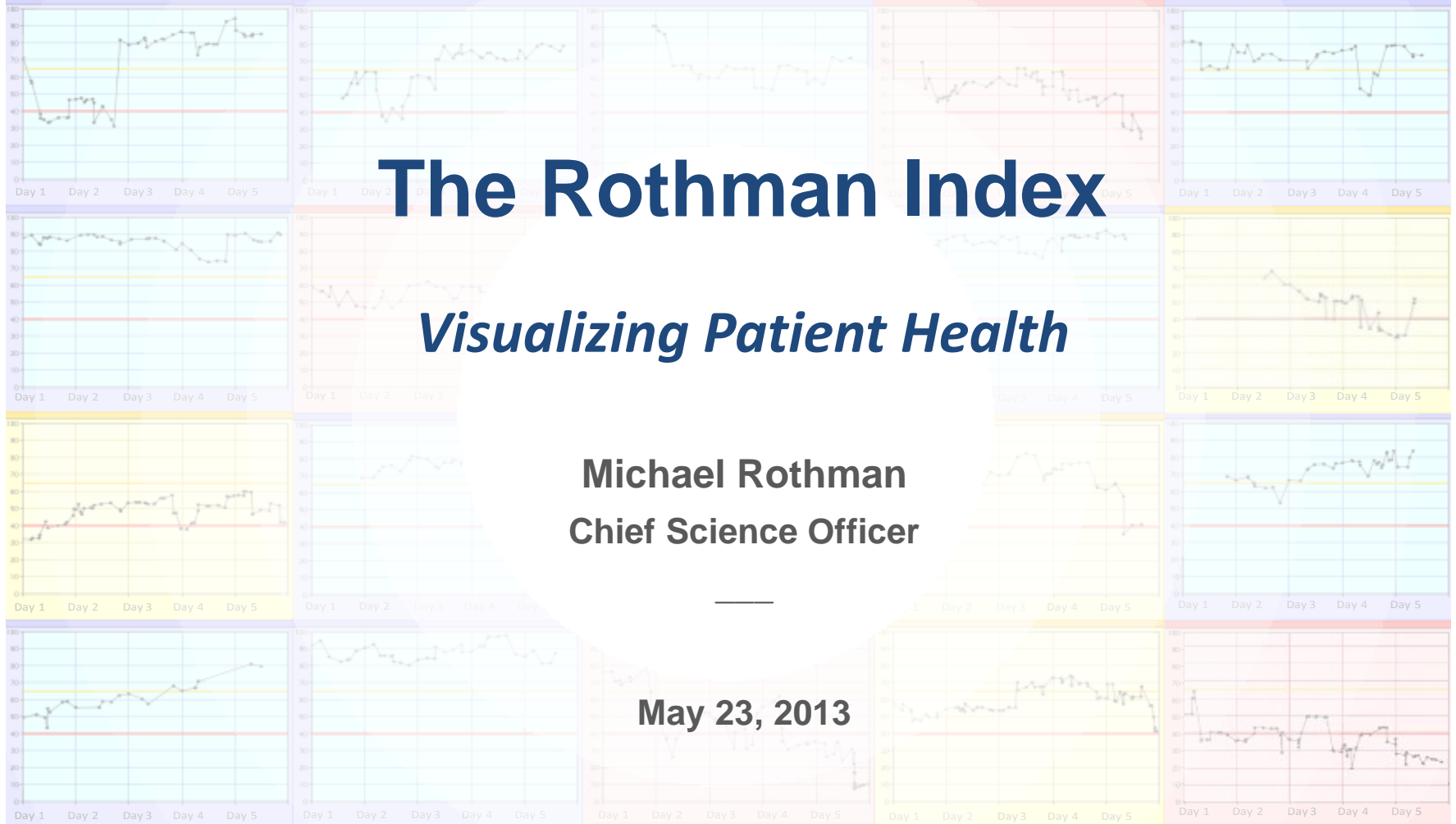


The Rothman Index

Visualizing Patient Health

Michael Rothman
Chief Science Officer

May 23, 2013



OUR INSPIRATION: FLORENCE ROTHMAN

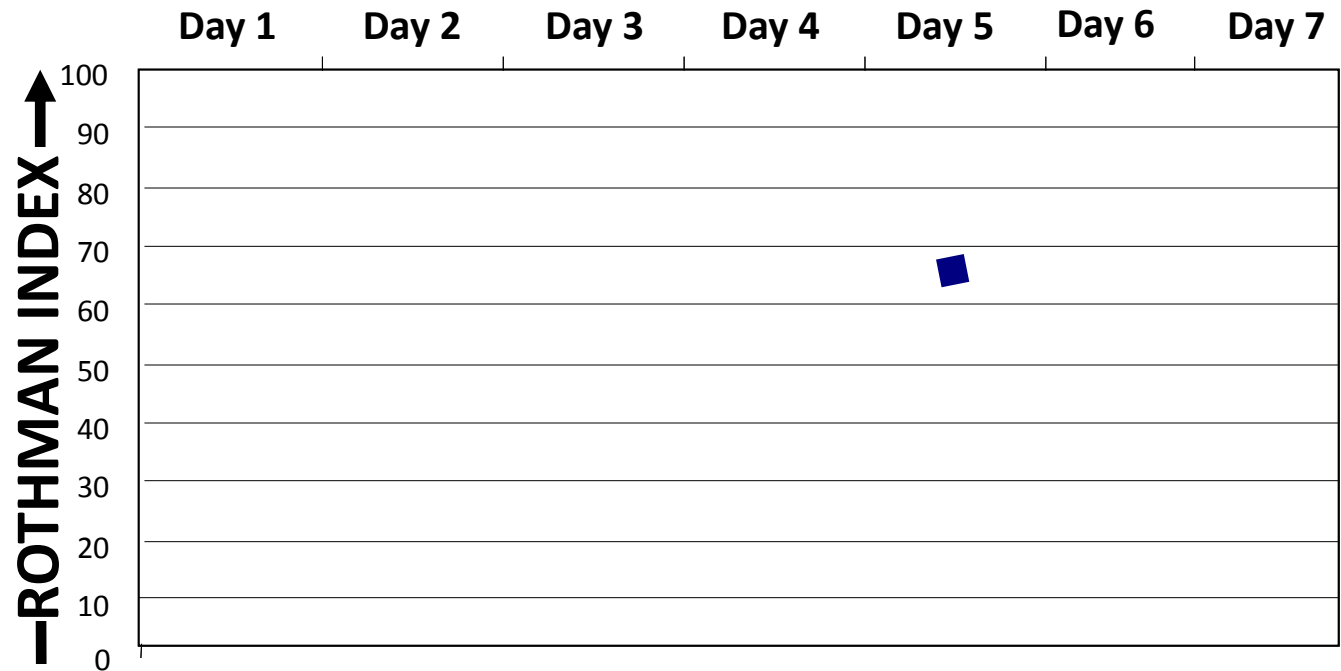
The System Failed Her



...We had an Idea

OUR INSPIRATION: FLORENCE ROTHMAN

The System Failed Her



...We had an Idea

OUR INSPIRATION: FLORENCE ROTHMAN

The System Failed Her

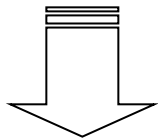


...We had an Idea

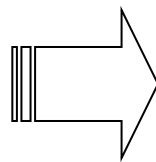
VISUALIZING DATA CAN ENABLE EARLY INTERVENTION

Existing EHR Data

Vital Signs
Pulse/Ox
Lab Values
Braden Score
Nursing Assessments



RI
Algorithm



Rothman Index Graph



An opportunity for earlier intervention.

The evolution of hospital care has created new problems with safety

- New tests, drugs, surgical techniques, devices, technology... → high costs



- High costs dictate shorter stays and sicker patients
- Primary Care Physicians have been replaced
- Communication becomes critical

The need

- *Communication is a major problem in delivering quality healthcare... IHI estimates an average of 24 hand-offs in a 5-day stay. The Joint Commission says that communication between care providers is a principal cause in over 60% of sentinel events*
- *A graphical presentation of the patient's acuity will aid in communication between clinicians at handoffs and through time*
- *To provide such a graph, one needs to measure patient condition across the full spectrum of acuity*
- *In order to be sensitive to acuity on a general med-surg unit, one must use nursing assessments (in addition to vitals and labs)*

The science – our approach

- *Goal - to construct a general measure of patient acuity applicable across the full range of patient acuity... which will facilitate communication among clinicians and over time... help prioritize visits and display trends*
- *Note – predicting outcomes is largely unproductive in individual patient care... the future is foggy, but the past is clear*
- *Cannot be a regression model, as there is no general measure of patient acuity to regress against*
- *Heuristic model – variable selection and risk evaluation*
 - *In the EMR... no additional data entry*
 - *Available for the general hospital population*
 - *Frequently measured*
 - *Sensitive to deterioration*
 - *Spanning all modes of deterioration*
 - *Nursing assessments show soft fails*
 - *“Excess risk” method captures univariate risk and addresses “data fusion” problem*

Excess risk method

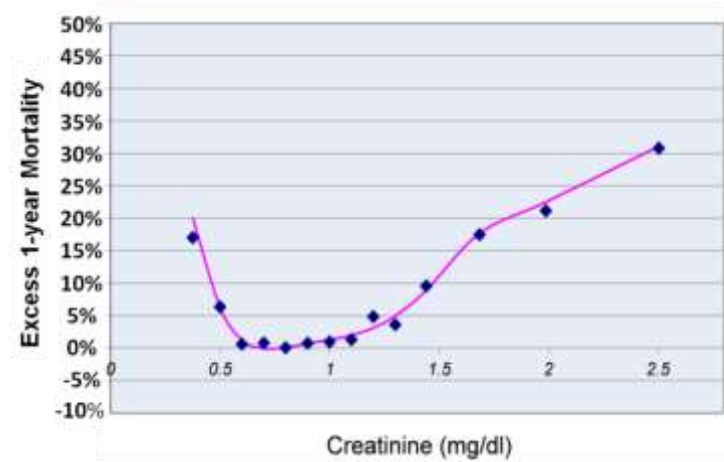


Figure 1 – Excess 1-year mortality risk as a function of serum creatinine. For values of 0.38 or below, the value is set at 20%. For values of 2.5 and above, the value is set at 30%. Based on 22,205 patient visits, confirmed on a 2nd set of 25,000 visits.

