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Estimating the Impact of Disease and Treatment on Life Expectancy

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Introduction

Health status and life expectancy reflect a nation's demographic, socioeconomic and public health conditions. One of the ultimate goals of economic and social development is to achieve better health outcomes and improve overall population welfare. Equipped with proper tools and measures, a forward-thinking government may identify populations at risk, allocate resources appropriately, and design health and wellness intervention programs to achieve better outcomes.

In 2009 the Health Authority–Abu Dhabi (HAAD) set out to improve quality of care and overall population health. The agency partnered with Verisk Health to understand and predict future costs, disease progression and the life expectancy of its residents. Utilizing data from large U.S. commercial and Medicare databases, we developed mortality and disease progression models specifically adapted to this international setting.

At the 2010 SOA Health Meeting in Orlando we presented preliminary results of modeling life expectancy on the basis of disease progression and treatment. This topic may be of interest not only to those working in health care, but also to those in life insurance. To address a broader audience, this article gives an overview of the high-level conceptual modeling and its implications.

Advances in Predictive Modeling

Business needs in the health care payer industry have led to the development of strongly quantitative models of medical risk. Historically these needs were focused on projecting one year into the future, but recent changes are shifting some of the emphasis to a multiyear perspective, matching members and patients. This study outlines a set of innovative predictive models that project medical and mortality risk simultaneously several years into the future.

Why Project Life Expectancy?

The burden of life-related noncommunicable chronic conditions is increasing significantly and presents a major challenge in the 21st century. As shown in related studies,[1] nearly one out of every two Americans—or 140 million people—has a chronic medical condition of one kind or another. This is projected to increase by more than 1 percent per year until 2030. Chronic diseases account for $3 of every $4 spent on health care, and they cause seven out of every 10 deaths.

HAAD understood the impact of chronic patients on the Emirate's health care system. HAAD sought a quantitative way to analyze the situation and to project it into the future in an actionable way—to improve the quality of health care and increase life expectancy for residents. In particular, it was important conceptually to bring together the public health and the financial perspective, and to align health and health care policy.

In this research project for HAAD, we develop several innovative predictive models based on a set of demographic and clinical information, which can project both medical and mortality risk several years into the future. We also assess treatment patterns to identify the best services or medications that may slow down disease progression and increase longevity. Deploying such tools will allow not only HAAD, but also other health care organizations, to spot trends and target programs most effectively.

Abu Dhabi Health Care System

Abu Dhabi is the largest of the seven emirates in the United Arab Emirates. Starting in 2005 the Emirate's leadership aligned on an ambitious shared vision for the health care system. One major effect of this vision has been the full implementation of mandatory employer-financed health care insurance for the entire population of about 2 million, 75 percent of which are expatriates. There are over 30 payers, 40 hospitals and more than 1,000 health care facilities in the Emirate, with public and private entities participating in the scheme on equal terms. HAAD, created in 2007, sets policies such as the public health agenda and acts as a one-stop shop regulator of health care, but does not itself provide health care.

[1] Kung, H.C., Hoyert, D.L., Xu, J.Q. and Murphy, S.L. 2008. Deaths: Final Data for 2005. National Vital Statistics Reports 56(10).

To discharge its functions effectively, HAAD needs timely, comprehensive coded clinical and financial data on the health behavior of its residents. HAAD used the introduction of mandatory health insurance to become the electronic clearing house for all health care claims. As shown in its health statistics (www.haad.ae/statistics), a large percentage of the people have common chronic conditions, for example, diabetes, hypertension, hypercholesterolemia, obesity, etc.

HAAD seeks to improve the quality of care and increase life expectancy for its residents. To this end, we designed several tools that are able to project the disease progression over time and compute the impact on the medical risk and life expectancy based on the current health status. Furthermore, we modify the morbidity and mortality assessment based on medical and surgical treatments for specific diseases. Our goal is to identify optimal treatments to slow down disease progression and increase the life expectancy.

Health Status Overview

		Male		Female	
	Adult Prevalence	National	Expatriate	National	Expatriate
Diabetes	19%	19%	20%	19%	16%
Hypercholesterolemia	18%	17%	20%	13%	13%
Hypertension	34%	21%	35%	25%	40%
Obesity	23%	29%	18%	37%	31%

Source: Abu Dhabi Statistics 2007

Estimating the Impact of Disease and Treatment on Life Expectancy

Instead of using a time series technique on an entire population, this study derives individuals' health status from coded diagnoses in administrative claims data (which is available for most health care organizations). Health Status H is defined as a state vector of 184 conditions, which is additionally characterized by age and gender, and calculated with DxCG's hierarchical condition category (HCC) classification system. The main assumption of predicting Health Status H, is that the future health status one year from now is related probabilistically to the current health status. The relationship between the current and future health status can be described by a state transition matrix. To increase the predictive power, the condition categories are augmented by comorbidities, as the latter contain rich information to understand an individual's severity and the trend of medical risk. As shown in the following table, the numbers in the first column can be treated as baseline parameters for future medical conditions. They assign the chances of having one specific condition in the next period even if someone may not have any medical conditions now. The diagonal parameters refer to condition persistence factors. The rest of the values represent the positive/negative impact of the existing conditions on future state.

