Predicting Inpatient Census with Viral Surveillance Data

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• Doctorate from the University of Kansas, Post-doctoral fellowships in Behavioral Genetics (University of Minnesota) and Psychiatric Epidemiology and Biostatistics (NIH/University of Iowa)
• Research focuses on: Familial Alzheimer’s Disease
• Organized the first International Conference on Familial Alzheimer’s Disease held in Tulsa, OK.
• Prolific writer with numerous works to his name including: Familial Alzheimer’s Disease, Caring for Alzheimer’s Patients, and Practical Predictive Analytics & Decisioning Systems for Medicine.
Conflict of Interest

**Nephi Walton, MD, MSc** employed by Washington University School of Medicine. He is also an instructor at the University of California.

Has no real or apparent conflicts of interest to report.

**Gary Miner, PhD** employed by Dell. He is also an instructor at the University of California.

Has no real or apparent conflicts of interest to report.
Agenda

• Short General Introduction of “THE PROBLEM” - Gary Miner

• SOLUTION(s) using specific examples - Nephi Walton
Learning Objectives

• Identify opportunities for using predictive analytics and big data sets to improve resource allocation

• Analyze the practical steps needed to take advantage of the opportunities

• Identify key challenges in using analytics to predict inpatient census

• Demonstrate a practical study of using predictive analytics to help with planning, guide staffing and resource allocation and reduce the cost of care
An Introduction of How Benefits Were Realized for the Value of Health IT

SATISFACTION: Hospital staff are happier with more predictable schedules. Patient satisfaction improved by better care with an appropriate nurse-to-patient ratio.

TREATMENT: Treatment is improved by having the appropriate resources available to meet patient needs.

ELECTRONIC INFORMATION: By harnessing the power of data and predictive analytics, we take the guess work out patient care and resource allocation by making accurate predictions about inpatient census.

PREVENTATION & PATIENT EDUCATION: Inadequate staffing and insufficient resources can lead to adverse events in a clinical setting. These models help prevent adverse events by ensuring appropriate nurse-to-patient ratios and adequate resources to handle patient workloads.

SAVINGS: Costs are reduced from avoiding adverse events and better resource prediction and allocation which reduces unnecessary expenses such as overstaffing.

http://www.himss.org/ValueSuite
THE HEALTHCARE CHALLENGE:
Predict patient census at a tertiary care children’s hospital to help with resource allocation, preventative measures, and staffing.

This challenge is not a new thing ......

Even in 2002 this was being discussed, as per this New England Journal of Medicine paper:

SPECIAL ARTICLE
Nurse-Staffing Levels and the Quality of Care in Hospitals
Medical epidemics and pandemics in children ...

From: MICHIGAN DEPARTMENT OF HEALTH AND HUMAN SERVICES, 2010;

Medical surge and Medical Surge Triggers...

2012

Another example is the NATIONAL ACADEMY OF SCIENCES stressing things like:

“Hospitals and acute care facilities providing acute medical care to the community have a “duty to plan” for mass casualty incidents, including planning for the expansion of clinical operations, commonly referred to as

...... surge capacity...”

From their report:

It all started with a different kind of mining......
The Healthcare Challenge

Predict patient census at a tertiary care children’s hospital to help with resource allocation, preventative measures, and staffing.
Step 1 – Defining the Problem

• Assessed the top reasons for patient admissions.

• The largest by far was viral respiratory illness especially during time of peak census.

• Admissions were further broken down by virus and Respiratory Syncytial Virus (RSV) was found to be the highest cause of respiratory viral admissions.
Goal: Predict when RSV outbreaks will occur.
Step 2 – Selecting Variables

**TRIGGERS**
- Weather
- Virus Stability
- Host Susceptibility
- Human Behavior
- Air Pollution
- Viral Activity

**SIGNALS**
- School Attendance
- Google Searches
- Outpatient Visits
- Grocery Store Purchases
- TV Viewing
- Viral Activity

**OUTBREAK**

Date:
- December
- January
- February
- March
- April
Findings

• We were able to forecast outbreaks up to 3 weeks in advance with sensitivity of 67% and specificity from 94% to 100%.

• Weather variable’s related to RSV are similar to those that cause inversions in the Salt Lake Valley.

• Interesting findings in relation to PM2.5, more data needed.
Next Challenge

To predict weekly average census for hospital staffing.
Background – Nurse Staffing

• Appropriate nurse staffing has been associated with less hospital-related mortality and adverse events.

• Methods have been proposed to handle nurse staffing.

