CKD & ESRD Population Health Cost Model

Background Materials

Why did we create this model?

Health care organizations systematically underinvest in CKD programs. We created this model to help kidney advocates and decision makers at health care organizations realize the positive financial implications of investing in CKD population health programs.

Our model can be used simply as a conversation starter for understanding current costs, or more rigorously as a tool to help make long-term organizational decisions.

How can the kidney advocate community help advance our work?

1) Our key goal is to recruit alpha-testers who will apply the model to work being done at their organizations. If you are interested in helping alpha-test the model, please visit the link below.
2) We are seeking additional feedback from the broader community. Please see the questions in the "What are our next steps?" section of this document.
3) We are developing use-cases for the model, and would appreciate your help in learning about successful CKD population health management programs across the country.

How can I get the model?

If you are interested in downloading the model, background materials, use cases, and get the link to a demo video, please visit the following link:

http://www.dihi.org/news/ckd-population-health-cost-model

What does the model do?

1) Simulates population level-disease progression from CKD Stage 3 to ESRD
2) Tracks aggregate costs of CKD stage sub-populations (3, 4, & 5), ESRD renal replacement therapy sub-populations (hemodialysis, peritoneal dialysis, transplant), and adverse events like cardiovascular events and hospitalizations
3) Projects and compares a "base case" scenario (no population health management intervention) to an "intervention case" scenario, ultimately providing estimates of the cost changes, revenue changes, and benefits associated with user-specified population health management interventions that:
    a. Slow CKD progression, reduce CKD mortality, and reduce adverse events like cardiovascular events and hospitalizations
    b. Optimize the transition to ESRD by reducing the incidence "crash" dialysis initiations, increasing the percentage of patients who receive transplant or peritoneal dialysis instead of hemodialysis, reducing mortality, and reducing adverse events like cardiovascular events and hospitalizations

c. Increase the efficiency of care and directly reduce costs without necessarily impacting clinical outcomes

What are the next steps?

1) We are working to develop use-cases for the model based on examples from Duke Health, Geisinger Health System, the Mayo Clinic, and other organizations. The use-cases are intended to help validate the model, as well as provide users and operational leaders with concrete examples of successful population health programs that they might consider evaluating for implementation at their own institution.

2) The Working Group welcomes additional feedback from the kidney community, we are particularly interested in the following areas:
    a. Ease and simplicity of the model.
    b. Any inputs or outputs that are missing from the model.
    c. Additional ideas that could demonstrate validation and value of this tool for operational leaders and clinicians.

Usability and usefulness of the model as a service to the community.

3) We are seeking alpha-testers who have an interest in applying the model at their institutions and providing more rigorous feedback.

How does the model work?

The tool uses a simple 6-state Markov model to project changes in sub-population sizes over time. The Markov model is governed by:

1) starting state population sizes, which are derived by scaling USRDS prevalence rates to the user-entered total patient population size
2) transition probabilities between states, which are derived from KDIGO guidelines and other publications, but can be fine-tuned using a Model Optimization tool to fit available historical prevalence data

The "intervention case" allows the user to employ evidence interventions which alter the transition probabilities between states (for example, ACE inhibitors decreasing the transition probability from CKD stage 3 to CKD stage 4). The effects of these interventions on transition probabilities were estimated using published data, and the magnitude of the effect in the model is governed by the percentage of the population (that the intervention is appropriate for) that the user applies the intervention to.

The "intervention case" also allows the user to directly reduce the cost of each state compared to the "base case" to simulate interventions that directly reduce costs without necessarily impacting clinical outcomes.

The costs of each state and adverse events like cardiovascular events and hospitalizations are derived from Medicare cost data, but can be manually entered by the user if custom data is available.

