Optimal Management of Blood Pressure and Cholesterol for Patients with Type 2 Diabetes

Jennifer Mason¹, Brian Denton¹,², Nilay Shah², and Steve Smith²,³

¹Edward P. Fitts Department of Industrial & Systems Engineering, North Carolina State University; ²Division of Health Care Policy and Research, Mayo Clinic; ³Division of Endocrinology, Mayo Clinic

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Objective

To design optimal treatment guidelines for the combined management of hyperlipidemia and hypertension for patients with type 2 diabetes.

Model

We use a Markov decision process (MDP) to define the optimal time for treatment:

- **Stages:**
  - Annual decision epochs at ages 40 to 100
- **States:**
  - Health States define the patient’s risk state based on cholesterol and blood pressure, and other risk factors
  - Event States define the occurrence of stroke, cardiovascular events, including CHD, or death from other causes
- **Decisions:** Initiate or delay initiation of cholesterol and blood pressure medications
- **Objective:** Maximize weighted rewards for life years (LYs) and minimize costs

US Guidelines

US Guidelines for Initiation of Cholesterol and Blood Pressure Treatment for Diabetes Patients:

- ATP III: LDL ≥ 100 mg/dL
- JNC 7: SBP > 130 mm Hg or DBP > 80 mm Hg

<table>
<thead>
<tr>
<th>Cholesterol Medications</th>
<th>Blood Pressure Medications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Statins</td>
<td>1. ACE Inhibitors/ARBs</td>
</tr>
<tr>
<td>2. Fibrates</td>
<td>2. Thiazides</td>
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<td></td>
<td>3. Beta Blockers</td>
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<td></td>
<td>4. Calcium Channel Blockers</td>
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Mathematical Model

- Actions:
  \[ A(\ell,m) = \begin{cases} \{l_i, W_i\} & \text{if } m_1 = 0 \\ \{W_i\} & \text{if } m_1 = 1 \end{cases} \]
  where \( A(\ell,m) = A(\ell,m_1) \times A(\ell,m_2) \times \cdots \times A(\ell,m_n) \), \( \ell \) = health state, \( m = (m_1, m_2, \ldots, m_n) \), and \( n \) = number of medications
- Yearly Reward for LYs minus costs:
  \[ r_\ell (\ell, m) = R(\ell, m) - C^O - (C^S(\ell) + C^{CHD}(\ell)) - \left(C^F(\ell) + C^CHD(\ell)\right) - C^{MED}(m), \forall \ell = 1, \ldots, T - 1 \]
- Optimality Equations:
  \[ v_\ell (\ell, m) = \max_{a \in (A(\ell, m))} \left\{ r_\ell (\ell, m) + \lambda \sum_{\forall (\ell', m')} p_{\ell}(\ell', m'|\ell, m) v_{\ell+1}(\ell', m') \right\} \quad \forall t = 1, \ldots, T - 1, \ell, m \]
  \[ v_T(\ell, m) = R(\ell, m) - C^O - (C^S(\ell) + C^{CHD}(\ell)) - \left(C^F(\ell) + C^CHD(\ell)\right) - C^{MED}(m) + E[PDHR], \forall \ell, m \]

Data

- Medical records and a diabetes registry for a cohort of patients diagnosed with type 2 diabetes at Mayo Clinic, Rochester, MN
- United Kingdom Prospective Diabetes Study Risk Engine
- CDC mortality tables

Relative Efficiency

Conclusions

- Patients begin treatment in the following order:
  - Statins, Thiazides, Beta Blockers, ACE/ARBs, and Fibrates (R ≤ $75,000 for men, R ≤ $100,000 for women)
  - Statins, Fibrates, Thiazides, Beta Blockers, and ACE/ARBs (R > $75,000 for men, R > $100,000 for women)
  - Calcium Channel Blockers are only ever initiated for R > $150,000 for men and R > $250,000 for women
  - Coordinated treatment could improve the efficiency of U.S. guidelines by providing greater average LYs and lower costs at the population level.