Modifying the Stroke Care Pathway to Improve Length and Quality of Life

ESD.00 (Introduction to Engineering Systems) – Spring 2011
Term Project Description

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Introduction

Stroke is a disease that affects the arteries leading to and within the brain. A stroke occurs when a blood vessel that carries oxygen and nutrients to the brain is either blocked by a clot or bursts. When that happens, part of the brain cannot get the blood (and oxygen) it needs, so it starts to die.

Stroke ranks third among leading causes of death in the U.S., and is the leading cause of disability. The annual occurrence rate is more than 800,000 new cases and nearly 150,000 deaths. It extracts an economic burden in excess of $70 billion dollars per year, accounting for direct costs of treatment, as well as indirect effects, such as the impact on family members who will need to miss work in order to serve as caregivers.

There are two types of stroke: Ischemic (85% prevalence) and Hemorrhagic (15% prevalence). Ischemic stroke results from an obstruction in a blood vessel supplying blood to the brain. This type of stroke can occur when a blood vessel is blocked by fatty deposits called plaque. Blood cells can build up around the plaque and form a clot, stopping the flow of blood to the brain. Hemorrhagic stroke results when a weakened blood vessel ruptures. The leaked blood kills certain cells and deprives other cells from receiving blood they need to keep them alive.

There is an effective treatment for ischemic stroke, if it can be administered soon enough. Currently, a stroke victim is rushed to the nearest member of designated centers in a national network, and given an emergency CT scan, to determine whether the stroke is hemorrhagic. If the patient arrives within three hours of symptom onset, shows no sign of hemorrhage upon CT and have no other contraindications, the drug, tissue plasminogen activator (tPA) can be administered to begin to reopen the blocked arteries. It is essential that tPA not be given to those suffering hemorrhagic strokes, as this "clot busting" treatment might cause them to bleed to death.

About half of the U.S. population lives geographically close enough to be transported to a stroke center within an hour, in an emergency vehicle. In the U.S., nearly all of eligible patients receive the drug, and the overall mortality rate from stroke is close to 17%.

Across the Atlantic Ocean, in the United Kingdom, the incidence, and the guidelines for treatment of a stroke are similar to those in the U.S. However, that country has many fewer members in its network of specialized stroke treatment centers, and less than one fourth the number of CT scanners of the U.S. The net result is that fewer than one per cent of stroke cases are evaluated while there is still time remaining in the three hour window when tPA is beneficial. The mortality rate in the U.K. is close to 45%.

An innovative imaging device is being evaluated that offers the potential to increase the number of stroke patients, whose evaluation could be completed quickly enough to facilitate treatment with tPA within the three hour therapeutic window. If successful, deployment of the new device within emergency vehicles, and/or hospitals that do not qualify to be members of the stroke care network, could facilitate greater patient eligibility to receive tPA, and hence better survival and lower disability rates.

Project Overview

ESD.00 students will be provided with a report on stroke care prepared by a team of MIT and Harvard graduate students who conducted exploratory work on this topic. An elementary, executable system dynamic model has also been prepared to help assess the costs, risks and benefits of changes to the stroke care pathway that could be considered, should the new, field-based imaging device become available. Throughout this project, students will identify key variables, determine a range of "justifiable" probabilities and other numerical estimates for them, and use the model to examine how these variables interact with one another, with the aim of learning whether perturbations and modifications to the stroke care pathway would produce tangible benefits to patients, and to the health care system. The goal of the project will be to identify impacts on survival rates, health care, and the cost-effectiveness of deploying this field-based technology in a given network. The implications could prove to be different if the changes to the stroke care pathway are implemented in the U.S. or the U.K.

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Methodology

1. Becoming familiar with the model
   As a first step, students will become acquainted with the baseline system dynamics model of the stroke care pathway utilizing an innovative imaging technology, including the relationships between variables nd policies within the model and uncertainties in data and diagnostics.
   a. System dynamics – Students will fi st be responsible for creating causal loop diagrams to identify and understand system relationships between stocks and flows in this healthcare pathway. They will then begin to work with the baseline systems dynamics model, implementing given data on stroke care pathway in US and UK, explaining outputs, correlating them with changing inputs and drawing conclusions on system behavior.
   b. System effects of changes in clinical practices and policies – Changes in clinical practices and policies will be implemented into the system dynamics model. Students will learn to measure policy results and outcomes in terms of health and cost savings, analyzing the complex side effects of the changes.
   c. Uncertainty
      i. Uncertainty in the model - Students will discuss the limits to the model in terms of uncertainty and variability in parameters used. They will identify the range of probabilities and impact on given variables.

      ii.   Diagnostic uncertainty - Students will identify uncertainties in brain imaging modes and consider the most efficient (and ethical) therapeutic decision-making process based on these diagnostic techniques. They will test the sensitivity of the simulated stroke care model to various parameters including costs and diagnostic accuracy.

2. Adding to the model
    Alternatives to the baseline system dynamics model that have variations in both technical and social factors will be identified.
    a. Students will implement adjustments to the scenarios in which the innovative imaging technology is utilized. Given relevant data, they will adjust the model to reflect differences in practices particular to the US and the UK. They will use network theory to identify better, or optimals locations for imaging services (in ambulances, rural hospitals, etc), and implement these changes in the care pathway into the model.
    b. Students will also introduce new scenarios for changing the care pathway based on new social or management practices. Given a few options for new practices (i.e. establishing a chief technician role in hospitals to coordinate stroke care) and relevant variables, they will implement these new scenarios.

3. Ranking the outputs
    Health – survival and dependency - and economic objectives will be used to evaluate the alternatives.
    a. Students will determine which scenarios (technology deployment vs. management in stroke care center) deliver greater benefits for survival, impact on health care system, and cost-effectiveness, considering differences in given networks in the US and UK. In all cases, they will include relevant discussions of uncertainty.

Deliverables

The results of the project (based on steps 2 and 3 outlined above) are to be incorporated into in a ten page report. The report will outline the overall issue that was investigated, the tools and methods employed in the analysis, key quantitative results and insights regarding the effectiveness of various stroke care treatment policies and practices, and conclusions and recommendations of policy directions that merit further detailed analysis, based on considerations of technical and social factors and uncertainty therein.

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