State Transition

Current State → Future State ↓	Baseline	Cold	Diabetes	DM side effect	DM progression	Depression
Baseline	1					
Cold	$\beta_{A\|0}$	$\beta_{A\|A}$	$\beta_{A\|B}$	$\beta_{A\|C}$	$\beta_{A\|D}$	$\beta_{A\|F}$
Diabetes	$\beta_{B\|0}$	$\beta_{B\|A}$	$\beta_{B\|B}$	$\beta_{B\|C}$	$\beta_{B\|D}$	$\beta_{B\|F}$
DM side effect	$\beta_{C\|0}$	$\beta_{C\|A}$	$\beta_{C\|B}$	$\beta_{C\|C}$	$\beta_{C\|D}$	$\beta_{C\|F}$
DM progression	$\beta_{D\|0}$	$\beta_{D\|A}$	$\beta_{D\|B}$	$\beta_{D\|C}$	$\beta_{D\|D}$	$\beta_{D\|F}$
Depression	$\beta_{E\|0}$	$\beta_{E\|A}$	$\beta_{E\|B}$	$\beta_{E\|C}$	$\beta_{E\|D}$	$\beta_{E\|F}$

After each year of simulation, hierarchical restrictions are applied to avoid different severity levels of a coexisting condition. For instance, it is not possible to have diabetes without complications coexist with diabetes with renal manifestation. Only the most severe manifestation of each distinct type of condition is credited. A diagnosis assigning a person to a higher-ranked HCC excludes the person from all lower-ranked HCCs.

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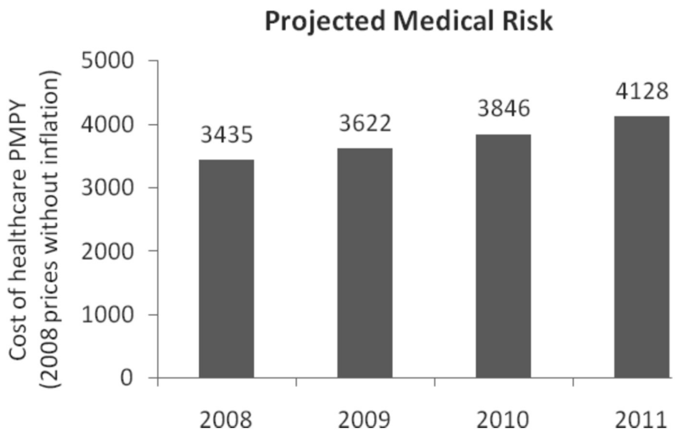

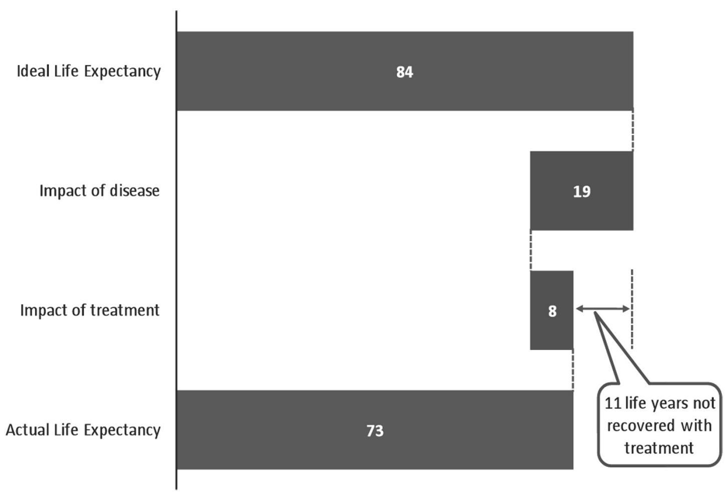

With the simulated medical profiles, we then summarize the collective impact in a prospective relative risk score. The model uses linear, additive formulas obtained from weighted least squares regressions to combine the medical risk associated with clinical groups (184 HCCs) and demographic factors (age and sex). We then investigate the impact of simulated medical profiles on the mortality, which can be used to compute life expectancy.

The ability to make early, accurate predictions about disease outcomes is extremely valuable, because it enables shorter clinical trials for drugs and other therapeutic interventions. Based on the above disease progression methodology, we used the Berenson-Eggers Type of Service (BETOS) procedure codes provided from the Centers for Medicare & Medicaid Services (CMS) and DxCG's pharmacy groupers to investigate the optimal treatments by calculating the deviation of actual medical profiles from the average treatments. We further estimate the statistical impact of deviations on the relative risk score and mortality to identify these treatments which may slow down the disease progression and achieve better health care outcomes.

Applications

There are several useful applications: This approach enables an insurance tool to be used to provide a quantitative public health perspective, and it provides an alternative to project population disease-based morbidities several years into the future.

We can also quantify the impact of diseases and impact of treatments in terms of life years. As shown in the following chart, assume that the ideal life expectancy for someone is 84 years. From the current health status, we can estimate a reduction of approximately 19 life-years. However, with appropriate treatments this person can gain back 8 life-years. That will help to estimate someone's actual life expectancy (73 years).

What makes this approach appealing comes from our inclusion of both the individual's comprehensive medical information and the comorbid conditions. Such an approach can help to identify people at risk early rather than later in their disease progression.
This study has myriad applications to other state planning initiatives. The ability to make multiyear morbidity predictions is highly relevant for budgeting and health system financing purposes. The ability to make multiyear mortality predictions would likely be useful for life insurers. Public health policy would benefit from being able to model both simultaneously to evaluate policy decisions relating to public health versus health system restructuring. ■