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## **Beyond BI: Building a Rapid-Response Advanced Analytics Unit**

Session 92, March 6<sup>th</sup>, 2018

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# Conflict of Interest

Jeremy Petch, PhD

Has no real or apparent conflicts of interest to report.

# Agenda

- Case study examining the business and technological architecture to establish a rapid-response advanced analytics unit at an academic hospital.
- Demonstrate one of the key tools we have developed to facilitate this approach, our analytic algorithm tool (interventional time series module).

# Learning Objectives

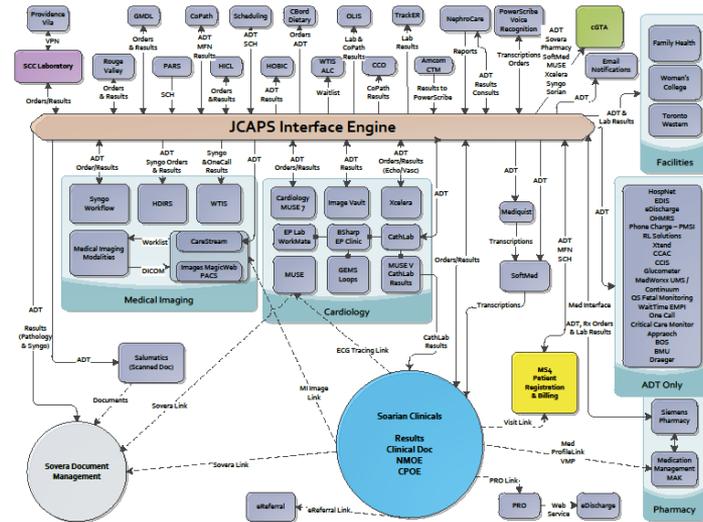
- Describe how an academic hospital has implemented a service-based advanced analytics unit to support clinical and executive decision-making
- Analyze the technological infrastructure needs for implementing advanced analytics
- Identify the business architecture features that can maximize the practical impact of advanced analytics

## Setting: St. Michael's Hospital

- 463 bed tertiary care teaching hospital in downtown Toronto, Ontario
  - 6,000 staff
  - 800 physicians
  - 1,700 nurses
- Annual patient volumes
  - 75,000 ED encounters
  - 500,000 ambulatory encounters
  - 25,000 inpatient admissions

# SMH data architecture, circa 2014

- “Best in Breed” clinical information system architecture
- Front-end integration, but data residing in silos
- Analysis required manual data integration, with a turnaround time of 3-8 weeks, depending on complexity
- Analysis purely descriptive



# Vision

To enable advanced and predictive analytics to support **high quality patient care** and increase **operational efficiency**.