Figure 1: Model Overview Schematic

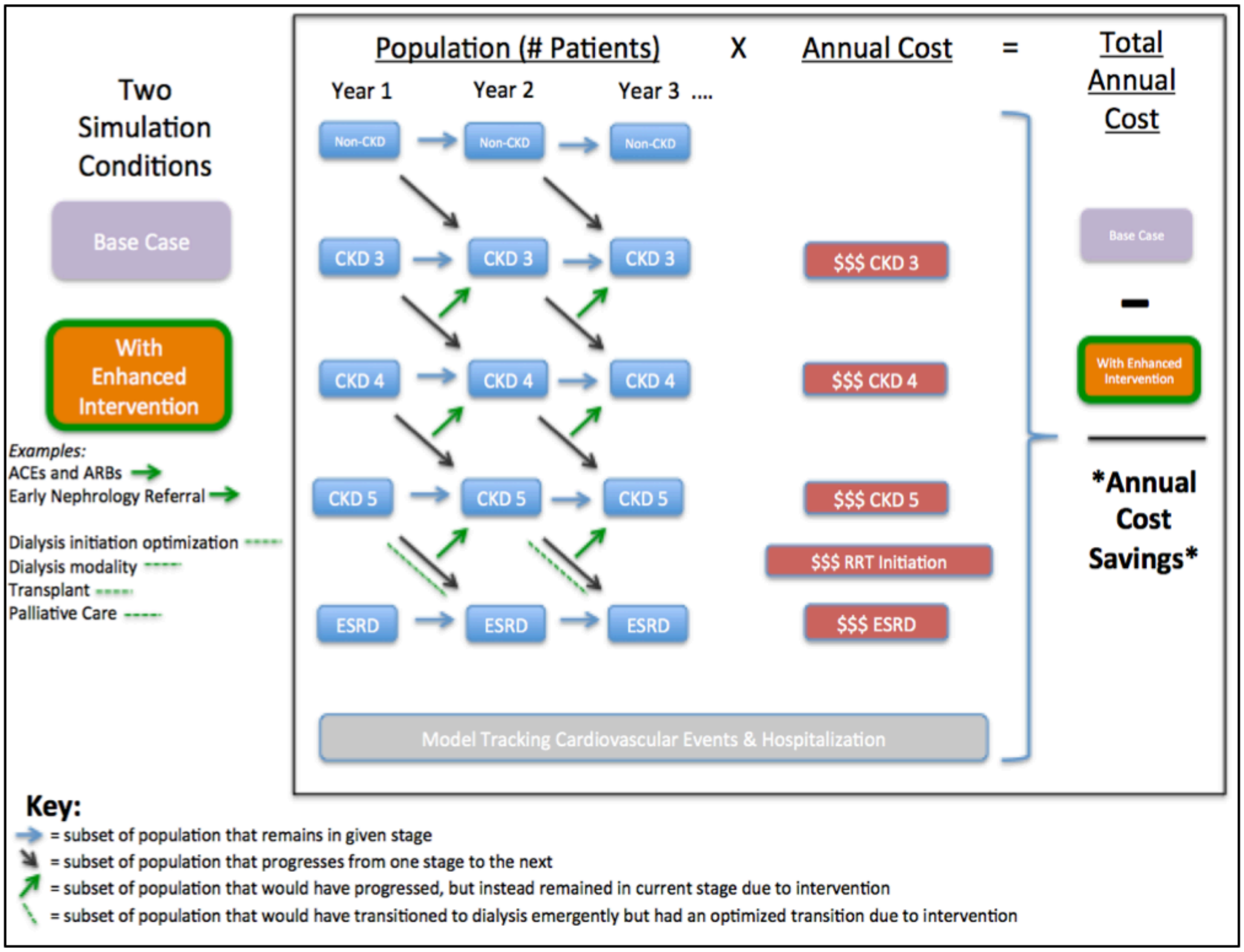

Figure 2: Markov Model Schematic

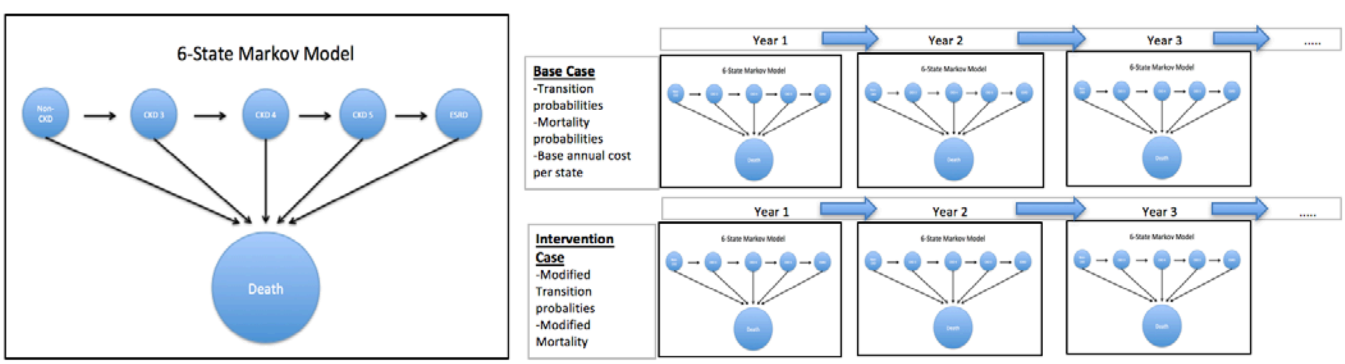

Figure 3: Excel Worksheet Summary

Sheet Number	Sheet Title	Sheet Purpose
1	Model Summary	Explanation of model organization and logic.
2	Inputs and Outputs	Facilitates input of basic parameters and visualization of model outputs.
3	CKD and ESRD Prevelance	Projects future CKD prevalence by CKD stage with and without intervention using a 6-state Markov Model. The Markov model contains transition possibilities for remaining in the current state, progression to the next state, and death.
4	Renal Replacement Therapy	Calulcates cost change effect of altering dialysis initiation timing (urgent-start vs. planned-start) and of altering renal replacement modality (hemodialysis vs. peritoneal dialysis vs transplant).
5	Adverse Events	Calculates numbers of adverse events (all cause death, cardiovascular events, and hospitalization) in both intervention and non-intervention groups and their associated costs.
6	Total Cost Projections	Calculates total cost of population using data from sheets 3, 4, and 5.
7	Progression Rates	Estimates proportion of CKD Stage population that remains alive and progresses to the next CKD stage each year, by using published data on GFR reduction rates by CKD stage and mortality rates by CKD stage. This is then used for the Markov Model transition probabilities in sheet 3.
8	Financial Inputs	Stores detailed financial inputs related to costs and reimbursement.
9	Clinical Inputs	Stores detailed, pre-populated inputs for population characteristics and clinical intervention effects using data obtained from systematic review
10	Model Fit	Compares model performance to historical data and allows for automated optimization of model parameters.
11	Sensitivity Analysis	Demonstrates which variables most greatly effect model outputs.

What are the key assumptions and simplifications that the model makes?

The key parameters that govern model dynamics are stage-specific progression rates, stage-specific mortality rates, and the effects of evidence-based clinical interventions. These parameters were derived through an extensive search of the available literature.

