Using System Dynamics Tools to Integrate Evidence into VA Stroke Care:

Part 1

Kristen Hassmiller Lich, PhD, MHSA (klich@unc.edu)

Project team: Hayden B. Bosworth PhD, Linda Williams MD, Dawn Bravata MD, Chris Beadles MD, Amy Kaufman MSW, Jack Homer PhD, Eric Cheng MD, David Matchar MD

January 25, 2011

VA QUERI Stroke — Quality Enhancement Research Initiative

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Our approach

- This project uses System Dynamics (SD) modeling to help key stakeholders of the Stroke QUERI achieve a comprehensive understanding of the complex systems involved in stroke prevention and treatment and provides **a tool to support effective stakeholder communication and the establishment of strategic actionable priorities.**

Our goals today:

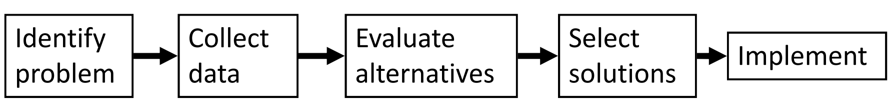
- To review **why we chose system dynamics modeling**
- To (briefly) **summarize the model** structure
- Present the **"base case"** and get familiar with key inputs and model output
- Present **simulated intervention results**
- To share **what it took** to implement these methods, **lessons learned**, and **next steps**

Why System Dynamics modeling?

Difficulties with standard approaches

- Challenges to effective, sustainable translation of research into action in the real world (our QUERI mission!):
  - ***Limited resources.*** funding does not cover development and evaluation of policies and clinical interventions. Furthermore, mistakes in strategic direction are costly.
  - ***Numerous policy options.*** It is difficult to develop a single strategic plan from the large and diverse evidence on stroke.
  - ***Multiple stakeholders, multiple visions.*** When dealing with complex problems, stakeholders often operate from conventional and often narrowly focused 'wisdom' about how to improve systems of care that all limit their ability to see new ways of operating.
  - ***Absence of a forum for integration.*** Multiple stakeholders are key to successful and sustainable implementation. There is a lack of existing linking structures in which key participants can come together to make change happen.

Steps in Standard Problem Solving



System Dynamics Modeling

Dynamic Modeling for Complex Policy Environments

Origins

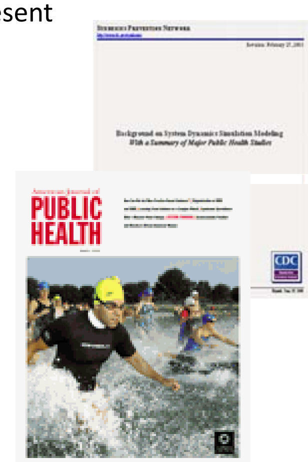
- **Jay Forrester, MIT, *Industrial Dynamics*, 1961 ("One of the seminal books of the last 20 years."-- NY Times)**
- **Public policy applications starting late 1960s**
- **Population health applications starting mid-1970s**

Forrester JW. Industrial Dynamics. Cambridge, MA: MIT Press; 1961.

Sterman JD. Business Dynamics: Systems Thinking and Modeling for a Complex World. Boston, MA: Irwin/McGraw-Hill; 2000.

System Dynamics Health Applications

1970s to the Present

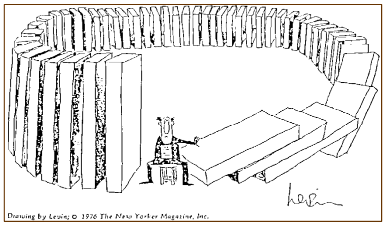


- **Disease epidemiology**
  - Cardiovascular**, diabetes, obesity, HIV/AIDS, cervical cancer, chlamydia, dengue fever, drug-resistant infections**
- **Substance abuse epidemiology**
  - **Heroin, cocaine, tobacco**
- **Health care patient flows**
  - **Acute care, long-term care**
- **Health care capacity and delivery**
  - **Managed care, dental care, mental health care, disaster preparedness, community health programs**
- **Health system economics**
  - **Interactions of providers, payers, patients, and investors**

Homer J, Hirsch G. System dynamics modeling for public health: Background and opportunities. *American Journal of Public Health* 2006;96(3):452-458.