$$Rothman\ Index = 100 - (Scale\ Factor) \sum_{Input=1}^{26} Excess\ Risk_{Input}$$

Validation – discharge disposition

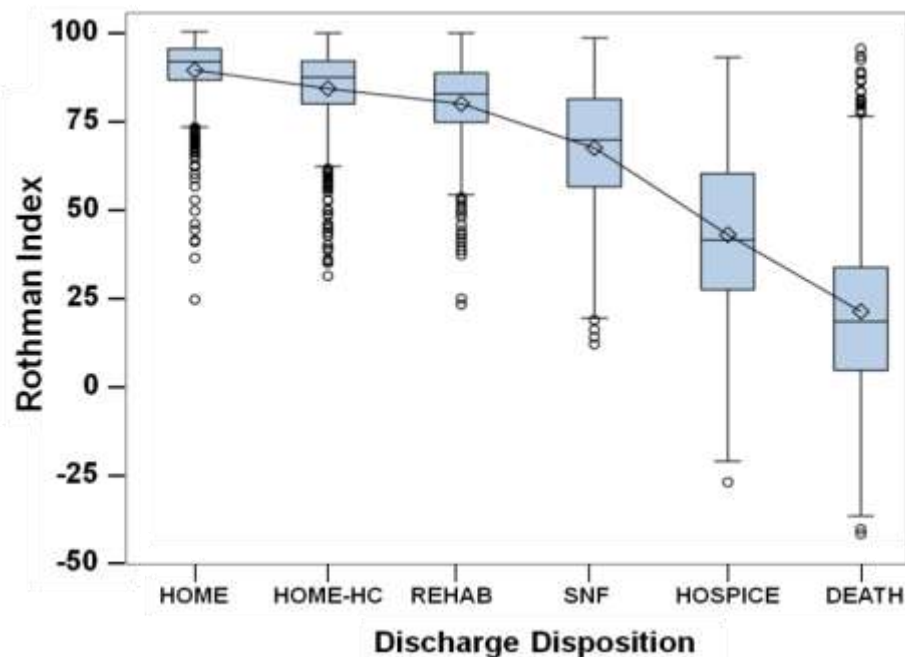


Figure 2 – Final RI versus Discharge Disposition.

Distribution of patient final Rothman Index prior to discharge vs. discharge categories: Home, Home with Health Care, Rehabilitation, Skilled Nursing Facility, Hospice, and Death.

ANOVA $f(5,22,205) = 6768$ ($p < 0.0001$)

Validation – 24-hour mortality

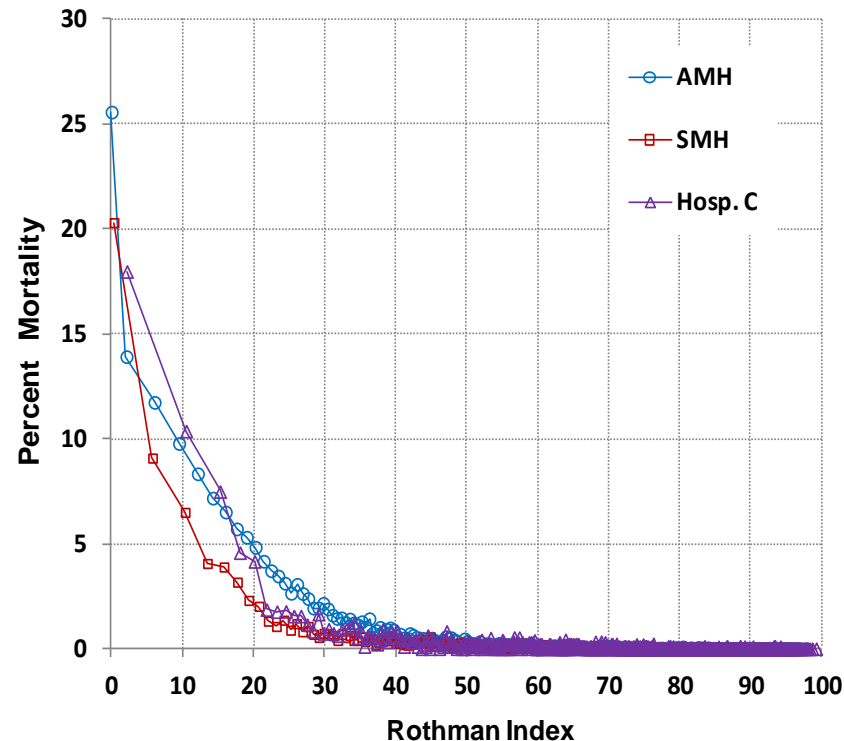


Figure 3 – 24-hour mortality as a function of the Rothman Index. Three hospitals... AUC=0.93 (0.92, 0.94) vs. ViEWS= 0.888 (0.88, 0.90)

Validation – Returns to hospital

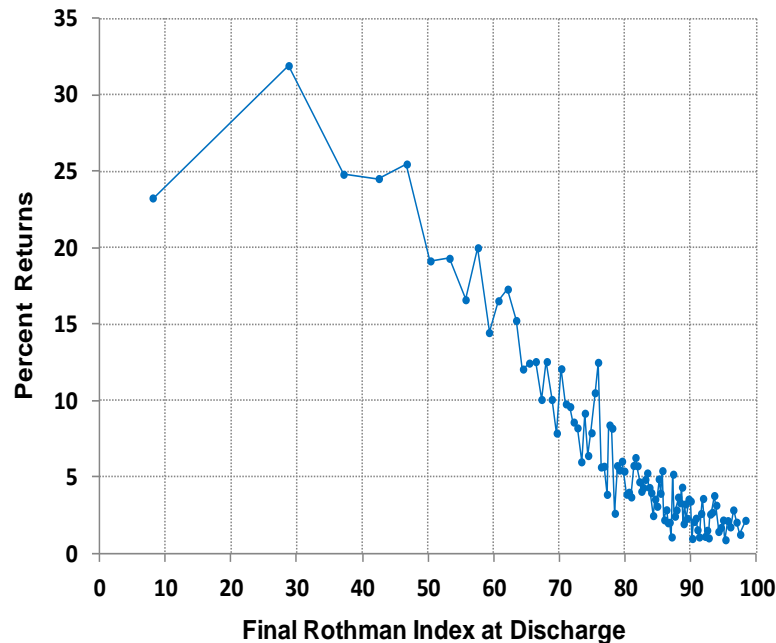


Figure 4 – Percent return to the hospital within 30 days for those patients discharged to home vs. the final measured Rothman Index prior to discharge. The data are from 25,942 patient visits to SMH between 1/2008 and 5/2010. AUC was 0.74 (95% CI 0.72-0.75).

Validation – Comparison to APACHE III

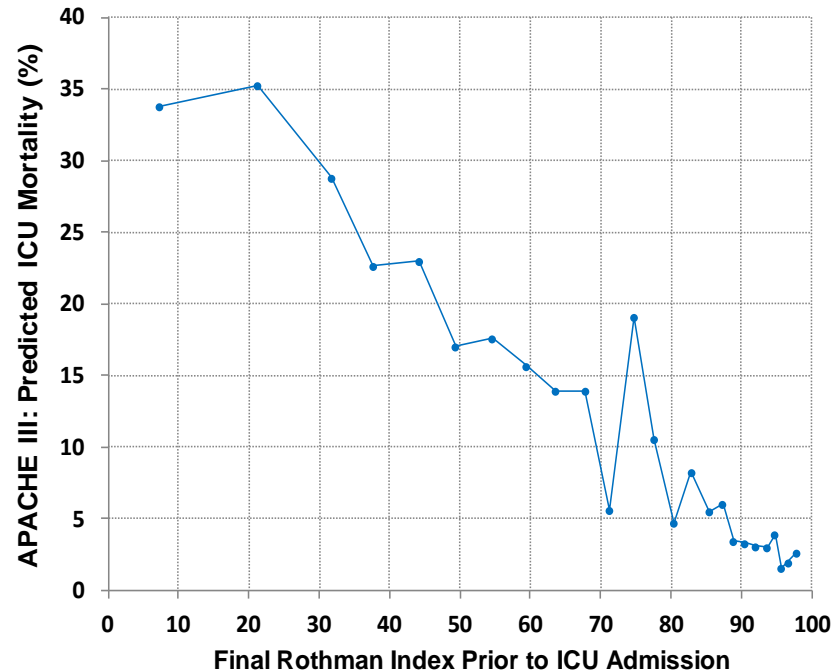
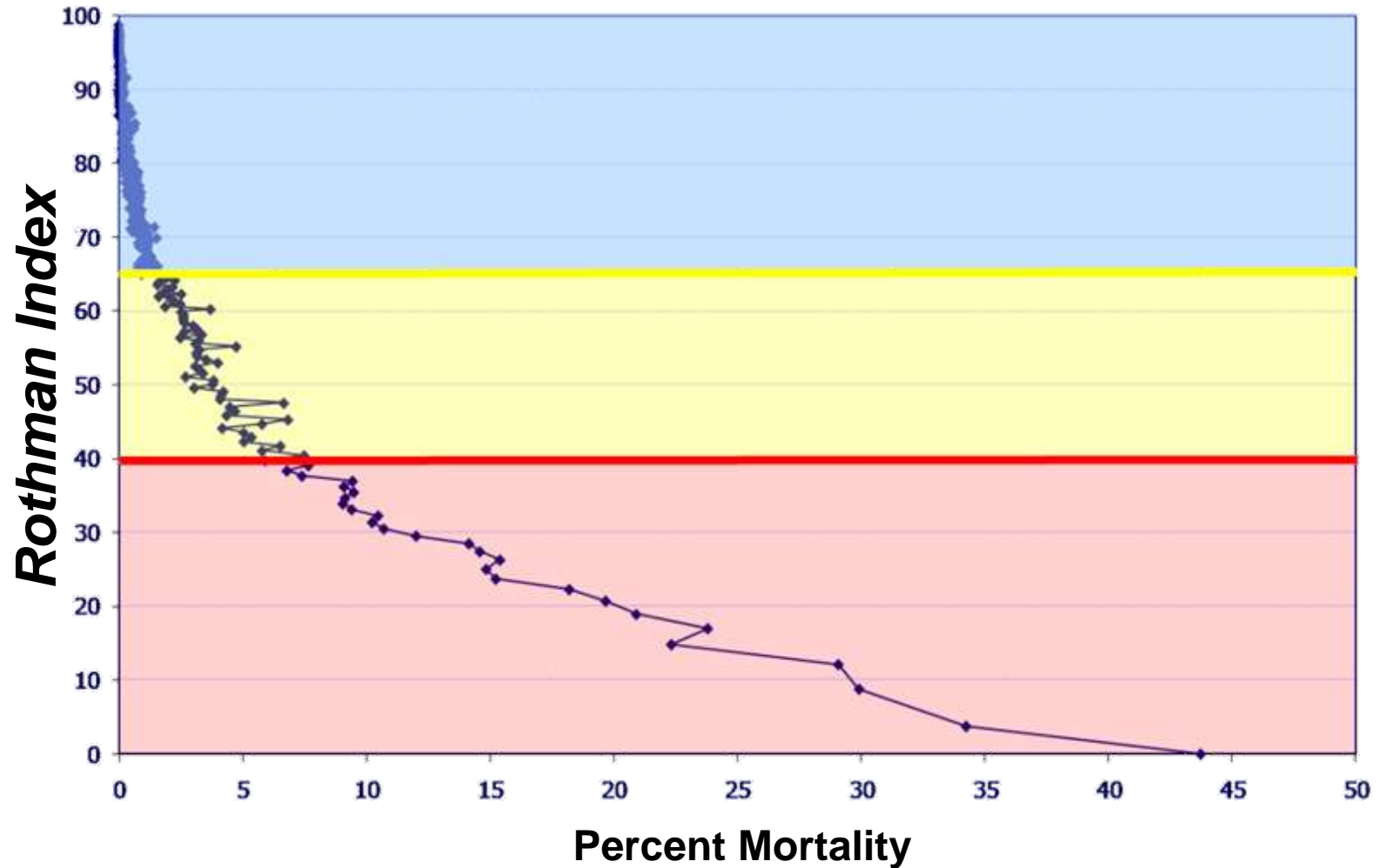


