Actionable Analytics: From Predictive Modeling to Workflows
March 1, 2016
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DISCLAIMER: The views and opinions expressed in this presentation are those of the author and do not necessarily represent official policy or position of HIMSS.
Conflict of Interest

Ari Robicsek, MD & Chad Konchak, MBA

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

• Introduction
• A cautionary tale – The Story of Wunderlich
• Getting Analytics into Workflows
• Use Cases
  – MRSA
  – Advance Care Planning
  – Patient Lists And Registries for Population Health
  – What’s Going Around
Learning Objectives

- **Learning Objective 1.** Describe EMR functionality that will allow you to integrate predictive modeling and analytics tools (e.g. dashboards and reports) into clinical workflows

- **Learning Objective 2.** Develop interactive dashboards and analytical tools within the context of workflows that takes advantage of and integrates with existing EMR workflows and functionality

- **Learning Objective 3.** Evaluate different modeling techniques against implementation considerations given the tools available to integrate predictive models into clinical workflows

- **Learning Objective 4.** Plan mechanisms to formalize the processes needed to govern predictive modeling efforts in your organization

- **Learning Objective 5.** Share real life use cases of actionable analytics
Value Summary

MRSA

Reducing MRSA Tests
Savings:
$10 per patient
X 50K Admissions
= $500K Per Year!
MRSA infection rate unchanged!

Readmissions

Reduction in Readmission rates for AMI

Population Health

Automated Outreach
Improve Lab Test Completion

Automated Outreach
Improve Management for Hypertension

Reduction in Utilization for high risk patients
Introduction

NorthShore Key Statistics

- 4 Hospitals
- 950 Beds
- 9000+ Employees
- 2700 Physician Medical Staff
- 850+ Employed Physician Medical Group
- 60,000 Annual Admissions
- 1.8 Million Annual Office Visits
- 125,000 Annual ED Visits
- $100M+ Research Institute
- University of Chicago principal teaching affiliate
A CAUTIONARY TALE
What is a ‘fever’ in the postoperative setting? This tool was designed to help clinicians determine whether their patient’s temperature is ‘normal’ on a given postoperative day. Enter a patient’s characteristics to see how their temperature compares to that of similar patients undergoing the same procedure; the higher the percentile, the more unusual the temperature. You can learn more here.

*denotes required field

Type of Surgery:

Post Operative Day:  

Today’s T-Max:  

Submit  

Reset  

Temperature Percentile Chart

To view the Temperature Percentile Chart, please input the values on the left and click submit

http://fad.northshore.org/wunderlich/Default.aspx
What is a ‘fever’ in the postoperative setting? This tool was designed to help clinicians determine whether their patient’s temperature is ‘normal’ on a given postoperative day. Enter a patient’s characteristics to see how their temperature compares to that of similar patients undergoing the same procedure; the higher the percentile, the more unusual the temperature. You can learn more here.

*denotes required field

Type of Surgery:

Lap Cholecystectomy

Post Operative Day: 1

Today’s T-Max: 100.4

Pre-Op T-Max: 

Anti-Pyretic?: Yes  No

Blood Transfusion?: Yes  No

Temperature Percentile Chart

To view the Temperature Percentile Chart, please input the values on the left and click submit.
What is a ‘fever’ in the postoperative setting? This tool was designed to help clinicians determine whether their patient’s temperature is ‘normal’ on a given postoperative day. Enter a patient’s characteristics to see how their temperature compares to that of similar patients undergoing the same procedure; the higher the percentile, the more unusual the temperature. You can learn more here.

*denotes required field

Type of Surgery: **Lap Cholecystectomy**

- Post Operative Day: **1**
- Today’s T-Max: **100.4**
- Pre-Op T-Max: 
- Anti-Pyretic?: 
  - Yes
  - No
- Blood Transfusion?: 
  - Yes
  - No

Percentile: 95%
What is a ‘fever’ in the postoperative setting? This tool was designed to help clinicians determine whether their patient’s temperature is ‘normal’ on a given postoperative day. Enter a patient’s characteristics to see how their temperature compares to that of similar patients undergoing the same procedure; the higher the percentile, the more unusual the temperature. You can learn more here.