System Dynamics Modeling

Dynamic Modeling for Complex Policy Environments



Origins

- **Jay Forrester, MIT, *Industrial Dynamics*, 1961 ("One of the seminal books of the last 20 years."-- NY Times)**
- **Public policy applications starting late 1960s**
- **Population health applications starting mid-1970s**

Good at Capturing

- **Differences between short- and long-term consequences of an action**
- **Time delays (e.g., incubation period, time to detect, time to respond)**
- **Accumulations (e.g., prevalences, resources, attitudes)**
- **Behavioral feedback (reactions by various actors)**
- **Nonlinear causal relationships (e.g., threshold effects, saturation effects)**
- **Differences or inconsistencies in goals/values among stakeholders**

Forrester JW. Industrial Dynamics. Cambridge, MA: MIT Press; 1961.

Sterman JD. Business Dynamics: Systems Thinking and Modeling for a Complex World. Boston, MA: Irwin/McGraw-Hill; 2000.

Mathematical models to inform strategic planning

Events

Patterns

Structure

Increasing:

- **Depth of causal theory**
- **Robustness for longer-term projection**
- **Value for developing policy insights**
- **Degrees of uncertainty**
- **Leverage for change**

Time Series Models
Describe trends

Multivariate Statistical Models
Identify historical trend drivers and correlates

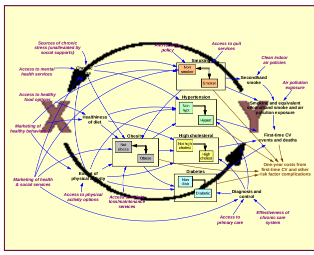
Dynamic Simulation Models
Anticipate new trends, learn about policy consequences, and set justifiable goals

Homer, 2010

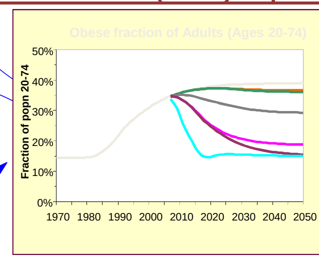
Modeling for Learning

Multi-stakeholder Dialogue

Dynamic Hypothesis (Causal Structure)



Plausible Futures (Policy Experiments)



SYSTEM

DYNAMICS

Morecroft JDW, Sterman J. Modeling for learning organizations. Portland, OR: Productivity Press, 2000.

Sterman JD. Business dynamics: systems thinking and modeling for a complex world. Boston, MA: Irwin McGraw-Hill, 2000.

Why Use System Dynamics Methods…

- Help us develop a **shared understanding** of the system
- Teach us to **think differently** about how systems behave (that is, in terms dynamics, circular causal feedbacks, accumulations, etc)
- Allow stakeholders to **view the larger system** they are embedded within
- Provide a **framework for integrating** what we know, and determining importance of what we don't know
- Support identification of **high impact leverage points**
- Offer a virtual world in which to **"try out" and compare policies**

“Effective” models of complex systems

- Causal (not correlational)
- Dynamic (not equilibrium)
- Grounded in empirical tests (econometrics, ethnography…)
- Broad boundaries (not limited to one disciplinary domain)

Engage stakeholders who develop “ownership”

THE MODEL: WHAT IT LOOKS LIKE AND HOW IT HAS BEEN DEVELOPED

Project time line

- **May 2008-October 2008:** 6-month RRP to develop preliminary model
- **May 2010:** 12-month RRP start-up! Initial day-long meeting with Core Modeling Team to walk through structure and assumptions in the current model, and ask for feedback
- **May-August 2010:** Model refinement (structural and numerical), recalibration and analysis
- **August 23 2010 Workshop:** Model-informed discussion of Stroke QUERI strategic plan
- **August 31 2010:**