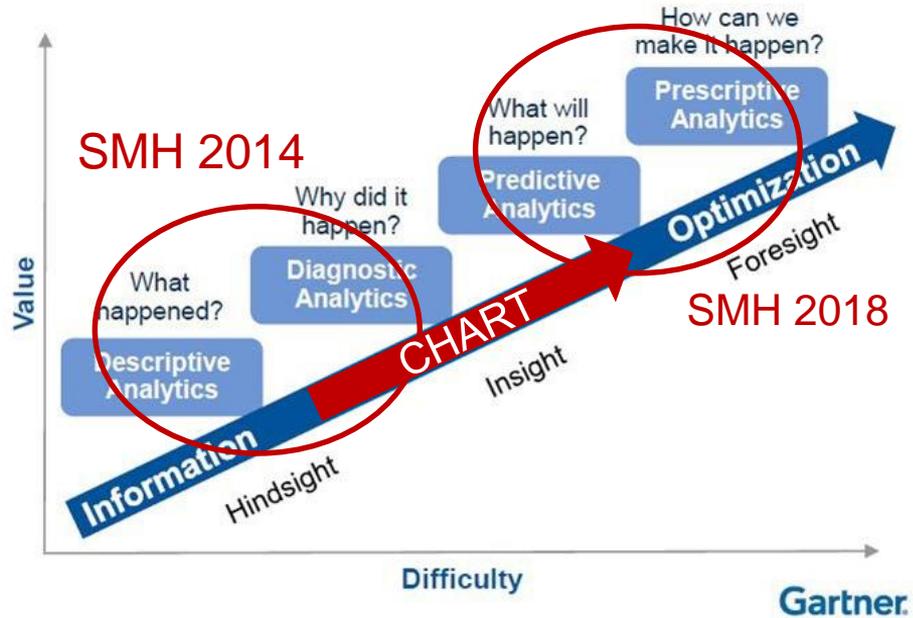
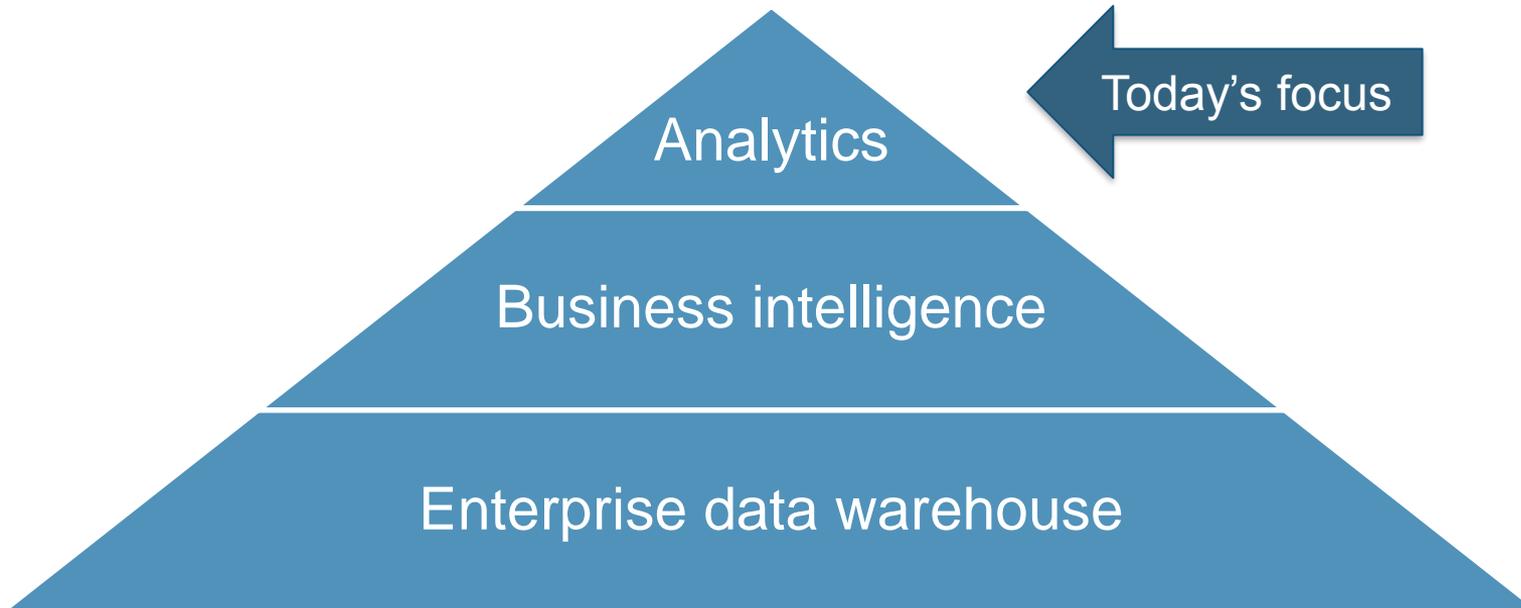


Image source: <https://www.flickr.com/photos/27772229@N07/8267855748/in/photostream>