* denotes required field

Type of Surgery: Hip Arthroplasty

Post Operative Day: 1

Today’s T-Max: 100.4

Age: 45

Anti-Pyretic?: No

Submit

Reset

Percentile: 65%

Temperature Distribution

Your Patient’s Percentile: 65%
What is a ‘fever’ in the postoperative setting? This tool was designed to help clinicians determine whether their patient’s temperature is ‘normal’ on a given postoperative day. Enter a patient’s characteristics to see how their temperature compares to that of similar patients undergoing the same procedure; the higher the percentile, the more unusual the temperature. You can learn more here.

*denotes required field

Type of Surgery: CV Surgery

Post Operative Day: 1

Today’s T-Max: 100.4

Pre-Op T-Max: 

Age: 45

Female?: Yes

Percentile: 80%
What is a ‘fever’ in the postoperative setting? This tool was designed to help clinicians determine whether their patient's temperature is 'normal' on a given postoperative day. Enter a patient’s characteristics to see how their temperature compares to that of similar patients undergoing the same procedure; the higher the percentile, the more unusual the temperature. You can learn more here.

*denotes required field

Type of Surgery: CV Surgery

Post Operative Day: 1

Today’s T-Max: 100.4

Pre-Op T-Max:

Age: 45

Female?: Yes

Percentile: 85%

Submit

Reset
What is a ‘fever’ in the postoperative setting? This tool was designed to help clinicians determine whether their patient’s temperature is ‘normal’ on a given postoperative day. Enter a patient’s characteristics to see how their temperature compares to that of similar patients undergoing the same procedure; the higher the percentile, the more unusual the temperature. You can learn more here.

*Type of Surgery: CV Surgery
*Post Operative Day: 1
*Today’s T-Max: 100.4
Pre-Op T-Max:
*Age: 85
*Female?: Yes

Submit
Reset

Percentile: 94%
Getting analytics into workflows
1. Data Sources

2. Standardization & Normalization

   EMPI

   Security Flags

   Data Normalization*

   *Tools to automate and manage mapping data to standard terminologies

3. Data Enrichment

   Patient Registries (Care Gap Definitions)

   Predictive Analytics*

   *Includes Risk Stratification, NLP, & GIS

   Data Grouping*

   *Tools to define, categorize, and manage multi-dimensional hierarchies

4. Workflow

   EMR & BI agnostic!

   Point of Care CDS
   - Alerts
   - Banners, etc

   Physician Portal
   1. Embedded within EMR
   2. Accessible outside

   Care/Case Coordinator Portal
   1. Embedded within EMR

   Patient Portal
   - Manage Care Gaps
   - Message care team

   Automated Outreach
   - Phone
   - Email
   - Text, etc

   Administrative Portal
   - Quality Scorecards
   - Utilization
   - Productivity / Auditing
   - Practice Variation

The Data Supply Chain

Critical step where raw data becomes actionable intelligence
Stages of Analytics

**Stage 1:** Bringing Raw Data into EDW from External Sources

**Stage 2:** Enriching Data & Transforming it into Information

**Stage 3:** Development of Actionable Business Intelligence

**Stage 4:** Integrating Intelligence into Business & Clinical Workflows To drive Decision Making

**Analytics Factory**

- Quality Scorecards
- Dashboards
- EMR Data-driven Workflow Support

**Care Gaps**
- Utilization Volume & $$$
- Risk Stratification
- Social Factors
- Physician Attribution
- GIS Mapping

**EMR**
- MG &IPA Clinical & Claims Data
- External Claims Data
- External CCD & Point to Point
- External Lab & Pharmacy Fill

**Enriched & Cultivated “Information”**

**Predictive Modeling**

**Raw “data” residing in EDW**

**To drive Decision Making**
Data Analytics Governance

Process for moving code to analytics server

**RFS will include**
- Input file(s) and Output file(s) details and logic
- Scheduling details.
- Additional R Packages used. (if any)
- R code.
- Email sample data set to R Admin

**R Code Review***
- Check template
- Check error handling
- Check efficiency and flow
- Etc.

*** R Code review and New R package evaluation will be done by a group of people appointed by mutual consent from all teams.

End Process

**Engage EDW team (if required)**
- Scheduling R code through ETL
- Data mart design changes
- BI changes

**Move Project in Production**
- Create
  - Standard directories, files and grants
  - Install packages (if required)
  - Etc.
Data Analytics Governance

200 page predictive Analytics manual

Analytical Standards for Regression-based Predictive Analytics: Methodologies, Naming Conventions and Coding Practices

NorthShore University HealthSystem
Clinical Analytics Team
9th January, 2015

Abstract
This document proposes a set of methodology and programming standards for the Clinical Analytics team. It is intended as a set of guidelines that will be developed over time as the needs of the team evolve. Guidelines include a review of statistics, survival analysis, general programming techniques, naming conventions, R coding practices and a general approach to tackling most common types of applied predictive analysis handled by the team.