Figure 5 – APACHE III initial estimate of mortality vs. final Rothman Index measured prior to entering the ICU. Pearson's correlation coefficient = -0.47, $p < 0.001$.

Validation – Rothman Index at four hospitals

	Sarasota Memorial Hospital	Abington Memorial Hospital	Hospital C	Hospital D
Patient visits	22,205	32,416	19,402	13,359
Home	88.5 (9.3) 60.4%	82.1 (11.4) 75.5%	85.5 (10.7) 83.7%	84.6 (10.8) 73.0%
Home health	83.3 (11.4) 15.2%	n/a	82.0 (11.2) 2.9%	78.0 (13.2) 8.2%
Rehab	78.8 (12.2) 5.1%	68.9 (15.7) 2.6%	74.1 (13.9) 1.5%	71.2 (13.1) 3.1%
SNF	66.1 (17.6) 13.3%	63.1 (16.0) 16.8%	66.8 (16.0) 10.0%	66.3 (15.4) 12.3%
Hospice	41.1 (23.2) 2.8%	35.0 (21.0) 2.3%	49.2 (23.0) 0.9%	51.4 (18.9) 1.6%
Death	19.1 (24.1) 3.0%	13.5 (20.9) 1.9%	22.9 (27.3) 1.1%	21.7 (19.4) 1.9%

Rothman Index vs. discharge to hospice or death within 48 hours



In practice

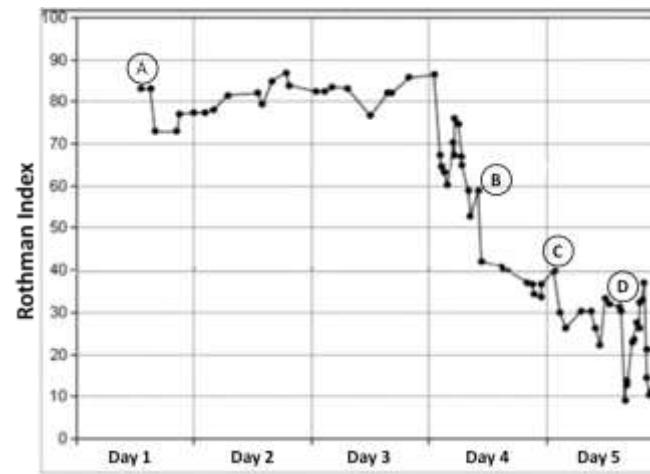
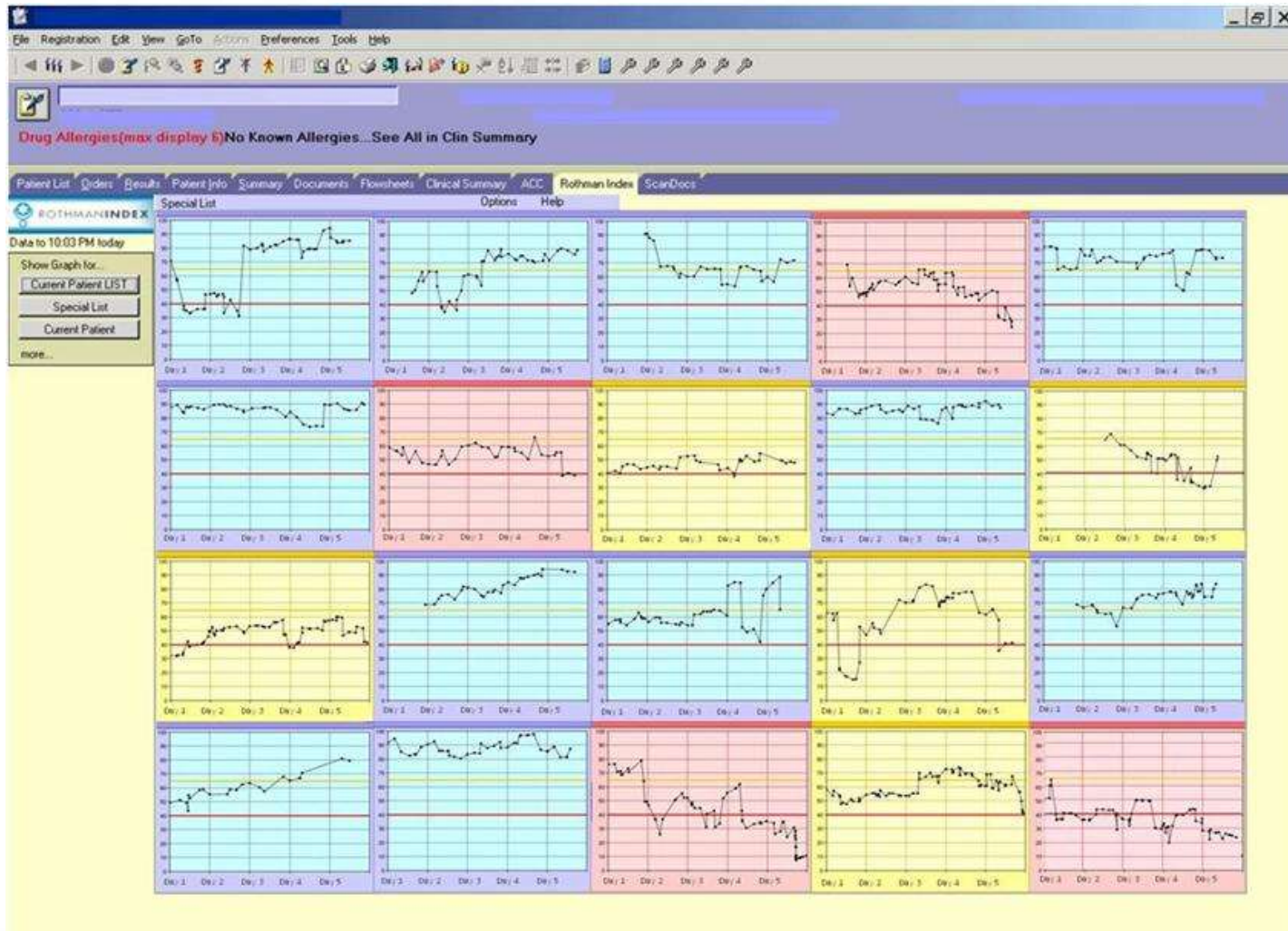


Figure 6 – Rothman Index graph. Each vertical line is at midnight. (A) Patient admitted for laparoscopic surgical procedure. (B) Nurse notes patient deterioration, majority of nursing assessments are failed. (C) Rapid Response Team called; patient treated and remains on floor (D) Rapid Response Team called again, patient transferred to ICU with sepsis.

PATIENT SURVEILLANCE AT A GLANCE





Clipboard icon and a text input field.

Drug Allergies(max display 6)No Known Allergies...See All in Clin Summary

ROTHMANINDEX

Data to 10:03 PM today

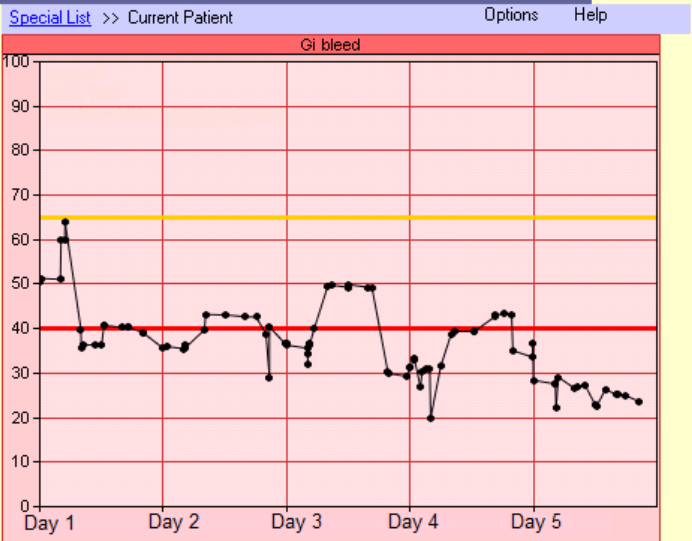
Show Graph for...