# Strategic components

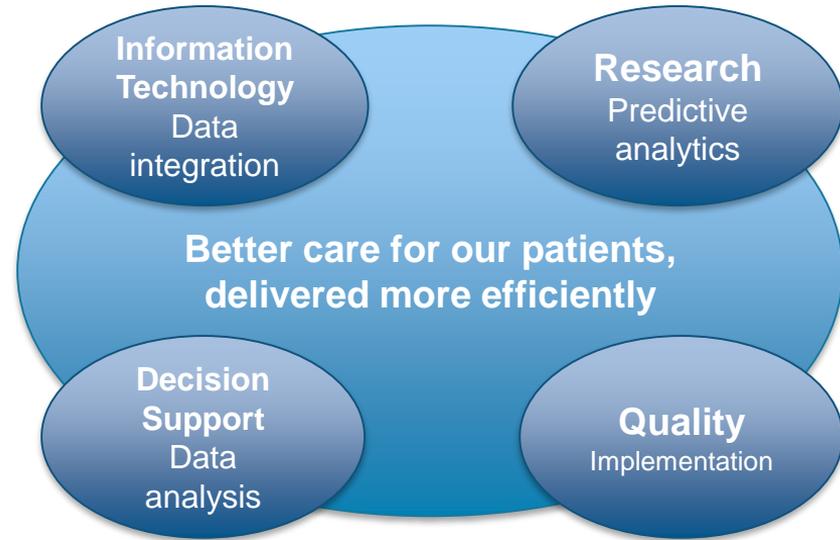


# Advanced analytics unit

- CHART – Centre for Healthcare Analytics Research and Training
- Core competencies:
  - Data science
  - Biostatistics
  - Simulation modeling
  - Change management
- Mandate to work on projects that would both A) improve patient care, and B) improve operational efficiency

# Business architecture

- The biggest business risk the unit faced was creating insights that were never actioned
- We therefore built unit on a partnership between knowledge generators and change makers
- Executive sponsorship across all domains



# Technical architecture

- Another key risk the unit faced was not being able to respond quickly enough, or be flexible enough, to be of value to decision makers
- Three elements of our technological architecture were designed to address this:
  - Data integration solution
  - Advanced analytics tools
  - Algorithm-based analysis

# Data integration solution



# Advanced analytics tools

Best tool for  
advanced  
analytics?

Proprietary or  
Open Source?

## Many tools will get the job done...



# The challenge with all the tools we tried is getting results fast enough

```
2003 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038
if(input$control == 'none') {
  control_ts <- control_time_series()$ts_df
}

N <- length(ts_df)

int_date <- input$int_date2
after_int <- time_seq > int_date
after_int <- which(after_int == 1)[1]

pre.period <- c(1, (after_int - 1))
post.period <- c(after_int, length(ts_df))

if(input$control != 'none') {
  data <- cbind(as.numeric(ts_df), as.numeric(control_ts))
  y <- as.numeric(ts_df)
  x <- as.numeric(control_ts)

  post.period.response <- y[post.period[1] : post.period[2]]
  y[post.period[1] : post.period[2]] <- NA

  ss <- AddLocalLevel(list(), data)
  bsts.model <- bsts(y ~ x, ss, niter = 1000)

  impact <- CausalImpact(bsts.model = bsts.model,
    post.period.response = post.period.response)
} else {
  data <- as.numeric(ts_df)

  post.period.response <- data[post.period[1] : post.period[2]]
  data[post.period[1] : post.period[2]] <- NA
}
```

# Algorithm-based analytic tool

CHART forecasting tool



# Demonstration

- Live demonstration begins here
- Link to program used for live demo:  
[https://joshmurray.shinyapps.io/sas\\_style\\_tim](https://joshmurray.shinyapps.io/sas_style_tim)
- Slides that follow illustrate the components of this demonstration as a backup in case of technical issues

# Data import

CHART forecasting tool

**Import data**

Select either a csv, Excel, or SAS file to load. The data must be must contain 1 row per time observation.

**Choose file type:**

CSV

**Choose file**

Browse... No file selected

Our in-house tool also allows direct connection to our EDW – this external facing tool for the data science community allows users to import their own data in CSV, Excel or SAS

# Data display

CHART forecasting tool

The screenshot shows the 'Import data' section of the CHART forecasting tool. A sidebar on the left contains navigation options: 'Load data', 'Create time variable', 'Generate time series', 'Explore time series', 'Model building', and 'Intervention analysis'. The main area is titled 'Import data' and includes instructions: 'Select either a csv, Excel, or SAS file to load. The data must be must contain 1 row per time observation.' Below this, there is a 'Choose file type:' dropdown menu set to 'csv', and a 'Choose file' section with a 'Browse...' button and a file named 'ed\_volumes\_month.csv'. A blue 'Upload complete' button is visible below the file name. A red dashed box highlights the table below, which contains 9 entries of data. The table has columns for 'month', 'volume', 'mean\_los', and 'mean\_pia'. A search bar is located to the right of the table.