Figure 3.1: A generic algorithm for proceeding with an analytical project within the framework of Clinical Analytics.

As mentioned in Section 1, the majority of predictive analytic problems can be solved by employing one of two wide types of forecasting methodologies: regression and classification. Regression\(^1\) should be used when the

\(^1\)Or another appropriate fitting technique
ALERTS AND BANNERS
US Legislation

- Illinois (2007)
  - ICU and “high risk”
- New Jersey (2007)
  - ICU and other “high risk” units
- Pennsylvania (2007)
  - LTCF and “high risk” patients
- California (2008)
  - ICU, certain surgical patients, readmits, LTCF residents, dialysis patients
- Washington (2009)
  - ICU and “high risk” patients
Predicted probability of MRSA = $e^{\text{LO}} / (1 + e^{\text{LO}})$
where \( \text{LO} = -4.655 \)

+ 0.083 x (Age/10) 
+ 0.135 (if Male) 
+ 0.421 (if Black or African-American\(^\dagger\)) 
- 0.229 (if other, non-White race\(^\dagger\)) 
+ 1.010 (if Nursing Home Resident) 
+ 0.267 (if Admission Service\(^\dagger\) = Internal Medicine) 
+ 0.421 (if Admission Service\(^\dagger\) = Psychiatry) 
- 0.249 (if Admission Service\(^\dagger\) = Surgery) 
+ 0.006 (if Inpatient within last year) 
+ 0.390 (if ICU > 2 days within last year) 
+ 0.153 (if Diarrhea on admission) 
+ 0.780 (if Feeding Tube on admission) 
+ 0.663 (if Pressure Ulcer on admission) 
+ 0.234 (if Microbiology test done on admission or in prior week) 
+ 0.480 (if Skin or Bone Infection on admission) 
+ 0.231 (if Albumin < 3) 
+ 0.245 (if Glucose ≥ 23) 
+ 0.355 (if Hemoglobin < 8.6) 
+ 0.133 (if Sodium < 131 or > 143) 
- 1.409 (if Cephalosporins in past month) 
- 0.212 (if Fluoroquinolones in past month) 
+ 0.316 (if Other Antimicrobials in past month) 
+ 0.322 (if Past VRE or ESBL) 
+ 2.146 (if Cystic Fibrosis) 
+ 0.019 (if Diabetes Mellitus) 
+ 0.324 (if Heart Disease) 
- 0.187 (if Dialysis past year) 
+ 0.479 (if Lung Disease) 
- 0.135 (if Stroke or TIA) 
+ 0.175 (if Venous Thromboemolism)
Real-life prospective validation

- All patients admitted and MRSA tested Sept-Nov 2011 (8899 patients)
- Ranked patients by scoring and determined MRSA ‘capture’ at a spectrum of thresholds
- Layered on additional logic (e.g. test all patients with MRSA history)
Day 1: no recent Staph PCR, MRSA past yr, ICU, random, score

Prospective validation, Sept-Nov 2011
Logic

• Alert will “fire” if:
  – Score is high enough ("magic number") OR
  – MRSA on problem list OR
  – ICU admission OR
  – Last digit in Encounter Number is ‘0’
    AND
  – No Staph PCR in past 30 days
Patient meets criteria for MRSA screening

Click here to order test
<table>
<thead>
<tr>
<th>Unit</th>
<th>Patient</th>
<th>Test needed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 North</td>
<td>Smith, John</td>
<td>Yes</td>
</tr>
<tr>
<td>3 South</td>
<td>Doe, Jane</td>
<td>Yes</td>
</tr>
<tr>
<td>4 East</td>
<td>Duck, Donald</td>
<td>No</td>
</tr>
<tr>
<td>3 South</td>
<td>Mouse, Mickey</td>
<td>Yes</td>
</tr>
<tr>
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<td>Of Arendelle, Elsa</td>
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</tr>
</tbody>
</table>
No increase in MRSA infections
Reducing MRSA Tests Savings:

$10 per patient
X 50K Admissions
= $500K Per Year!

