
It remains to be seen whether work that combines knowledge from fields as diverse as computer science, decision making and the management of clinical care, can contribute to the development of such concepts.

But as Sherlock Holmes said to Watson “… the game is afoot…”