Once imported, tool displays data

	month	volume	mean_los	mean_pia
1	2011-04-01	5362	0.19972622155912	87.5880268556509
2	2011-05-01	5606	0.211698144844809	86.3375557537913
3	2011-06-01	5839	0.214986401781127	86.0851464793558
4	2011-07-01	6119	0.207666693904233	85.4767898005884
5	2011-08-01	6113	0.206993800098151	81.7004743988222
6	2011-09-01	5916	0.219001301555105	90.5831643002028
7	2011-10-01	6087	0.195726499096435	85.2504107788367
8	2011-11-01	5705	0.224641840490798	81.8397896581946
9	2011-12-01	5618	0.194809896760413	76.656756275592

# Generate your time series

CHART forecasting tool

**Generate the time series**

Select from among the columns in your data to represent your time series. After selecting the variable of interest, click on the generate time series button and an interactive time series plot will be displayed.

Select a time variable:

volume

Generate time series

**Time series plot**

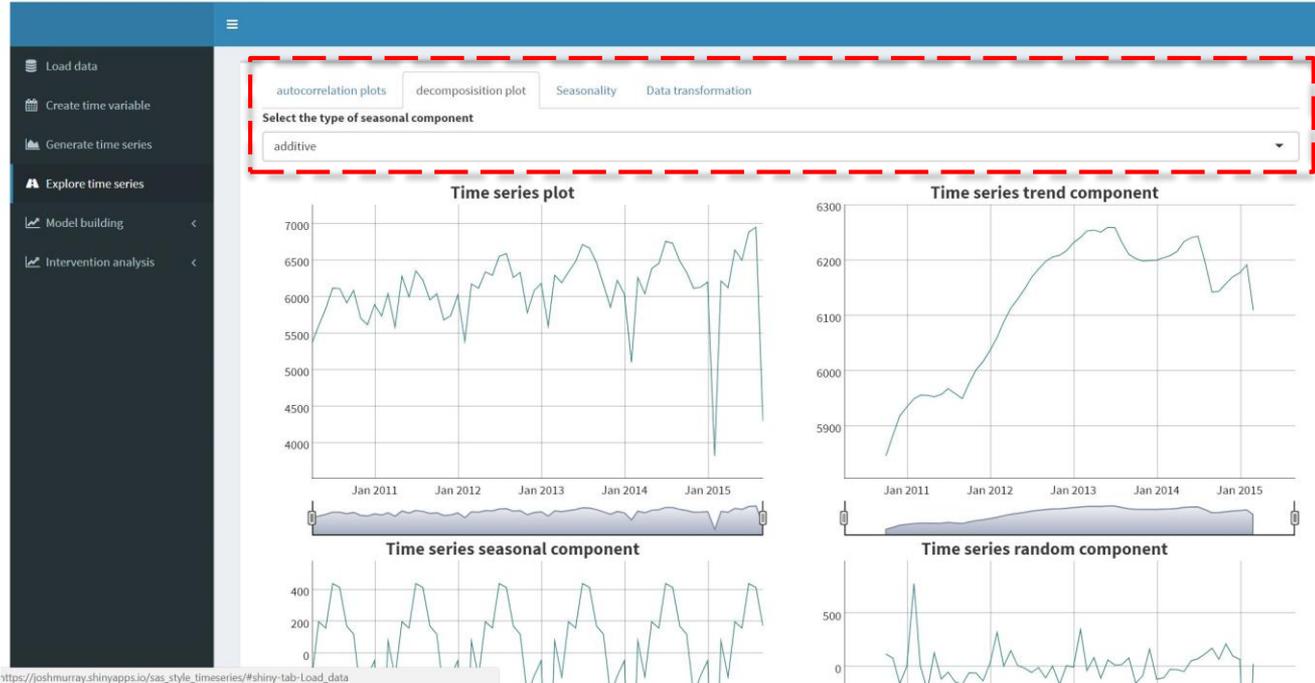
The plot shows a line graph of data from July 2010 to July 2015. The y-axis ranges from 4000 to 7000. The x-axis shows time points: Jul 2010, Jan 2011, Jul 2011, Jan 2012, Jul 2012, Jan 2013, Jul 2013, Jan 2014, Jul 2014, Jan 2015, Jul 2015. The data shows a general upward trend with significant fluctuations, including a sharp dip in early 2015.