MRSA infection rate unchanged!
Advance Care Planning

• Mortality in patients with chronic heart failure is high (~10% annually).
• Many of these patients would benefit from conversations with their cardiologist about advance care planning – especially patients at highest mortality risk.
• Can predictive modeling be used to systematically identify the highest-risk patients?
Heart Failure Mortality Model

Formula

\[
\text{logit}_{HF} = \ln \left( \frac{p_{death}}{1 - p_{death}} \right) = 3.31 + 0.06 \times \text{Age (per year)} \\
- 0.51 \times \text{Female} - 0.01 \times \text{sBP (per mmHg)} - 0.11 \times \text{Hb} \\
- 0.05 \times \text{BMI} - 0.04 \times \text{Sodium} + 0.0003 \times \text{BNP} \\
+ 1.61 \times \text{Cancer (active)} \\
+ 0.73 \times \text{Code Status Order Placed} \\
+ 0.51 \times \text{Diabetes Mellitus} + 0.80 \times \text{Dementia} \\
+ 0.41 \times \text{Hypertension} + 0.58 \times \text{Chronic kidney disease} \\
+ 0.98 \times \# \text{ of hospitalizations in the last 30 days} \\
+ 0.15 \times \# \text{ of hospital visits in the last 12 months} \\
- 0.06 \times \# \text{ of cardiological visits in the last 24 months}
\]

\[
p_{death} = \frac{1}{1 + e^{-\text{logit}_{HF}}}
\]

AUC 0.82
Every night, the model is applied to our whole population of HF patients to identify those at highest-risk...

\[
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\]

\[
P_{\text{death}} = \frac{1}{1 + e^{-\text{logit}_{HF}}}
\]

This high-risk list is then made available to clinical staff in Epic to facilitate Advance Care Planning.
**Mortality risk banner**

<table>
<thead>
<tr>
<th>Patient has a high 1-year mortality risk. Click <a href="#">here</a> for details.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Smith, John</strong></td>
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<tr>
<td>Problems:</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
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<td>Hypertension</td>
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<td>Lung cancer</td>
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<td>COPD</td>
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<td>Osteoarthritis</td>
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<tr>
<td>CHF</td>
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<tr>
<td>History:</td>
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<tr>
<td>Appendicitis</td>
</tr>
<tr>
<td>CABG</td>
</tr>
</tbody>
</table>
PATIENT LISTS & REGISTRIES
## Population Health – Disease Management
### Electronic List

<table>
<thead>
<tr>
<th>Unit</th>
<th>Patient</th>
<th>MRN</th>
<th>PCP</th>
<th>Home phone</th>
<th>Due for HbA1c?</th>
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Process Impact

Time to HbA1c Completed

Pilot

50% of OFI patients Completed in 5.5 weeks

Control

50% of OFI patients Completed in 11 weeks

p-value < 0.01 : Kaplan-Meier Survival Analysis
## Population Health – Disease Management

**Bulk Messaging**

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Clinical Impact

Hypertension Management

Automated Outreach
Improved Management for Hypertension
30-day Readmissions

- Prospective validation
  - 948 patients discharged from pilot units between Jan 6 and Feb 12 2012

<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Number of Patients</th>
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<td>632</td>
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### 30-day Readmissions

#### Hospital System List

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</tr>
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<td>3 South</td>
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</tr>
<tr>
<td>4 East</td>
<td>Duck, Donald</td>
<td></td>
</tr>
<tr>
<td>3 South</td>
<td>Mouse, Mickey</td>
<td>✗</td>
</tr>
<tr>
<td>4 North</td>
<td>Of Arendelle, Elsa</td>
<td></td>
</tr>
<tr>
<td>3 South</td>
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</tr>
<tr>
<td>4 North</td>
<td>Strike, Cormoran</td>
<td>✔</td>
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<tr>
<td>3 South</td>
<td>Hutt, Jabba</td>
<td></td>
</tr>
<tr>
<td>4 East</td>
<td>Man, Spider</td>
<td>✔</td>
</tr>
<tr>
<td>3 South</td>
<td>Man, Ant</td>
<td>✔</td>
</tr>
<tr>
<td>4 North</td>
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<td>✔</td>
</tr>
<tr>
<td>3 South</td>
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<td>✔</td>
</tr>
<tr>
<td>4 East</td>
<td>Man, Aqua</td>
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## Patients Discharged in Past 30 days or Currently Admitted: NorthShore Hospitals