Current Patient LIST

Special List

Current Patient

more...



Search bar

Drug Allergies(max display 6)No Known Allergies...See All in Clin Summary



Data to 10:03 PM today

Show Graph for...

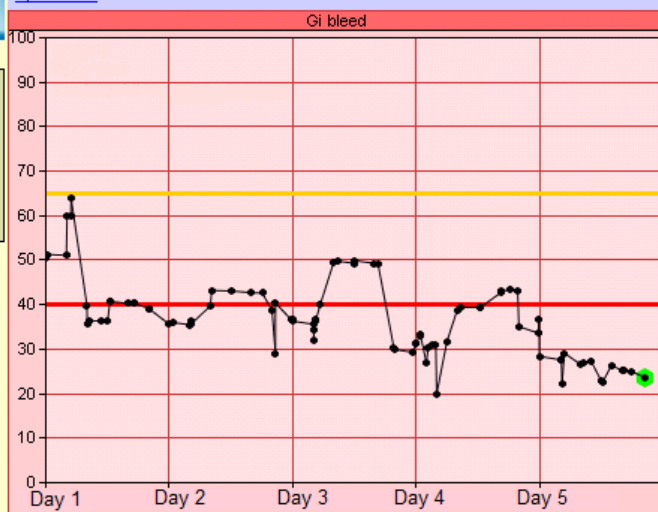
Current Patient LIST

Special List

Current Patient

more...

Special List >> Current Patient Options Help



<input checked="" type="checkbox"/>	Day 5 8:29 PM
Rothman Index	23.7
Temperature	98.6
Systolic BP	138
Diastolic BP	78
HeartRate	94
RespRate	22
PulseOx	93
HeartRhythm	SR
Braden	11
Cardiac	met
Food	not met
Gastrointestinal	not met
Genitourinary	not met
Musculoskeletal	not met
Neurological	not met
Peripheral-vasc	not met
Psycho-social	not met
Respiratory	not met
Safety	not met
Skin	not met
BUN	7
Creatinine	0.9000
wBC	10.5
HGB	10.2
Chloride	104
Sodium	135
Potassium	4.0000
Observations:	click here



Search bar with a magnifying glass icon and a text input field.

Drug Allergies(max display 6)No Known Allergies...See All in Clin Summary



Data to 10:03 PM today

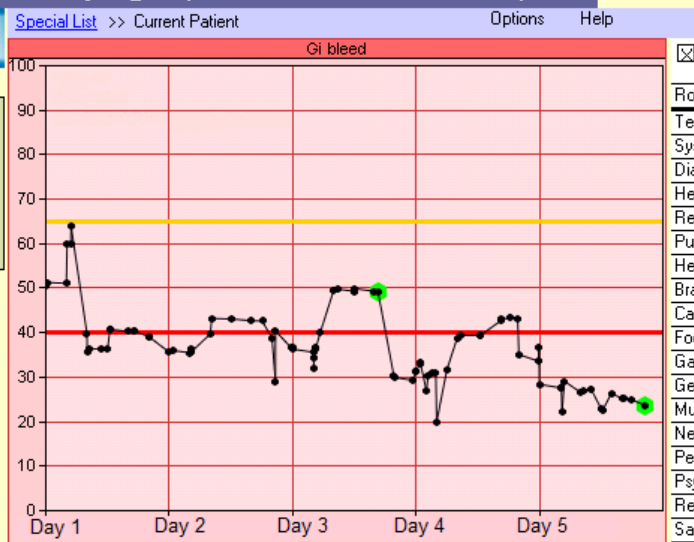
Show Graph for...

Current Patient LIST

Special List

Current Patient

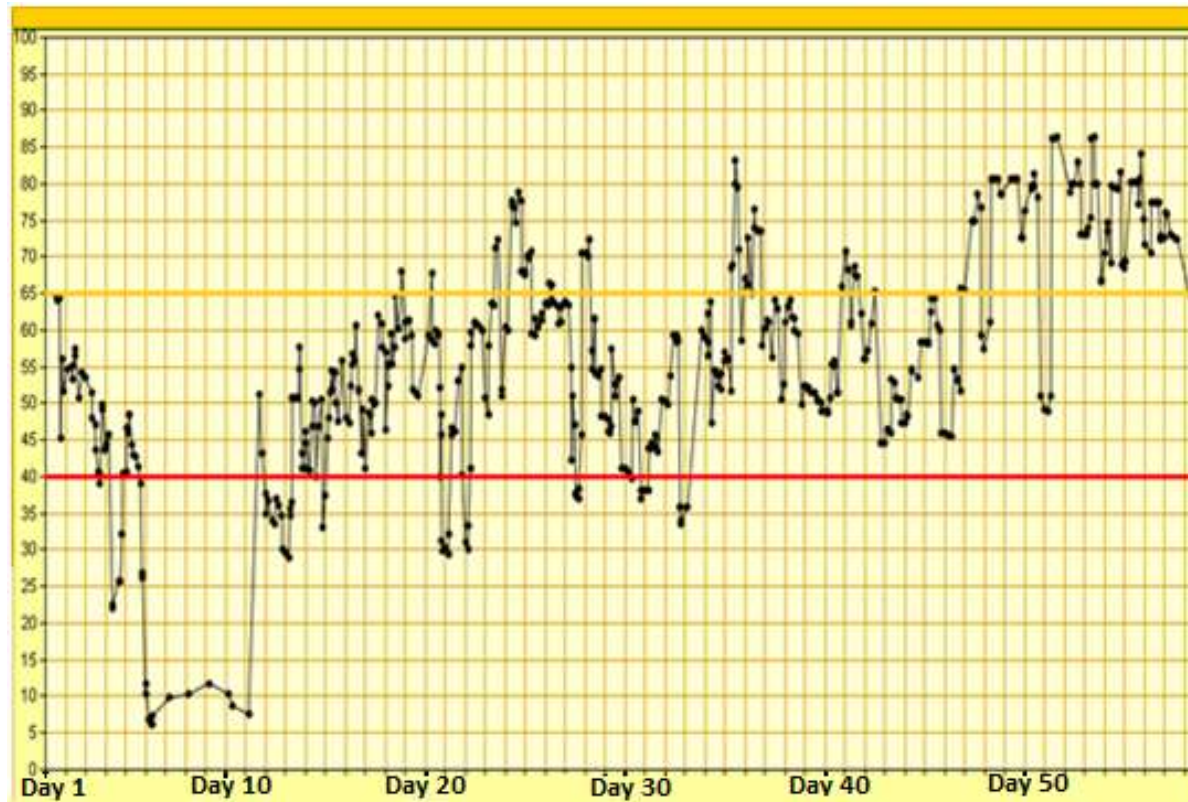
more...



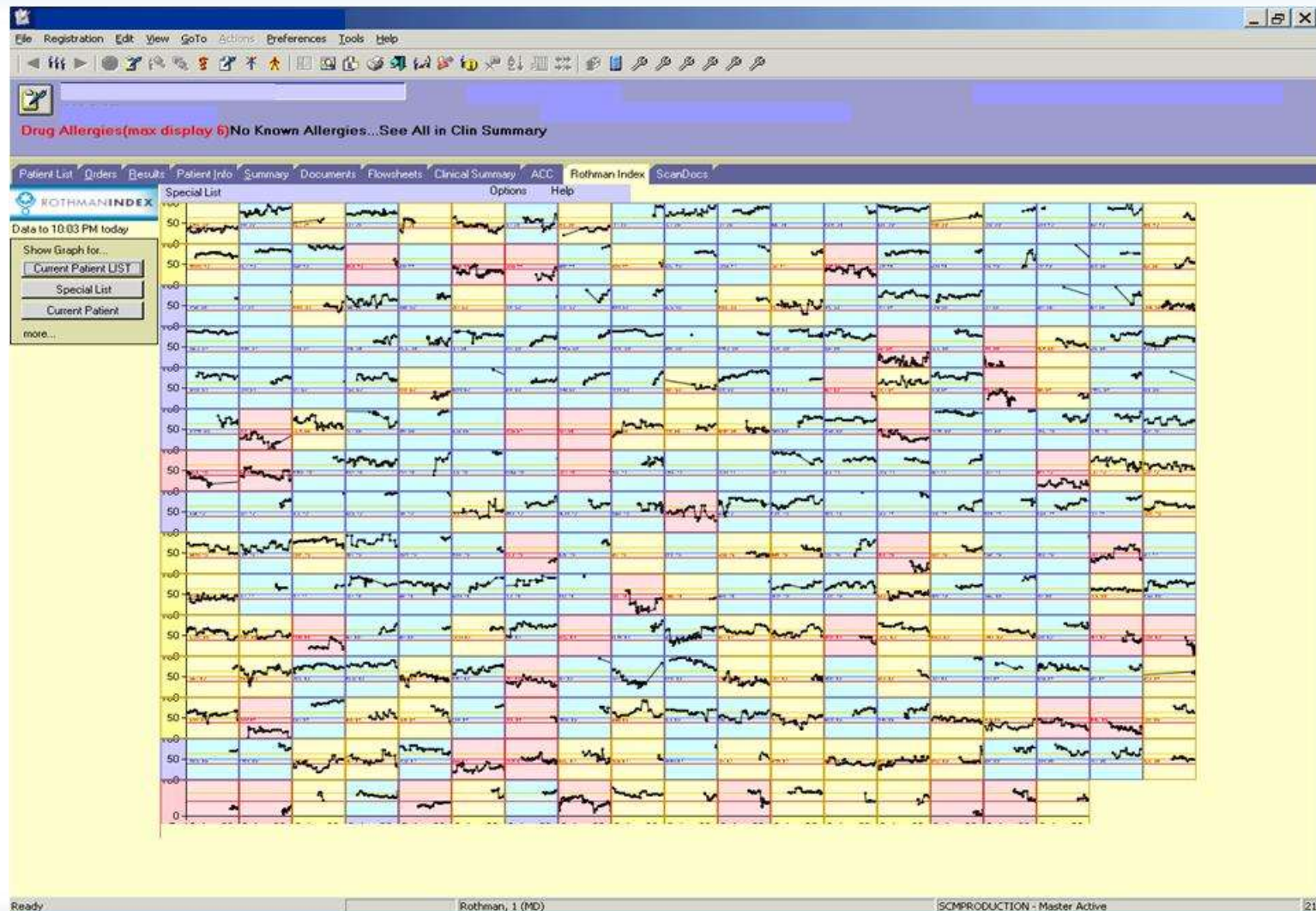
<input checked="" type="checkbox"/>	Day 3 4:36 PM	Day 5 8:29 PM
Rothman Index	49.2	23.7
Temperature	98.2	98.6
Systolic BP	141	138
Diastolic BP	82	78
HeartRate	78	94
RespRate	20	22
PulseOx	95	93
HeartRhythm	SR	SR
Braden	18	11
Cardiac	met	met
Food	not met	not met
Gastrointestinal	not met	not met
Genitourinary	not met	not met
Musculoskeletal	not met	not met
Neurological	not met	not met
Peripheral-vasc	not met	not met
Psycho-social	met	not met
Respiratory	not met	not met
Safety	not met	not met
Skin	not met	not met
BUN	9	7
Creatinine	0.8000	0.9000
wBC	9.8	10.5
HGB	9.8	10.2
Chloride	103	104
Sodium	134	135
Potassium	3.7000	4.0000
Observations:	click here	click here

VISUALIZING PATIENT DATA

A single patient who has spent two months in the hospital...