Once a time variable is selected, the tool will generate a time series

# Explore your time series

Tool allows multiple explorations of your time series, including a decomposed view, illustrating trend, seasonality and randomness

CHART forecasting tool



# Forecasting component

- Key business application is predicting what will happen to support planning and management. For example:
  - Forecasting ED volumes to optimize staffing
  - Forecasting whether programs will meet quarterly or annual targets

# Forecast model building

CHART forecasting tool

The screenshot displays the CHART forecasting tool interface. On the left is a dark sidebar with navigation options: Load data, Create time variable, Generate time series, Explore time series, Model building (highlighted with a red dashed box), Exponential smoothing models, Arima models, and Intervention analysis. The main area is titled 'Custom or automatic exponential smoothing model' and includes tabs for Model selection, Explore models, Cross validate models, Build forecasts, and Save forecasts. Below these are dropdown menus for Error component (Additive), Trend component (Additive damped), and Seasonal component (None). A 'Time series plot' shows data from Jan 2011 to Jan 2015. A table on the right lists generated models with columns for model\_name, error, trend, season, transformation, RMSE, MAPE, and AIC.

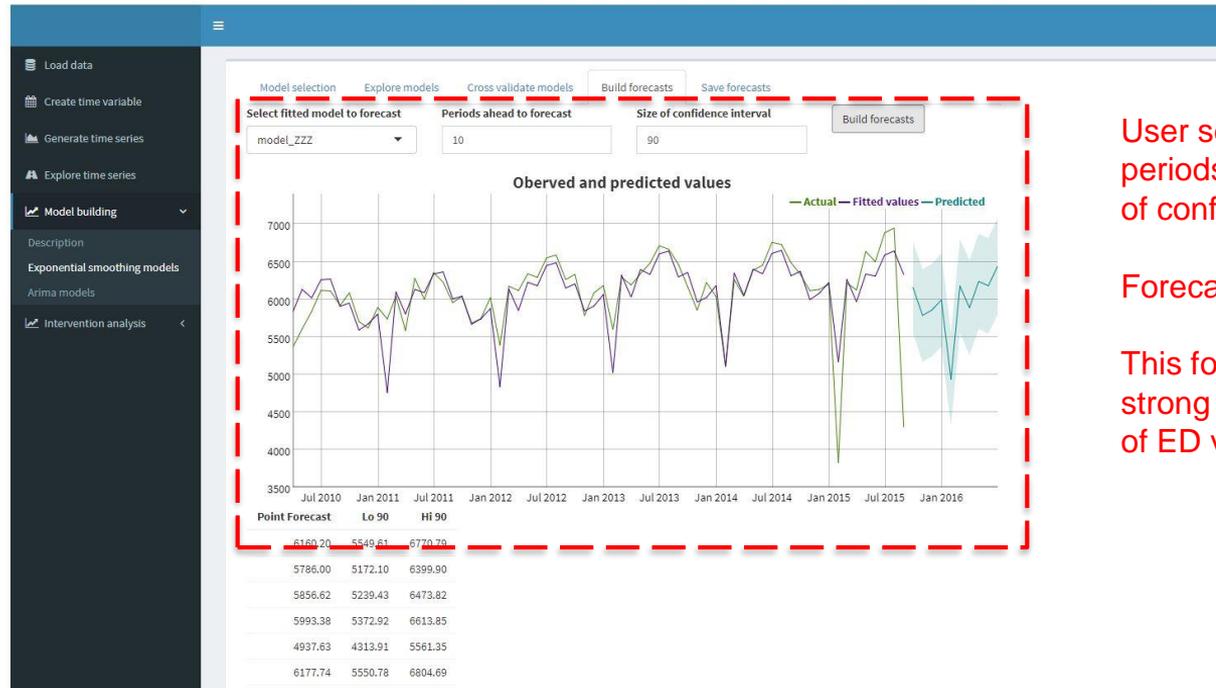
Tool allows user to build multiple customized models (or automatic generation for best-fit)

Tool allows user to build models using exponential smoothing or Arima

	model_name	error	trend	season	transformation	RMSE	MAPE	AIC
1	model_ZZZ	automatic	automatic	automatic	automatic			
2	model_ANN	Additive	None	None	FALSE			
3	model_AAdN	Additive	Additive damped	None	FALSE			

# Forecast results

CHART forecasting tool



User selects number of periods to forecast and size of confidence intervals.

Forecast displayed in green.