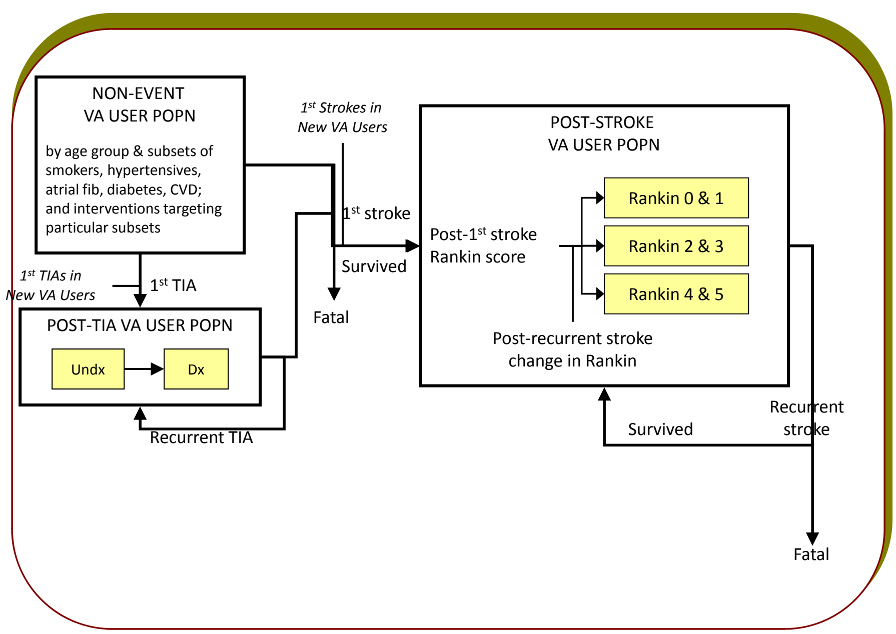
Project time line

- **May 2008-October 2008:** 6-month RRP to develop preliminary model
- **May 2010:** 12-month RRP
with Core Modeling Team
assumptions in the curre
- **May-August 2010:** Mode
numerical), recalibration
- **August 23 2010 Worksho**
Stroke QUERI strategic pl
- **August 31 2010:** Pause!

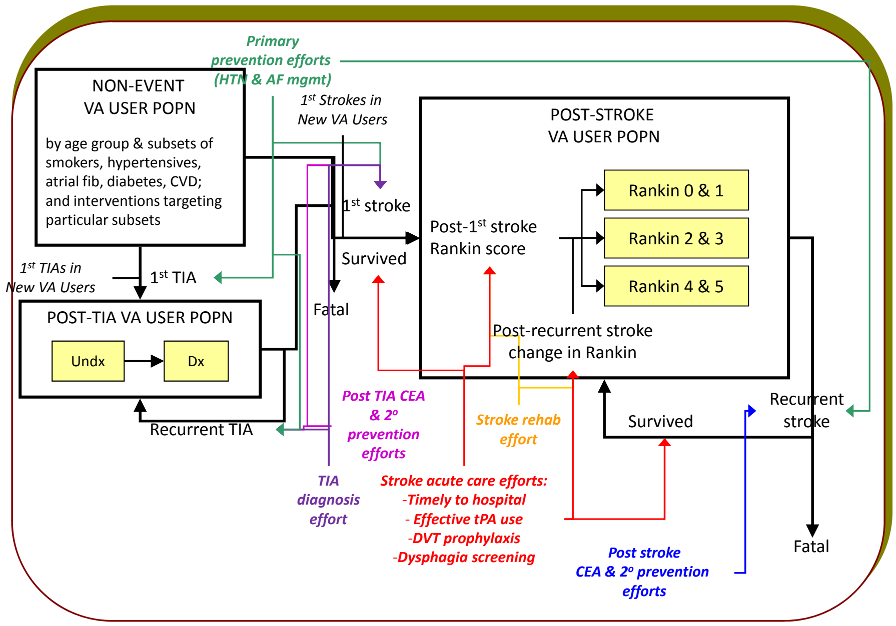
Project time line

- **May 2008-October 2008:** 6-month RRP to develop preliminary model
- **May 2010:** 12-month RRP start-up! Initial day-long meeting with Core Modeling Team to walk through structure and assumptions in the current model, and ask for feedback
- **May-August 2010:** Model refinement (structural and numerical), recalibration and analysis
- **August 23 2010 Workshop:** Model-informed discussion of Stroke QUERI strategic plan
- **August 31 2010:** Pause!
- **August-May 2010:** Designing and executing sensitivity analysis, preparing manuscripts and toolkit, presenting work, brainstorming next steps