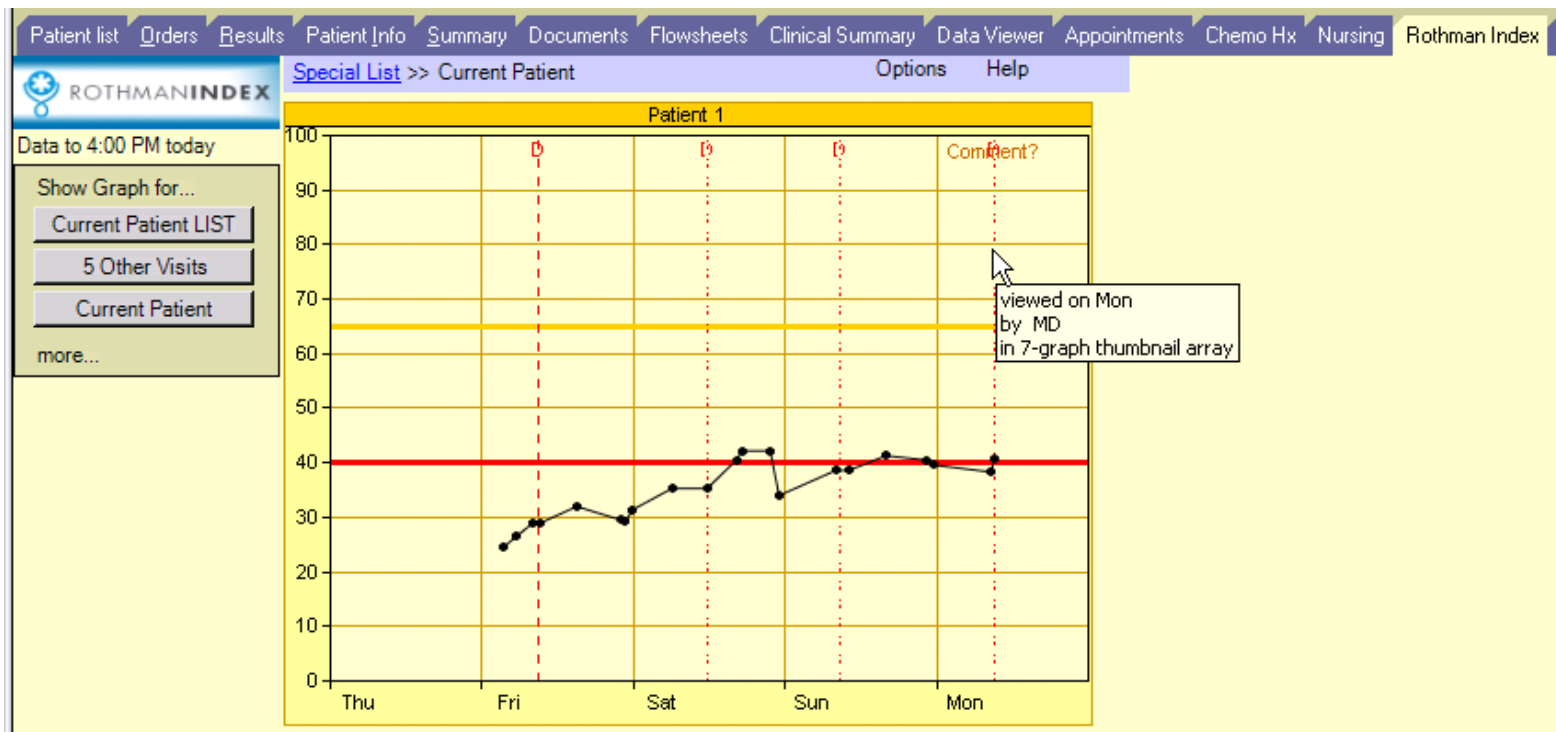


...OR THE ENTIRE HOSPITAL



Evolution of the tool based on our work with our hospital partners

- We created a single panel showing all past admissions
 - *Here is a single visit... click on the “other visits” button and ...*



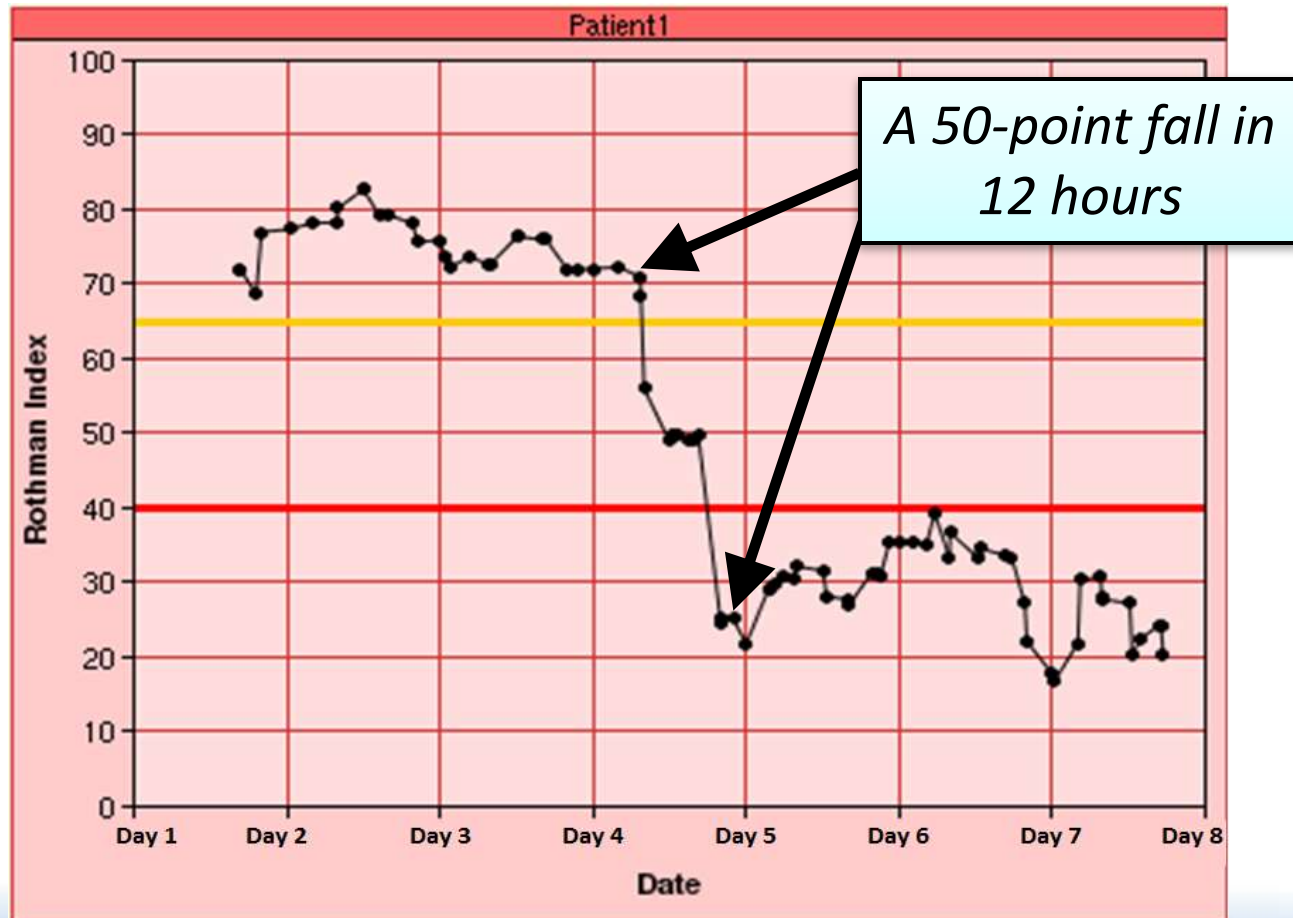
Evolution of the tool based on our work with our hospital partners

- ... now we see the four prior admissions, showing continuing deterioration from one visit to the next, to the next, and so on.



CASE STUDY 1

A CMO asked us to look at the records of a patient who died unexpectedly.



VITAL SIGNS WERE STABLE...