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### Service
- All

### Discharged / In Hospital
- All

### Readmission Risk
- All
30-day Readmissions

AMI Readmission Rate

Readmission predictive modeling integrated into workflow

Reduction in Readmission rates for AMI
# Population Health – Case Management

## New Patients

**New Patient Criteria**: All Patients

**Sort Patients By**: Preventable Hospitalization

**Conditions**: All Patients

## Patient Table Filters - copy

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<th>Payer Group</th>
<th>Cur Pcp Phy Name</th>
<th>Admission Date Time</th>
<th>Department Name</th>
<th>Hosp Disch Date</th>
<th>Dx Or Reason</th>
<th>Suggested Call Time</th>
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### Population Health – Case Management

#### Patient Details - Preventable Hospitalization Score

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<td>Congestive Heart Failure</td>
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<td>Complicated Diabetes</td>
<td>Paralysis</td>
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<td>Complicated Hypertension</td>
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<td>Drug Abuse</td>
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### New Patients

#### New Patient Criteria

**All Patients**

#### Sort Patients By

**Preventable Hospitalization**

#### Conditions

**All Patients**

#### Department Name

**All**

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Population Health – Case Management

Utilization Rates Per Year and Care Gaps -- Pre and Post Enrollment

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<td>Other ED Visits</td>
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* = statistically significant (p<0.05)
- = not significant

A1C Over 10

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DM Lipid Uncont.

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NorthShore Charges

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<td>$5,028</td>
<td>$3,800</td>
</tr>
</tbody>
</table>

NorthShore Charges HB

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$4,058</td>
<td>$3,031</td>
</tr>
</tbody>
</table>

Reduction in Utilization for high risk patients
THE WEB
Figure 4. Percentage of patients with FRI who received antibiotics based on the number of patients with FRI seen by their physician in the previous week.

FRI = febrile respiratory illness.

What's Going Around Overview
Syndromic Surveillance Across the NorthShore Population

Click a syndrome for details.

- Influenza-Like Illness
  MEDIUM

- Pediatric Asthma
  MEDIUM

- Strep Throat
  LOW

- Gastroenteritis
  MEDIUM

- Pertussis
  HIGH
What’s Going Around
Syndromic Surveillance Across the NorthShore Population

Colors represent the proportion of all patients seen in the Medical Group who had the syndrome of interest. Areas with insufficient data for accurate estimates are not colored.

Influenza  Strep Throat  Pertussis  Pediatric Asthma  Gastroenteritis

Pertussis as of November 10, 2013
Three-Year Lookback Period

Sample Maps  Change Location  How WGA Works  Feedback

Sample Low  Sample Medium  Sample High

Dark Blue < 0.07%  Red >= 1.0%
What's Going Around
Syndromic Surveillance Across the NorthShore Population

Pertussis as of November 10, 2013:
Three-Year Lookback Period

Colors represent the proportion of all patients seen in the Medical Group who had the syndrome of interest. Areas with insufficient data for accurate estimates are not colored.

Below BLUE line = LGW syndromic activity. Above RED line = HIGH syndromic activity.

Sample Maps | Change Location | How WGA Works | Feedback
Go-live preparation; October 30, 2013
Dear Parents and Guardians,

We have an update to our recent email notification - eight cases of pertussis, also called “whooping cough,” have been reported in our school, with a few more test results pending. Thank you to parents who have informed us of positive cases and concerns. Pertussis is caused by bacteria infecting the mouth, nose and throat. It is spread through the air by coughing.

Symptoms can appear 5 to 21 days after infection. Usually only close contacts of someone with Pertussis may become infected. Pertussis may start with cold-like symptoms (i.e., sneezing/runny nose) followed by a cough that can gradually become worse. Others may develop the cough without any cold symptoms. Those with Pertussis are most contagious during the beginning, cold-like stage and the first 2 weeks after cough onset. The cough
Movie

http://vimeo.com/90437195
Value Summary

MRSA

Reducing MRSA Tests
Savings:
$10 per patient
X 50K Admissions
= $500K Per Year!
MRSA infection rate unchanged!

Readmissions

Reduction in Readmission rates for AMI

Population Health

Automated Outreach
Improve Lab Test Completion

Automated Outreach
Improve Management for Hypertension

Reduction in Utilization for high risk patients
THANK YOU!

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Chad Konchak:  ckonchak@northshore.org