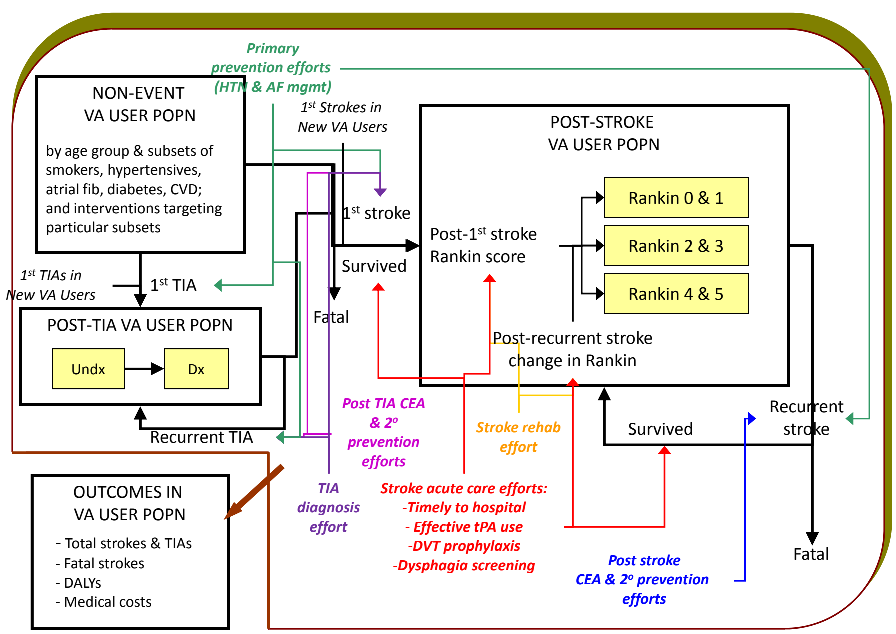
A Framework for Stroke Strategic Planning



A Framework for Stroke Strategic Planning



A Framework for Stroke Strategic Planning



Model overview: Outcomes

- **Total number of diagnosed TIAs and strokes:** the number of diagnosed TIAs and strokes that occur per year, the incidence rate per 1,000 enrollees per year, and the total number of strokes occurring in the next 5 years, 10 years, and 20 years.
- **Total number of fatal strokes:** the number of stroke fatalities per year (enrollees who died as a result of their stroke within 3 months after the event), the rate per 1,000 enrollees per year, and the total number of fatal strokes occurring in the next 5, 10, and 20 years.
- **Average Rankin score for enrollees post stroke:** the average modified Rankin score 3 months post stroke per year.
- **Disability-adjusted life years (DALYs):** the difference between scenarios, over 5 years, 10 years, and 20 years.
- **Medical costs:** the costs related to stroke for which the VA would be responsible each year and cumulatively for the next 5, 10, and 20 years.

Model overview

- Stock and flow model
- Programmed using Vensim software (www.vensim.com)
- Focus is on veteran users, defined as VA enrollees that have had at least one primary care clinic visit in the past 12 months
- Simulates population of veteran users from 2010-2030
- Used VA data whenever possible
  - Worked closely with Dr. Bruce Vogel to identify relevant VA data sources, including published reports, published journal articles, and VA databases (including VA Enrollment File, VA Decision Support System National Data Extracts, and VA Functional Status Outcomes Database)
- When VA data was unavailable, estimates were based on scientific literature and/or expert opinion
- Cost data is most imperfect

Model overview: Inputs

- **Stock-related parameter values:** parameters that initialize the number of users in each stock.
- **Flow-related values:** parameters that shape the flows between stocks over time (for example, controlling the incidence rate of stroke among pre-event users, functional loss post stroke, and death rates).
- **Current quality of care:** parameters that establish the current quality of care in the VA along the key dimensions delineated.
- **Cost parameters:** parameters that specify the per-event costs and the per-person per year costs included in the model.
- **Level of functioning per stock:** estimates of the level of functioning per stock that are used to calculate DALYs.
- **Ability parameters:** parameters that specify the extent to which interventions can alter model flows.