Time	Rothman Index	Temp	Systolic	Diastolic	Resp Rate	Pulse-Ox	Heart Rate
07:25	71.0	97.7	161	79	18	97	84
07:30	68.4	99.1	163	85	20	95	82
08:00	56.0	99.1	163	85	20	95	82
11:56	49.0	99.1	163	85	20	95	82
12:30	49.8	99.3	153	77	20	95	73
13:04	49.9	99.3	153	77	20	95	73
14:46	49.0	99.3	175	84	20	95	74
15:50	49.1	99.3	175	84	20	95	74
16:28	50.0	98.1	168	80	20	95	77
20:00	24.7	98.1	168	80	20	95	77

...BUT THE NURSES KNEW THIS PATIENT WAS IN TROUBLE

Time	Rothman Index	Braden	Cardiac	Food	Gastro	Genito	Musculo	Neuro	Perivasc	Psych	Safety	Skin
07:25	71.0	18	Fail	Pass	Pass	Pass	Fail	Pass	Fail	Pass	Pass	Fail
07:30	68.4	18	Fail	Pass	Pass	Pass	Fail	Pass	Fail	Pass	Pass	Fail
08:00	56.0	16	Pass	Pass	Pass	Pass	Fail	Fail	Pass	Pass	Fail	Fail
11:56	49.0	16	Pass	Pass	Pass	Pass	Fail	Fail	Pass	Fail	Fail	Fail
12:30	49.8	16	Pass	Pass	Pass	Pass	Fail	Fail	Pass	Fail	Fail	Fail
13:04	49.9	16	Pass	Pass	Pass	Pass	Fail	Fail	Pass	Fail	Fail	Fail
14:46	49.0	16	Pass	Pass	Pass	Pass	Fail	Fail	Pass	Fail	Fail	Fail
15:50	49.1	16	Pass	Pass	Pass	Pass	Fail	Fail	Pass	Fail	Fail	Fail
16:28	50.0	16	Pass	Pass	Pass	Pass	Fail	Fail	Pass	Fail	Fail	Fail
20:00	24.7	12	Fail	Fail	Pass	Fail	Fail	Fail	Fail	Fail	Fail	Fail

Clinical Trial – Sarasota Memorial (2008)

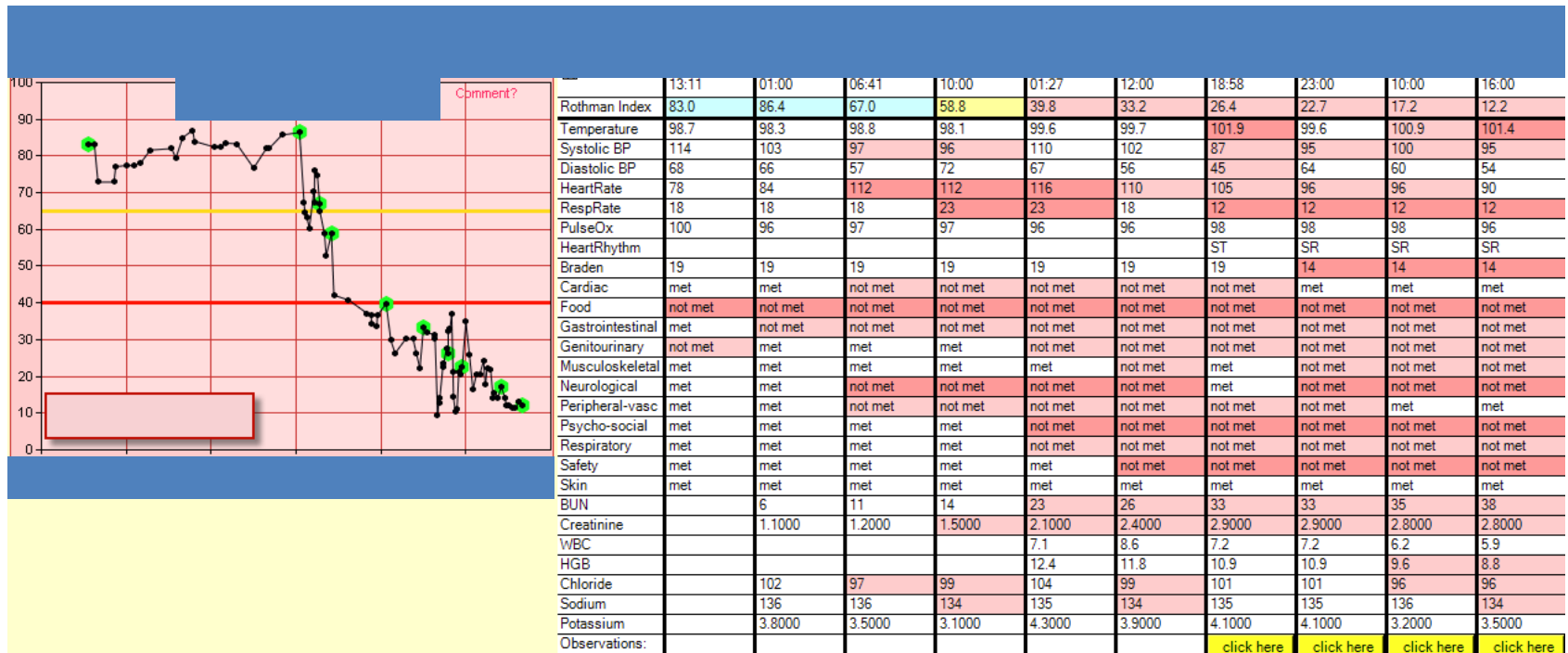
With monitoring, better care was delivered



Table 1. Clinical trial results at a 500-bed Community Hospital. Means in bold, standard dev. in parentheses.

	Intervention	Control	p
Patient visits	833	832	
Length of stay	5.78 (5.59)	5.64 (5.42)	0.60
Case Mix Index	1.60 (1.51)	1.54 (1.13)	0.36
Age	66.2 (18.4)	66.6 (18.9)	0.65
Discharge: Home or Home Health	67.2%	62.6%	0.05
Discharge: Rehab or SNF	22.7%	25.4%	0.20
Discharge: Hospice or due to death	7.0%	8.5%	0.25

sepsis



ROTHMAN INDEX HOSPITALS

- Community Hospitals
 - Sarasota Memorial Hospital, FL
 - Blessing Hospital, IL
 - Shannon Hospital, TX
- Academic Medical Centers
 - The Methodist Hospital, TX
 - Orlando Regional Medical Center, FL
 - Yale New Haven Hospital, CT
 - Shands Hospital, FL
 - UPMC Children's Hospital
- Many others in process

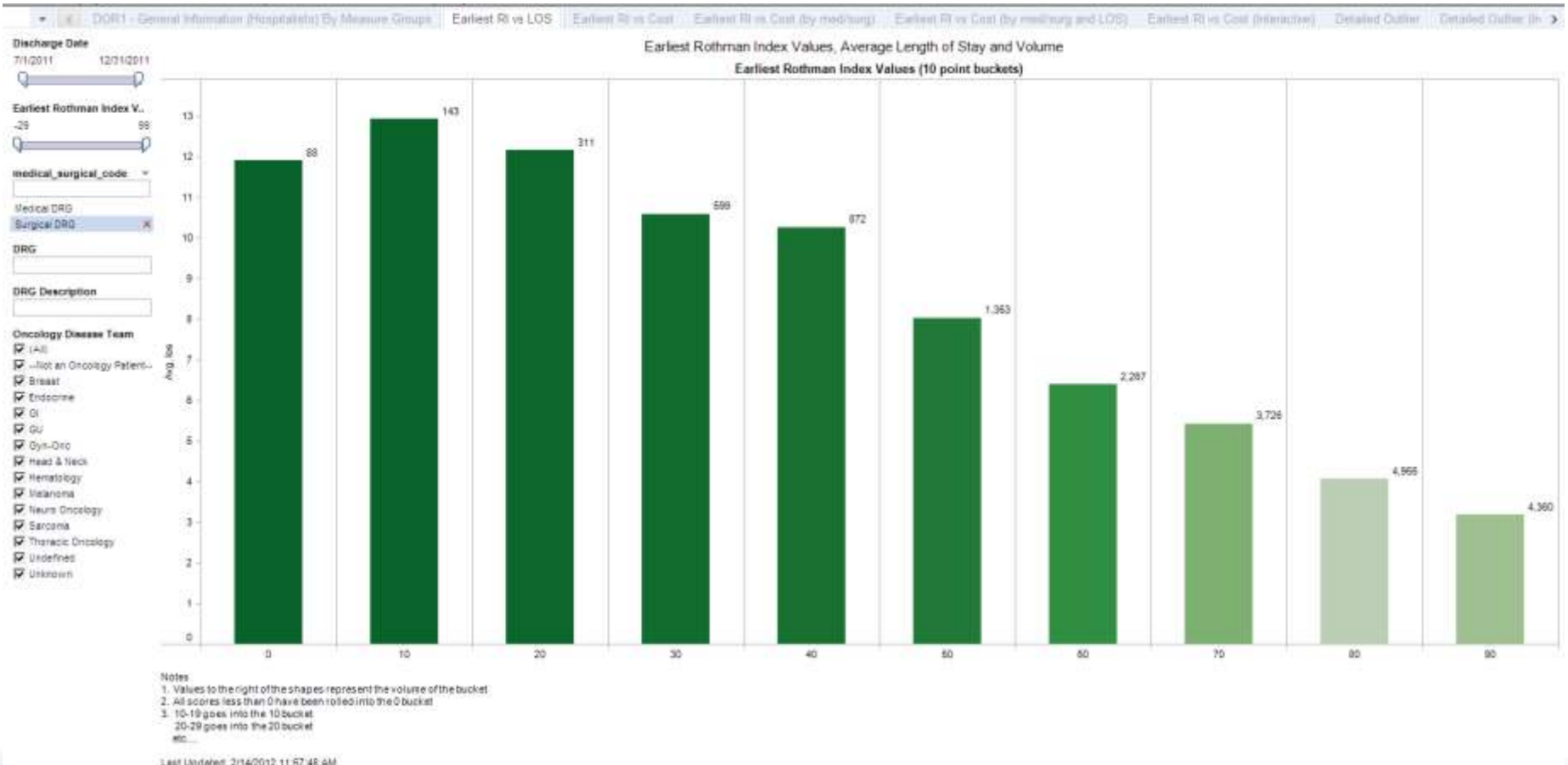
Publishing

- ***Automated Identification of Postoperative Complication: The First Fruits of Transition to an Electronic Medical Record***, Joseph J. Tepas, MD, U of Florida College of Medicine, Allen L. Hsiao, MD, Yale University School of Medicine and Yale New Haven Hospital, Joan M. Rimar, DNSc, RN, Yale New Haven Hospital – abstract submitted for a presentation to the 2012 Surgical Forum of the Clinical Congress of the American College of Surgeons.
- ***Algorithm-based proactive Rapid Response Team rounds: Developing - a safety net for patients and nurses***, Valerie Danesh, Orlando Health, Edgar Jimenez, Orlando Regional Medical, accepted for presentation at the 2012 Congress of Critical Care Medicine, published in a supplemental issue of Critical Care Medicine 12/2011
- ***Reviewing Patient Events to Improve Crisis Identification and Response: A Novel Algorithm***, *The 6th International Symposium on Rapid Response Systems*, Pittsburgh, 2010, Edgar Jimenez, MD, Orlando Regional Medical Center
- ***Visualizing Your Patient's Condition – Facilitating Communication between Caregivers to Improve Care*** – presented at the U. of Pennsylvania School of Nursing, 8th Annual National Patient Safety Conference, 11/11
- ***The Rothman Index – Foundations 1. A Longitudinal Measure of Patient Condition from Analysis of the Electronic Medical Record: Clinical Implications and Validity of Nursing Assessments*** submitted to the BMJ Open
- ***The Rothman Index – Foundations 2. A Real-Time Measure of General Patient Condition Spanning the Hospital Acuity Spectrum: Model Development and Construct Validation*** to be submitted to BMJ
- ***System and Method for Improving Hospital Patient Care by Providing a Continual Measurement of Health*** – US Patent 8,093,207.
- ***System and Method for Providing a Health Score for a Patient*** – US Patent 8,100,829.