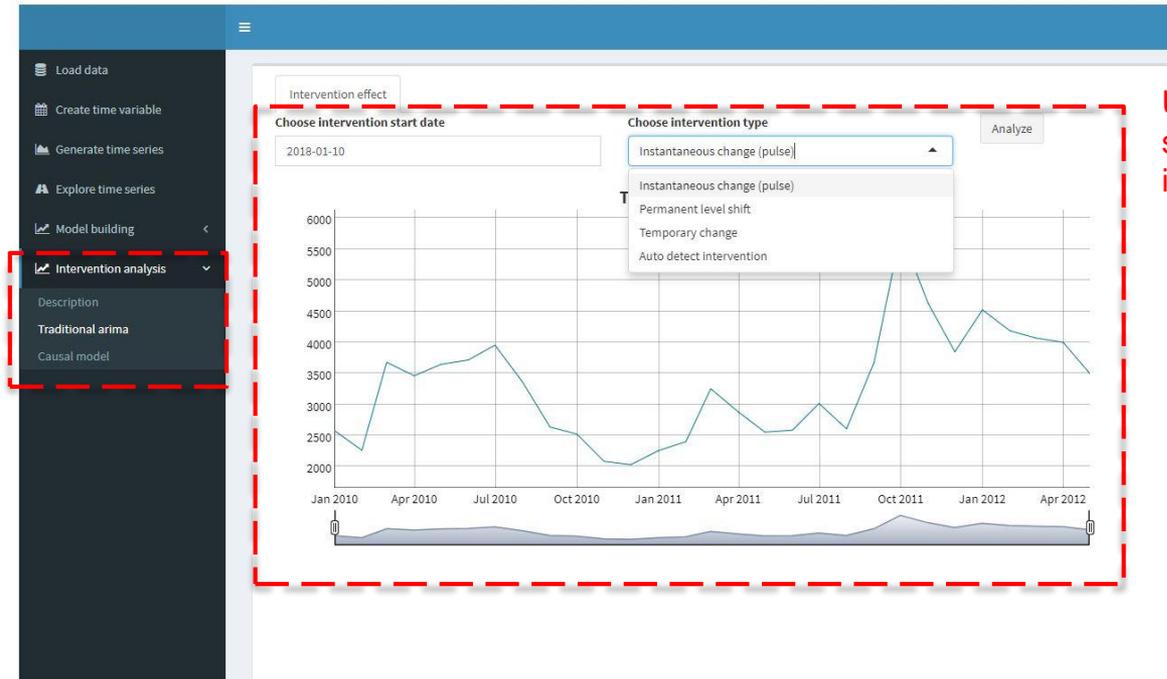
This forecast reflects very strong seasonal component of ED volumes.

# Intervention analysis

- Business application is to retrospectively measuring the impact of an intervention
- Supports measuring a variety of intervention types:
  - Pulse: measure the impact of a very brief event, such as a disaster
  - Temporary change: measure the impact of short-term change, such as opening surge beds for flu season
  - Permanent change: measure the impact of a long-term change, such as a new screening protocol for VRE.

# Building the analysis

CHART forecasting tool



Tool supports traditional ARIMA or Causal Impact (an application from Google)

User selects intervention start date, and type of intervention (or auto-detect)

# Analyzing results

CHART forecasting tool



Tool illustrates impact of intervention by modeling forecasted values against actual observed values

## Sample projects underway

- **Operational** - ED early-warning system: Generalized Additive Model, integrating hospital data with geo-mapped local event data (marathons, concerts, etc) and weather data, to predict Emergency Department volumes in six hour increments, out to 72 hours in advance
- **Clinical** - ICU early-warning system: recurrent neural network using lab results and vital signs recorded in patient charts to generate predictions of patients at highest risk of being transferred to ICU to facilitate early intervention

## Outcomes

- **Advanced analytic tool** has reduced time required to complete retrospective analysis from an average of 3 days to an average of two hours. This has allowed the unit to remain lean, while maintaining a level of responsiveness that has maintained executive buy in.
- **ED early warning** system has achieved a 6% error rate (MAPE)
  - With an volume of 200 visits in a day, margin of error is only +/- 12)
  - Because high variability in our ED volumes day to day (SD=40), this provides significant improvement in predictive power over a naïve approach

# Questions

- Jeremy Petch, PhD
- [petchj@smh.ca](mailto:petchj@smh.ca)

**OUR SHARED  
PURPOSE**

**PROVIDENCE**  
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Inspired Care.  
Inspiring Science.

- Please complete the online session evaluation!