Interventions – What is possible?

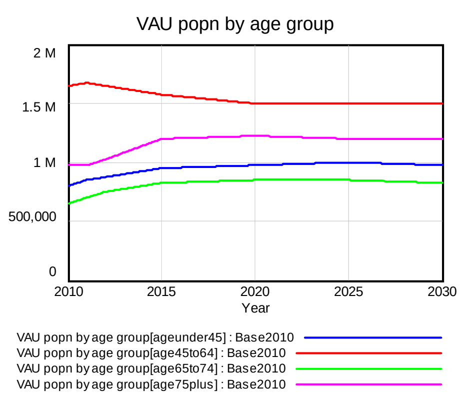
INTERVENTION:	DESCRIPTION:
TARGETING THE PRE-EVENT POPULATION	
HTN All	For hypertensives with pre-intervention SBP of 140+, enhance BP tx*
HTN Severe	For hypertensives with pre-intervention SBP of 160+, enhance BP tx*
HTN for DM	For hypertensives with diabetes, enhance BP tx*
HTN-AF for CVD	For NEVAUs with CVD, enhance BP tx* and increase good AF mgmt from 34% to 60%
AF All	For all NEVAUs with AF, increase good AF mgmt from 34% to 60%
Cluster: HTN-AF all	HTN All + AF All
TARGETING THE POST-TIA POPULATION	
TIA Dx	Increase TIA diagnosis from 65% to 75%
TIA Mgmt	For diagnosed TIA pts, increase good preventive mgmt from 50% to 90%
TIA CEA	For the 15% of diagnosed TIAs eligible for CEA, increase fraction getting CEA from 35% to 70%
Cluster: TIA Dx-Mgmt	TIA Dx + TIA Mgmt
TARGETING THE POST-STROKE POPULATION	
S Timely	Increase fractions of strokes arriving timely to hospital: 1st strokes raise from 18% to 60%; recurrent strokes raise from 18% to 60%
S tPA	Improve use of tPA: for eligibles (33% of those timely to hospital), increase effective use from 6.2% to 50% and decrease ineffective use from 2.2% to 0.5%; for ineligibles, decrease use from 0.3% to 0.5%
S Rehab	For the 70% of survived strokes eligible for rehab, increase use of good rehab from 70% to 90%
S DVT	Increase the fraction of strokes getting DVT prophylaxis from 78% to 95%
S Dysphagia	Increase the fraction of strokes getting dysphagia screening from 23% to 80%
S Mgmt	For post-stroke pts, increase good preventive mgmt from 70% to 90%
S CEA	For the 15% of strokes eligible for CEA, increase fraction getting CEA from 35% to 70%
Cluster: Stroke 6	S Timely + S tPA + S Rehab + S DVT + S Dysphagia + S Mgmt

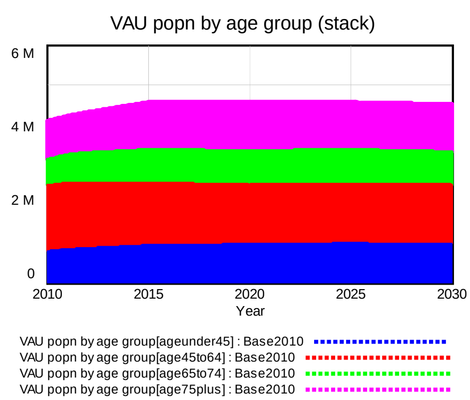
* "Enhance BP tx" brings under control (i.e. to SBP<140) 60% of pts starting at SBP 140-159, and 40% of pts starting at SBP 160+