The risk of significant error in progression and mortality rates is mitigated by a built in "Model Optimization" tool, which fine-tunes these parameters through a solver function that fits the model using historical data. The model includes a "Sensitivity Analysis" sheet which demonstrates the extent to which small changes in these key parameters effect model outputs.

To minimize the risk of significant error in the simulated effects of evidence-based clinical interventions, the effect sizes of the interventions were reviewed by various members of the working group to ensure that published data was appropriately integrated into the model.

What are the general limitations of the model?

As with all models, there is a fine balance between complexity and practicality. The model was designed to be as user-friendly and accessible as possible. Therefore, it was built in Excel to enable near-universal usability.

While this model is less sophisticated and potentially less accurate than more complex models that could be built using software like TreeAge Pro, it allows the average user to manipulate the model inputs and interpret the model outputs more easily.

What are some issues the work group has already thought about and addressed?

The work group has spent the past several months discussing potential issues and making appropriate assumptions and simplifications. Some of these decisions are discussed below.

- Adopting a population-level, prevalence-based approach, as opposed to simulating disease progression at an individual patient level (minimize complexity)

- Using a Markov framework, as opposed to a Semi-Markov process or Monte Carlo simulation (minimize complexity)

- Limiting the sub-populations to CKD Stage 3, CKD Stage 4, CKD Stage 5, and ESRD, and excluding CKD Stages 1 and 2 (focus the most clinically and financially relevant patient populations)

- Not taking population demographics such as race and age into account, and instead relying on the model's optimization tool. The optimization tool can fit key parameters to historical data, and therefore will indirectly account for any significant differences between healthcare organizations' patient populations.

- Limiting renal replacement therapy modalities to center hemodialysis, peritoneal dialysis, and transplant, as less data is available for other options like home hemodialysis and palliative care