The business

- *2005 – 2 brothers built model based on 70 cardiac patients, applied for patents*
- *2006-2007 – obtained data, developed excess risk method, refined model*
- *2008-2009 – finished software development, integrated with Eclipsys, ran clinical trial, formed LLC, started speaking to hospitals, EMR companies, attended user group conferences, self-funded, part time*
- *2010-2011 – formed c-corp, hired professional management, friends and family round, angel round, installed in 3 more hospitals, staff 13*
- *2012 – two patents granted, anticipate investment from strategic partner, integrating with McKesson, Cerner, Epic, installing at 5 more hospitals, staff expected to grow to 20*
- *Revenues... 2010 - \$200K, 2011 - \$700K, 2012(E) - \$3,000K*
- *Challenges in taking RI to market*
 - *New market – recognizing the need (quality of care alone not sufficient)... very conservative*
 - *ROI*
 - *Publishing the model and validation*
 - *Outcomes*

Earliest Rothman Index & ALOS



The future

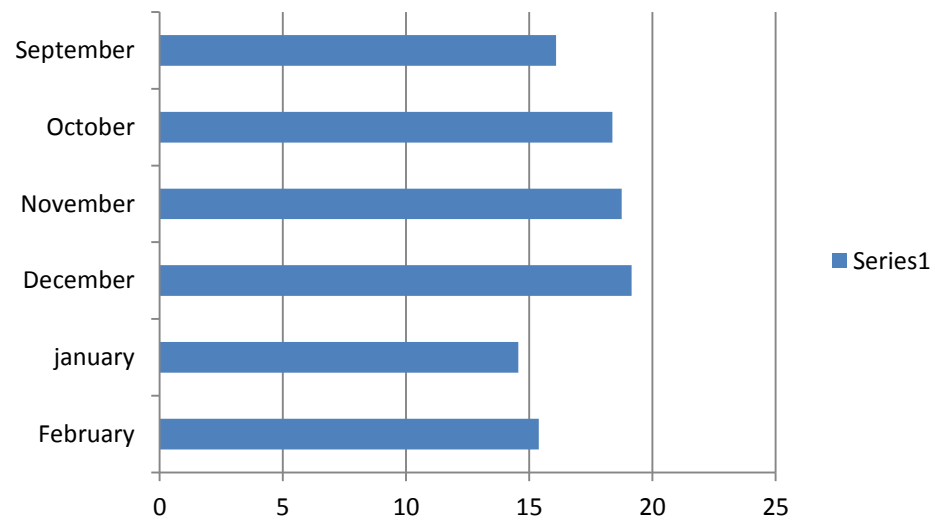
- *Hospitals are investing in infrastructure*
- *EMRs today are basically electronic copies of paper hospitals*
- *There is enormous potential in using the infrastructure, the digitization of medical data*
- *Our future*
 - *RI to be pervasive –*
 - *RI to catch deterioration earlier...*
 - *in skilled nursing facilities, assisted living, at home for patients managing chronic illness, at doctor's offices, as the unifying principle in health records...*
 - *helping provide telemedicine to remote areas...*
 - *as the basis for optimization of hospital functions,*
 - *discovery of poor procedures,*
 - *patient flow,*
 - *resource management,*
 - *screening for sepsis,*
 - *saving lives,*
 - *reducing the cost of healthcare*

Summary

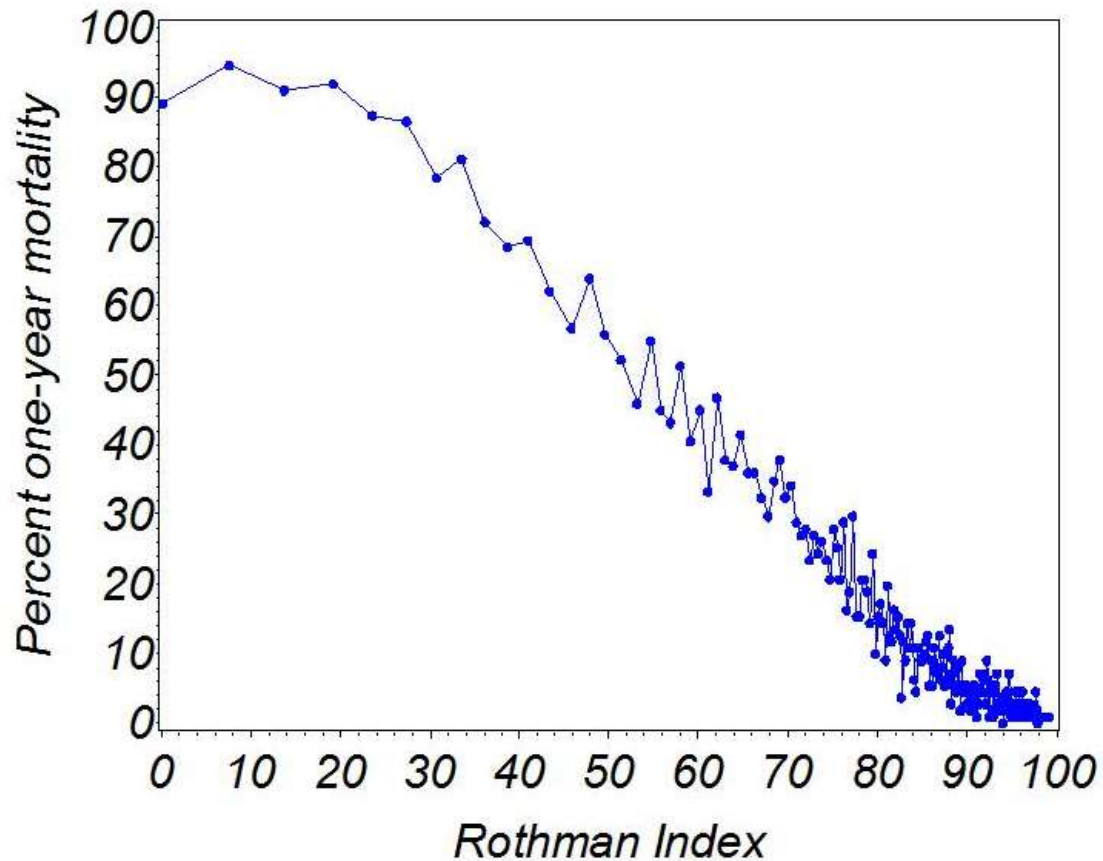
- ***graphs + nursing data = improved quality***
 - *Improving continuity of care*
 - *Earlier detection of deterioration*
 - *Better outcomes, lower cost*