Illustrative key input parameters

Variable	Value	Primary source
% of the population that is post-stroke	4.1%	Cornell, 2007
% of the population that is post-TIA and diagnosed	0.9%	Cornell, 2007
% of all strokes preceded by a TIA	7%	OQP 2007
% of all strokes that are recurrent	18%	OQP 2007, AHA 2010
Annual incidence rate of stroke in pre-event population	3-6 per 1,000 per year	AHA 2010
Average life expectancy post stroke	6-7 years	AHA 2010
% of strokes that are fatal (30 days)	8-12%	OQP 2007, AHA 2010
% of survived first strokes that are R23	31%	VA FSOD
% of survived first strokes that are R45	46%	VA FSOD
% TIAs have a recurrent TIA w/in 90 days	16.5%	OQP 2007
% TIAs have a stroke w/in 90 days	13.8%	OQP 2007
% TIAs have a stroke after 90 days	0.8% per year	AHA 2010
% strokes have a recurrent stroke w/in 90 days	5%	Johnston, 2007
% strokes have a recurrent stroke after 90 days	3.6% per year	Hankey, 1998

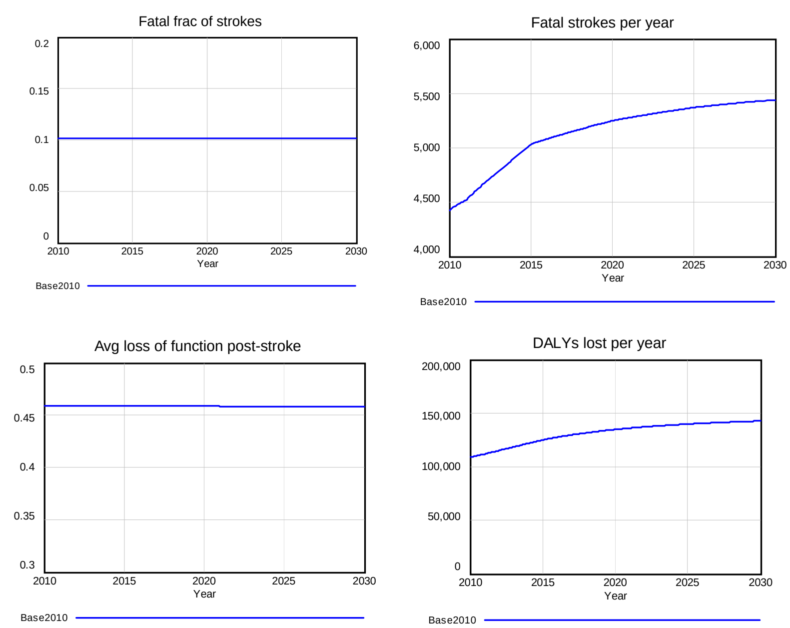
Base Run Assumed VAU Population by Age Group





THE MODEL: RESULTS

Base Run Stroke Mortality & Morbidity



	5 yr totals			10 yr totals			20 yr totals		
Intervention	**Reduction in Cumulative DALYs lost**	**Reduction in Cumulative Stroke Fatalities**	**Reduction in Cumulative Strokes**	**Reduction in Cumulative DALYs lost**	**Reduction in Cumulative Stroke Fatalities**	**Reduction in Cumulative Strokes**	**Reduction in Cumulative DALYs lost**	**Reduction in Cumulative Stroke Fatalities**	**Reduction in Cumulative Strokes**
All Interventions	24,328	2,114	12,401	99,000	5,733	36,842	300,000	15,201	92,535
HTN All	7,396	585	5,896	31,000	1,753	17,522	96,000	4,443	44,040
HTN-AF for CVD	5,260	417	4,204	22,000	1,282	12,815	72,000	3,360	33,307
HTN for DM	4,478	355	3,576	19,000	1,090	10,892	62,000	2,898	28,730
S Rehab	4,473	11	37	25,000	58	171	84,000	181	428
S DVT	2,202	334	-32	6,000	926	-130	11,000	2,154	-382
TIA Mgmt	2,196	173	1,740	9,000	496	4,950	26,000	1,190	11,788
S Dysphagia	1,772	268	-26	5,000	745	-105	9,000	1,734	-307
AF All	1,738	138	1,389	8,000	418	4,180	23,000	1,059	10,495
S Mgmt	1,240	305	2,655	4,000	864	7,503	9,000	2,059	17,824
S tPA	1,064	91	-5	4,000	256	-17	11,000	151	-58
HTN Severe	472	38	377	2,000	113	1,124	6,000	288	2,848
S Timely	363	31	-1	2,000	88	-6	4,000	205	-20
TIA CEA	341	28	277	2,000	94	936	5,000	269	2,668
TIA Dx	314	26	257	2,000	91	905	5,000	268	2,661
S CEA	162	48	468	1,000	215	1,972	3,000	766	6,757

