$2 Billion Reduction in U.S. Healthcare Costs Identified in Mayo Clinic Biomedical Systems Dynamics Study

Project Team: James Rogers, Advance Management Group; Edward Gallaher, Advance Management Group; Craig Hocum, Mayo Clinic; David Steensma, Dana-Farber Cancer Institute; T. Ronald Chrisope, Advance Management Group; David Dingli, Mayo Clinic; James McCarthy, Mayo Clinic

Contributors: Carolyn Niehaus, Rebecca Niles, Kris Wile, Matthew Bigman

Systemic, long-view approach to End Stage Renal Disease treatment increases patient well-being while decreasing drug costs by $2 million per year at Mayo Clinic in Rochester, MN.

Craig Hocum, a Physician's Assistant focused on Nephrology and Hypertension at Mayo Clinic, along with Jim Rogers and Ed Gallaher of the Advance Management Group, were blown away by the insights their team came to as a result of the integration of systems thinking and clinical practice in End State Renal Disease (ESRD). Their team developed a tool that uses System Dynamics to provide improved, individualized Erythropoietic Stimulating Agent (ESA) dosing regimens for dialysis patients, creating positive effects on patient health and well being, while reducing Mayo's yearly drug and hospitalization costs by $2 million. Though not precisely quantified, additional savings of about the same scale have been realized through reduced hospitalizations.

"Behavior over time graphs have become my tool of choice in clinical decision making for my patients,"
- Craig Hocum, P.A., Mayo Clinic

Rogers and Gallaher were originally commissioned to develop an ESRD reporting system, but their long history of Systems Dynamics work helped them find potential leverage in the longitudinal per-patient data that was not normally considered in other dialysis treatment plans. Combining this big-picture view with Hocum's direct experience managing ESA treatment led the team to a strong understanding of the underlying biophysical dynamics and a highly effective individualized treatment solution.

Assessing the Data through System Dynamics

The administration of ESA is intended to raise red blood cell levels for patients undergoing dialysis treatment. When Hocum, Rogers, and Gallaher looked at the historical dialysis patient data, they saw oscillations both above and below the optimal red blood cell count as a result of both over- and under-administration of ESA. Both too high and too low red blood cell levels

have negative effects: low blood cell levels are associated with fatigue and poor quality of life, while high red blood cell levels are associated with increased risk of stroke and cardiovascular disease. ([1], p3)

By mapping the situation using Systems Dynamics tools, the team identified that the wide oscillations occurred due, in part, to a delay of 20 days or more in the effect of the ESA. This delay in impact resulted in patients being administered a second dose before the first had taken effect, which meant over-administration of the ESA and higher than intended red blood cell levels. Once the caregiver noted these high red blood cell counts, they would then delay additional administration of ESA in order to allow the red blood cell levels to lower on their own. Again, due to the significant delay in the effect of the ESA, it would then be "too late" at the next administration to prevent very low levels in the red blood cells. In Systems Thinking, this system of impact is referred to as a delayed feedback loop, where each factor impacts the next with a delay.

"[We were] reducing the amount of ESA by almost 50%, which results in a cost savings of more than $2 million per year"
- Jim Rogers, MS, MBA, Advance Management Group

Misunderstandings Mapped and Corrected

Once they identified the delayed feedback loops in the system of ESA administration, the team then created a stock and flow diagram of the key components (see figure below). When talking with David Steensma, a hematologist, this clear representation of the system and its elements provided a clear, accurate way to communicate the idea of systemic delays, which allowed Steensma to easily identify and correct a misunderstanding present in the team's model.

[1] Rogers, Jim, Ed Gallaher, Craig Hocum, et al. "Individualized Medicine and Biophysical System Dynamics: An Example from Clinical Practice in End Stage Renal Disease." http://www.systemdynamics.org/conferences/2011/proceed/papers/P1299.pdf

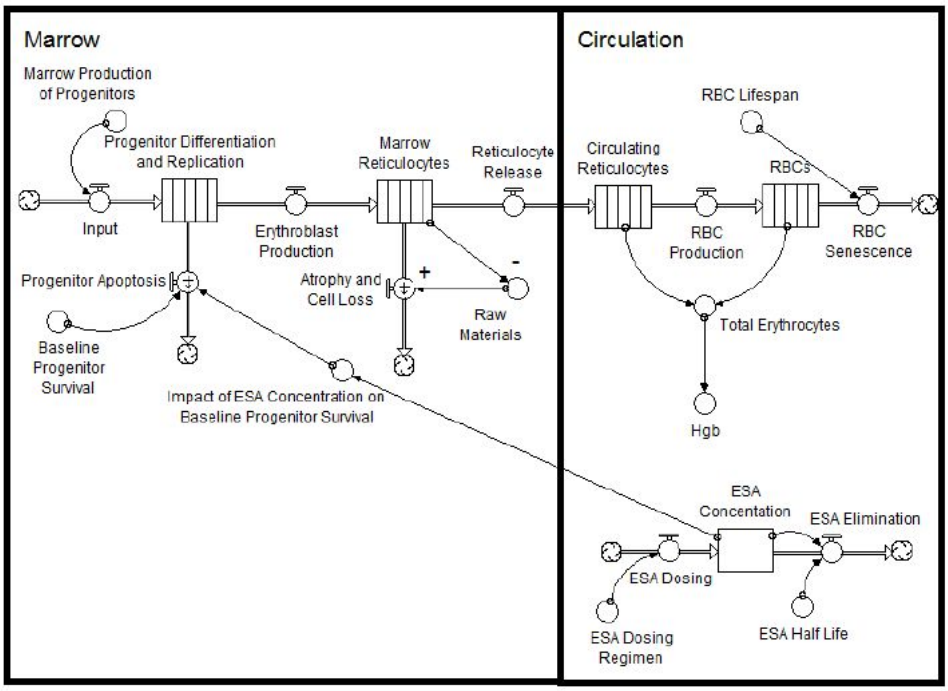

Figure 1: This stock and flow diagram allowed the researchers to effectively communicate with specialists and resolve key misunderstandings in their work.

