Treating Cardiovascular Disease: Optimization Models vs Risk-based Heuristics

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Cardiovascular Disease

• With more than half a million deaths in 2015, cardiovascular disease is the leading cause of death in America.
• Most common risk factors: blood pressure and cholesterol.
• Traditional treatment approach: independent treatment of risk factors with one size fits all threshold based policy guidelines.
• Our research objective is to develop clinical algorithms that can be used to improve treatment for the prevention of cardiovascular disease.

Markov Decision Process

Check the patient’s risk profile

- Risk profile: SBP, TC, HDL, race, diabetes, smoking, age, risk calculator, gender
- Objective: to maximize quality adjusted life years (QALY)
- Pill burdens considered instead of monetary costs.
- Each continuous risk factor discretized into 4 states
- Decision epochs from age 40 to age 74.
- Mayo clinic electronic records are used to fit a linear model for 3 risk factors and effect of medications on targeted risk factor.
- Framingham and ACC/AHA CVD risk calculators are used for assessing 10 year risk of developing CVD.
- Boundary condition: life expectancy after 75 years normalized for CVD risk profile at 75.
- Important assumptions: only one medication initiated at a time and 100% adherence to medications

Initiate a medication?

6 different medications are evaluated for their impact on reducing risk of CVD

Decision making Process for MDP

- Choose which medications (if any) to initiate
- Observe metabolic factors and medication status associated with state:
- State evolves probabilistically
- Choose which medications (if any) to initiate
- Observe metabolic factors and medication status associated with state:
- Epoch t+1
- Epoch t+1

V^*(s) = \max_{a_t \in A(s)} \left\{ r_t^{a_t}(s) + \lambda \sum_{j \in S} p_t(j|s, a_t)V^*_{t+1}(j) \right\}

a_t^*(s) = \arg \max_{a_t \in A(s)} \left\{ r_t^{a_t}(s) + \lambda \sum_{j \in S} p_t(j|s, a_t)V^*_{t+1}(j) \right\}

Simulation Model

Patient Demographics

- Estimate CVD Risk
- Add Medications

Update risk factors

Survive with no event

- Adjust CVD risk due to medication use
- Stroke or Heart Attack
- Death from Other Cause

Yes

No

End Simulation for Patient

Age \leq 75

Risk Heuristic

Conclusions

• Risk Heuristic (RH) performs best followed by MDP across all performance metrics for all combinations of risk calculators and disutilities.
• Framingham risk calculator leads to lower life expectancies in CVD simulation due to overestimation of CVD risk compared to ACC/AHA risk calculator.
• MDP and RH increase life expectancy by introducing medications earlier.
• MDP and RH outperform old and new “one-size-fits-all” guidelines in terms of life gained relative to medication burden.

Current Guidelines

- Old Guidelines: JNC7 for SBP and ATP3 for cholesterol
- New Guidelines: JNC8 for SBP and ATP4 for cholesterol
- SBP guidelines use threshold of SBP at which to begin treatment
- Cholesterol guidelines use lipid profile along with general risk profile to begin treatment

Future Scope

• Establishing the generalizability of Risk Heuristic and MDP through larger and more diverse data set.
• Incorporating lifestyle changes as part of treatment regimen to better reflect medical practices.
• Developing a decision support system for medical professionals to use to evaluate alternative guidelines.