	5 yr totals			10 yr totals			20 yr totals		
Intervention	**Reduction in Cumulative DALYs lost**	**Reduction in Cumulative Stroke Fatalities**	**Reduction in Cumulative Strokes**	**Reduction in Cumulative DALYs lost**	**Reduction in Cumulative Stroke Fatalities**	**Reduction in Cumulative Strokes**	**Reduction in Cumulative DALYs lost**	**Reduction in Cumulative Stroke Fatalities**	**Reduction in Cumulative Strokes**
All Interventions	24,328	2,114	12,401	99,000	5,733	36,842	300,000	15,201	92,535
What can we accomplish by focussing on acute care?									
S tPA	1,064	91	-5	4,000	256	-17	11,000	151	-58
S Timely	363	31	-1	2,000	88	-6	4,000	205	-20
tPA + Stroke timely	3,633	318	-17	15,000	937	-62	8,000	1,033	9,406
DVT + Dysphagia	3,937	596	-58	10,000	1,655	-232	40,000	1,850	18,338
tPA + Strk timely + DVT + Dysphagia	7,498	902	-74	25,000	2,555	-288	35,000	3,227	29,421
What if we focussed on targeted primary or secondary prevention?									
HTN All	7,396	585	5,896	31,000	1,753	17,522	96,000	4,443	44,040
AF All	1,738	138	1,389	8,000	418	4,180	23,000	1,059	10,495
HTN for DM + HTN/AF for CVD	8,789	695	7,009	37,000	2,092	20,874	129,000	7,550	72,362
HTN for DM + HTN/AF for CVD + TIA/Strk mgmt	10,469	1,030	9,964	42,000	3,028	29,156	166,000	12,451	79,612
CEA for TIA/Strk + HTN/AF for CVD	5,747	490	4,926	25,000	1,580	15,625	96,000	4,443	44,040
What if we focussed on acute care, secondary prevention, and rehab?									
tPA+DVT+Dysphagia+ CEA+Rehab+ Strk Mgmt	10,796	1,027	3,051	44,000	2,959	8,834	128,000	7,195	23,581
What if we focussed on targeted primary and secondary prevention and acute stroke care?									
HTN for DM + HTN/AF for CVD + TIA/Strk mgmt +CEA for TIA/Strk + tPA +DVT + Dysphagia	15,581	1,731	10,542	57,000	5,039	31,391	187,000	13,328	92,352

THE MODEL: NEXT STEPS

Sensitivity analysis

GOAL:	QUESTION:
Assess robustness of interventions	How sensitive are intervention rankings to uncertainties in the model?
Prioritize uncertainties	Which uncertain parameters are most capable of changing the magnitude of the impact of each intervention on DALYs lost the most?

Implementation science

- To date, our work has really helped us learn about how powerful potential interventions could be
- But, models such as this can be incredibly useful for helping a group identify new leverage points, conceptualize interventions, and think about the trade-off between feasibility and impact

→ **next workshop (May 2011?)**

LESSONS LEARNED

Lessons learned

- Start broad; add detail iteratively
- Keep it simple
- (It won't take much "reality" to make things quite complex!)
- Data issues will arise
- Work with a diverse group of stakeholders throughout
- It's hard to know what data, etc you need until you are going (again, iterate)

Lessons learned

- Start broad; add detail iteratively
- Keep it simple
- (It won't take much "reality" to make things quite complex!)
- Data issues will arise
- Work with a diverse group of stakeholders throughout
- It's hard to know what data, etc you need until you are going (again, iterate)

ITERATE

Lessons learned

- Having the right project team matters
  - Engaged stakeholders are critical
  - Core modeling team teleconferences were incredibly useful
  - RAs need to understand modeling, and need to be able to immerse themselves in the evidence
  - Communication between the modeling team and system stakeholders is important, and difficult!
  - Steep learning curve for programming these models

This is very much a work in progress, so stay tuned!

(Feel free to contact us for more information: klich@unc.edu)