Systems Thinking provided the tools to clearly communicate across discipline-boundaries and to gain insight into the true nature of what they were trying to understand. In Rogers' words: "As Ed astutely pointed out...we [didn't] have a nephrology problem, we [had] a hematology problem." And as Ed Gallaher himself later noted, the team was "collaborating from different disciplines…each discussion was a teachable moment for everyone involved."

With their misunderstanding corrected and a cross-disciplinary arsenal of knowledge, the team was able to develop a System Dynamics model that used an individual's historical data to generate an optimal dosing regimen, customized for each patient.

New Protocol Leads to Improved Health and Savings

The use of the dosing protocol defined by the System Dynamics model provides a high level of accuracy and customization that has reduced overall hospitalization time by 25% while also reducing the amount of ESA administered to patients. If this dosing method were to be applied across the United States, it could cut the use of ESA in half, saving approximately $2 billion dollars a year.

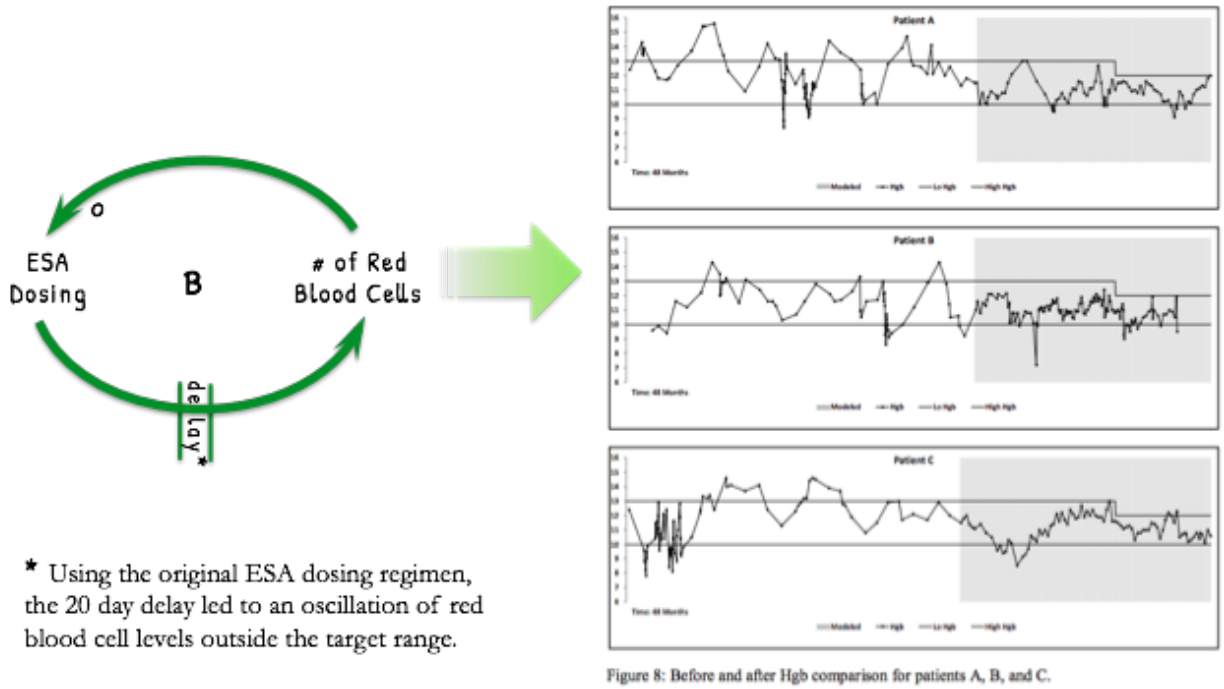

Figure 2. Behavior over time graphs generated at the conclusion of the study show that the oscillation patterns of the new treatment plans (indicated with a grey background) now fall within the optimal red blood cell levels (indicated by the two horizontal lines).

In addition to saving money, the new protocol also leads to dramatically improved health outcomes for patients. “It’s important to go back to individualized medicine – [the model is] based on how [patients] respond, which gives insight into their overall health,” says Hocum. When using the new model, fluctuations outside of the expected range of red blood cell levels generally indicate other bodily system failures or complications. In this way, the model allows doctors to monitor and address these complications earlier on, adding to an overall decrease in costly hospitalizations.

In Hocum’s words, systems thinking allows users to predict a patient's trajectory: “If we have a good model and a good fit, not only do we get stabilization…[but,] if a person has the time to look at it, there is predictability.”

With billions of dollars to be saved, and opportunities to increase a patient's’ well-being, “we’re surprised that diffusion of this thinking has taken as long as it has” says Rogers. After they were nominated for the System Dynamics Society bi-annual Application Award, the team is moving forward with the Biomedical Systems Dynamics Special Interest Group and looking forward to sharing these tools and insights in related fields where Systems Dynamics can yield similar results. Fields

“We are very excited about this development. This is an excellent example of individualized medicine. We feel if this were extended throughout the United States we could potentially save Billions of dollars in our healthcare system.”

- James T. McCarthy, MD, Chair of Division of Nephrology and Hypertension, Mayo Clinic

like methadone treatments, glucose and insulin treatments, thyroid hormone care, and long-term pain management all seem likely to yield substantial benefits from a similar systemic approach to dosing protocols.

Thanks to Jim Rogers, Ed Gallaher, and Craig Hocum for taking the time to share their story.