• It has been suggested that the most difficult part of staffing is predicting inpatient census.
Background – Neural Networks

- Capable of modeling complex non-linear relationships.
- Modeled after the workings of neurons in the human brain.
- Model is a black box that cannot easily be interpreted.
Findings and Gaps

- **Emergency Department Admissions** prediction models found good results based on calendar variability, meteorological data was not effective.
- Minimal literature on forecasting models for patient census. Models that do exist are Auto-Regressive Integrated Moving Average (ARIMA) time series models based on past census numbers.
- Only data mining based patient census forecasting model found was authors previous study using neural network time series models.
Goal

To Develop a real-time model to forecast patient census in a tertiary care children’s hospital.
Hypothesis

- Calendar variables, viral data, and behavioral inputs can be used with machine learning techniques to forecast patient census at a tertiary care children’s hospital.
Methods – Assessment of factors affecting patient census

Top Sources of Admissions

- Bronchiolitis
- Chemotherapy
- Dehydration/Gastroenteritis
- Asthma
- Seizure / Febrile Convulsions
Methods – Assessment of factors affecting patient census.

- **Calendar**
  - Month
  - Day of Week

- **Behavioral**
  - School
  - Holidays
  - BYU/Utah Games
Methods – Data Sources

- **Lab Data – Viral Tests - Intermountain Health Care (IHC)**
  - Weekly average
  - 7 day slope
  - 14 day slope

- **Inpatient Elective Surgery Census – IHC**
  - Weekly average

- **Inpatient Census Primary Children’s Medical Center (PCMC)**
  - Weekly average

- **Federal Holidays - U.S. Office of Personnel Management**

- **BYU-Utah Games – “Holy War“ - Wikipedia**

- **Data captured from 2007 - 2011**
Methods – Geographic Region

- Clinical Data obtained for Salt Lake County from Intermountain Healthcare Hospitals and Clinics.
- Intermountain Healthcare is the largest healthcare provider in Utah and includes Primary Children’s Medical Center.
Methods – Variable Selection

- Feature selection was performed on a continuous dependent variable and all variables with a p-value < 0.01 were selected for inclusion in the model.

- Feature selection was performed separately for each week in advance the prediction was made up to 3 weeks, resulting in 3 sets of variables.
Methods – ANN Prediction Model

• Weekly patient census averages calculated based on average patient census from Tues through Sunday.
• Input variables selected by feature selection.
• Output variable is continuous variable representing average weekly census of week predicted.
• Years 2007 – 2010 used for training (85%) and testing (15%), 2011-2012 season used for validation.
• Ran 100 ANN models using Statistica Data Miner and selected best one and applied it to the validation set.
Results – Feature Selection

- Holidays
- Month
- School in Session
- Current Weekly Average Census
- Total Respiratory Viral Tests
- Adenovirus
- Human Metapneumovirus
- Influenza A
- Influenza B
- Rhino Virus
- RSV
Results – ANN

• 1 Week in advance correlation coefficient 91%
• 2 Weeks in advance correlation coefficient 80%
• 3 Weeks in advance correlation coefficient 88%
Results – ANN

• Using viral test results outside of PCMC viral activity decreased performance in the “1 week in advance” model, but increased performance when predicting further out.

• Removing actual elective surgery number inputs from the model did not affect performance in any of the models.
Artificial Neural Network Predictions 1 Week in Advance

Hospital Census

Week of the Year

Actual and Predicted Hospital Census Over the Year
Artificial Neural Network Predictions 2 Weeks in Advance

Hospital Census vs. Week of the Year

Actual vs. Predicted

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Artificial Neural Network Predictions 3 Weeks in Advance
Comparison to ARIMA models

- Performance was far better but not directly comparable to the ARIMA models used.
- ANN correlation for 1, 2, and 3 week forecasting are 0.91, 0.80, and 0.88, which is higher than the best ARIMA value of 0.71 on the same data.
Discussion – Confounders

- **H1N1 outbreak of 2009.**
- **Changes in RTU have lessened patient stay for 2010-2011 season.**
Discussion

- Elective surgery does not have a significant impact on census surges.
- Outside viral activity is better for predicting long term trends.
Conclusions

• ANN models can be effective for forecasting patient census up to 3 weeks in advance.

• Results are comparable to if not better than reported performance of ARIMA models.

• Respiratory viral data, calendar information, holidays, and school attendance appear to be good predictive variables.

• Elective surgeries have minimal impact on census prediction.
Future directions

• **Modify model to work on a more granular level.**

• **Build Disease specific models i.e. asthma, gastroenteritis.**

• **Deploy model and monitor prospectively.**

• **Include other measures of community disease burden, such as ICD9 coded visits from urgent cares, in the model to improve performance.**
Back to the Mining Analogy

Harnessing the signals from our own body and using our genetic information ("make"/"model") we may be able to predict failure/disease and intervene before failure occurs.
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Questions ???

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