End of presentation

For more information contact
michael@rothmanhealthcare.com

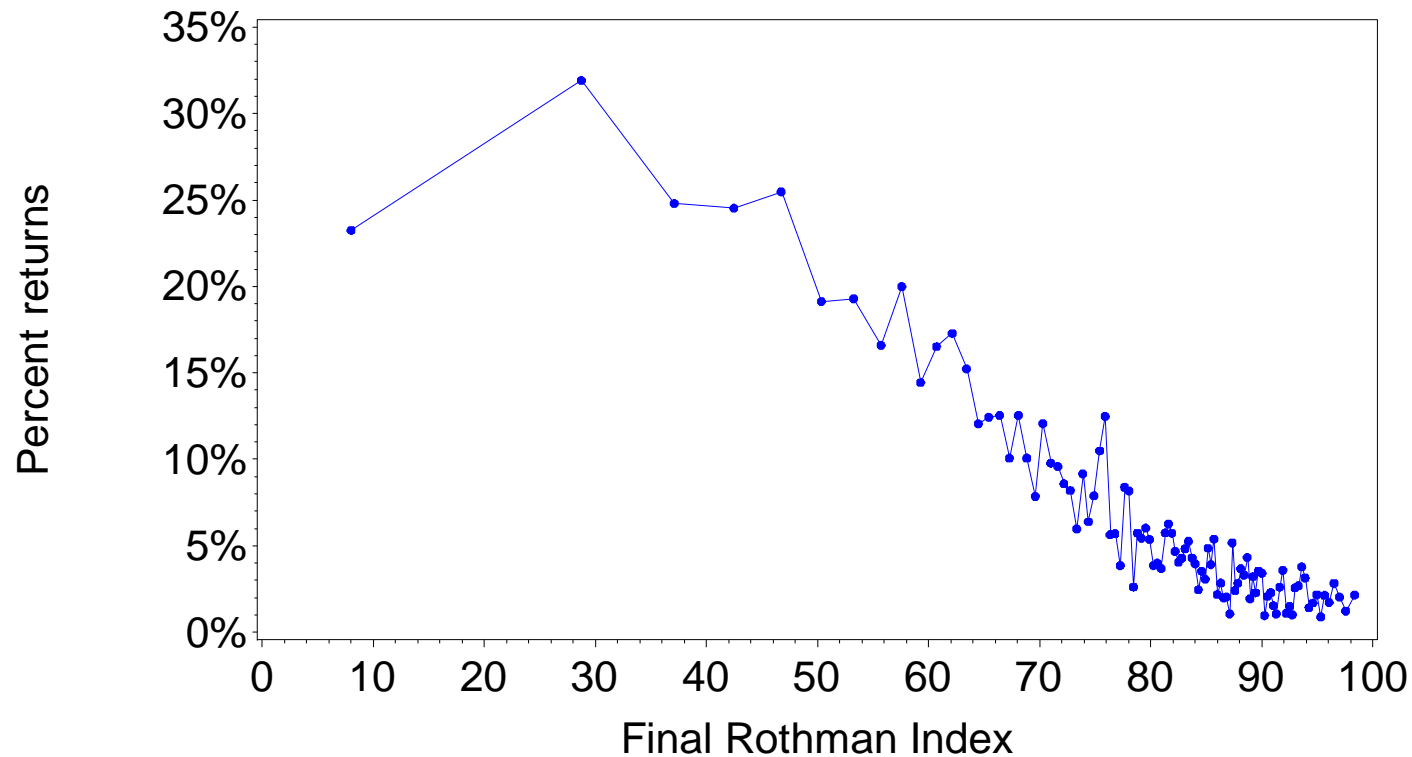


ONE-YEAR MORTALITY VERSUS FINAL ROTHMAN INDEX



22,205 patient visits to SMH from 2004

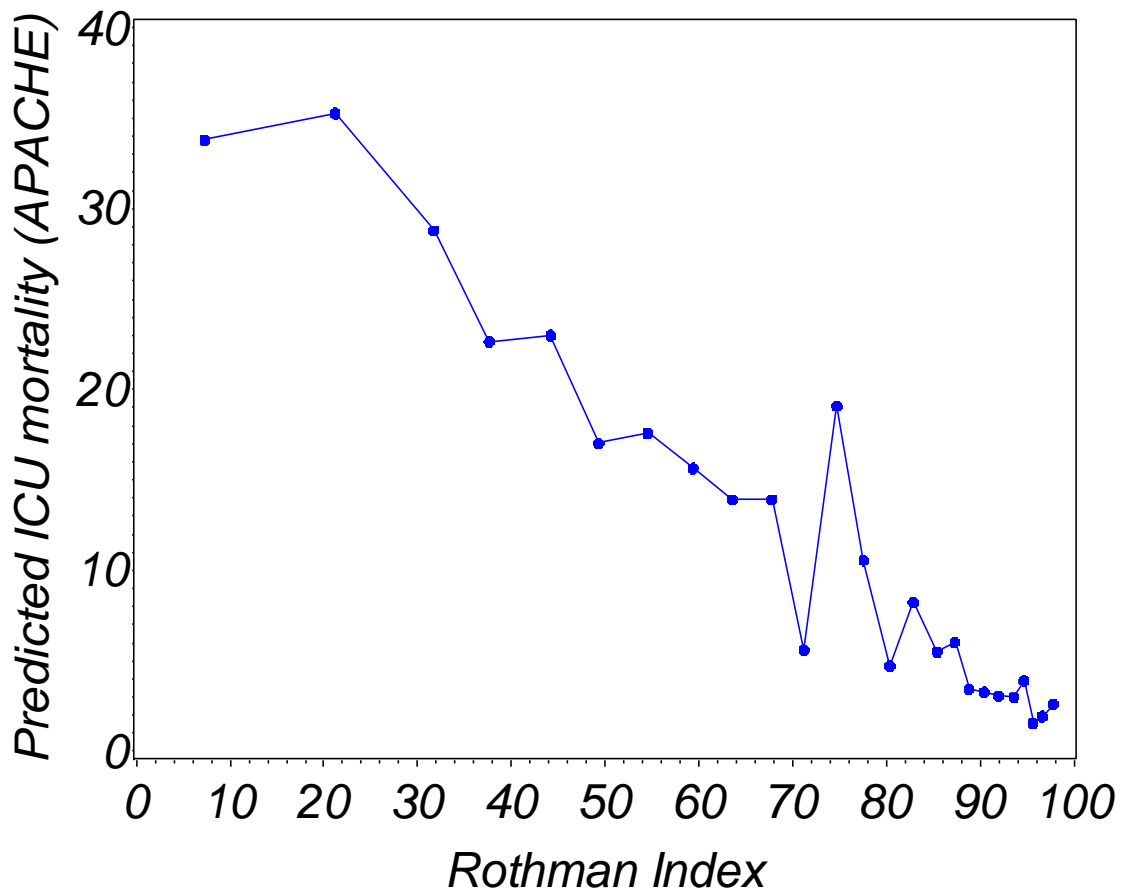
RETURNS TO THE HOSPITAL IN 30 DAYS – IF DISCHARGED TO HOME



25,942 patient visits to SMH between 1/2009 and 6/2010.

CORRELATION WITH APACHE III

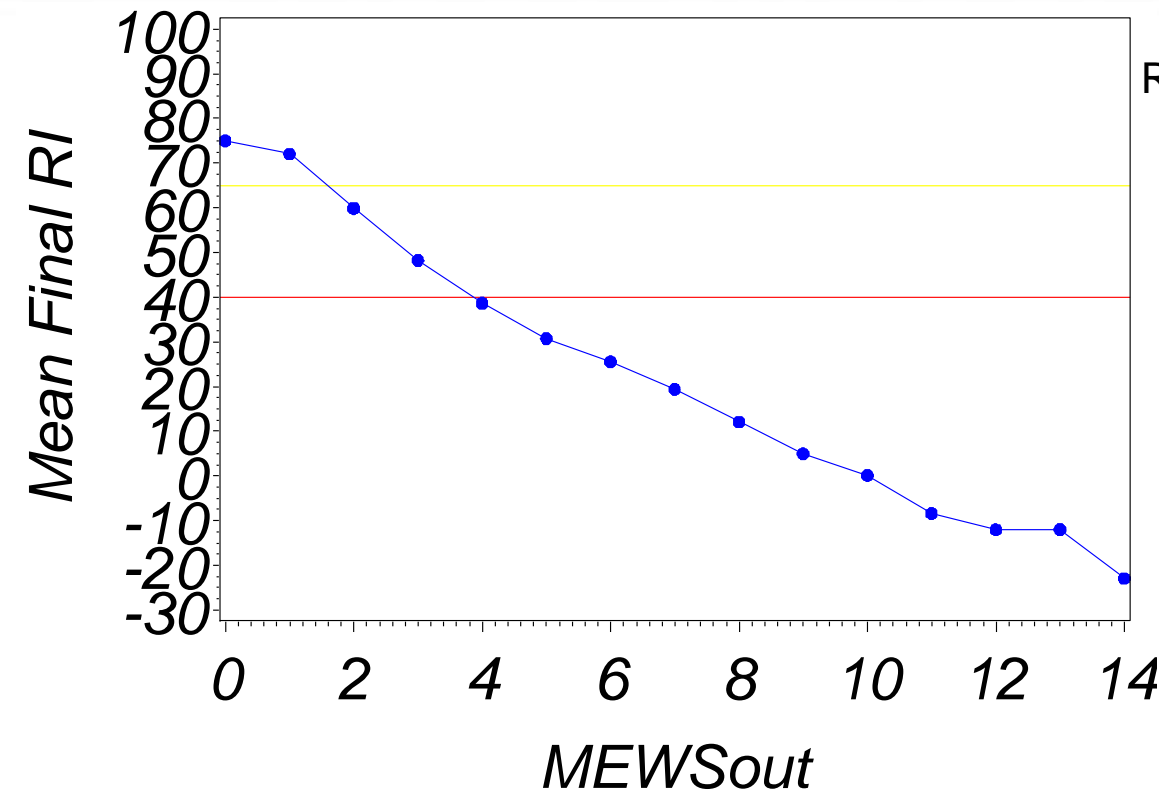
Predicted ICU mortality (APACHE III) versus last RI measured prior to ICU admission (804 patients)



Many applications... it seems every hospital has their own focus

- Rapid Response Team – *better calls*
- Med-Surg – *see deterioration*
- Hospital surveillance – *backstop doctors*
- Sepsis screening – *earlier detection*
- Case Management – *appropriate discharges*
- Patient Flow – *move patients appropriately*
- ...

ROTHMAN INDEX AS A FUNCTION OF MEWS (r^2 .64 vs. .35)

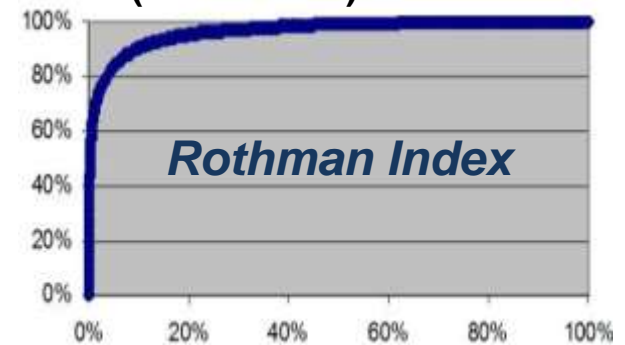


1,842,844 data points from 32,582 patient visits

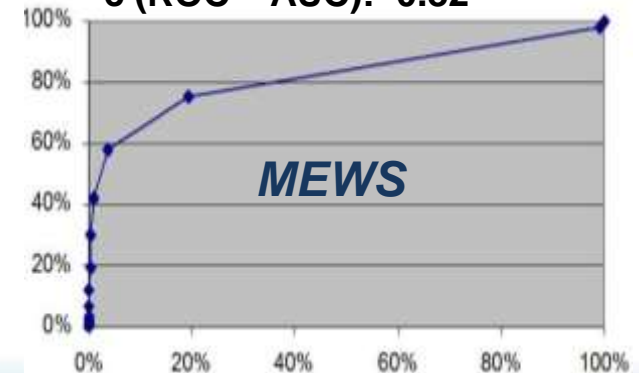
Discharge to Hospice or Death

ROC curves (sensitivity vs. 1-specificity)

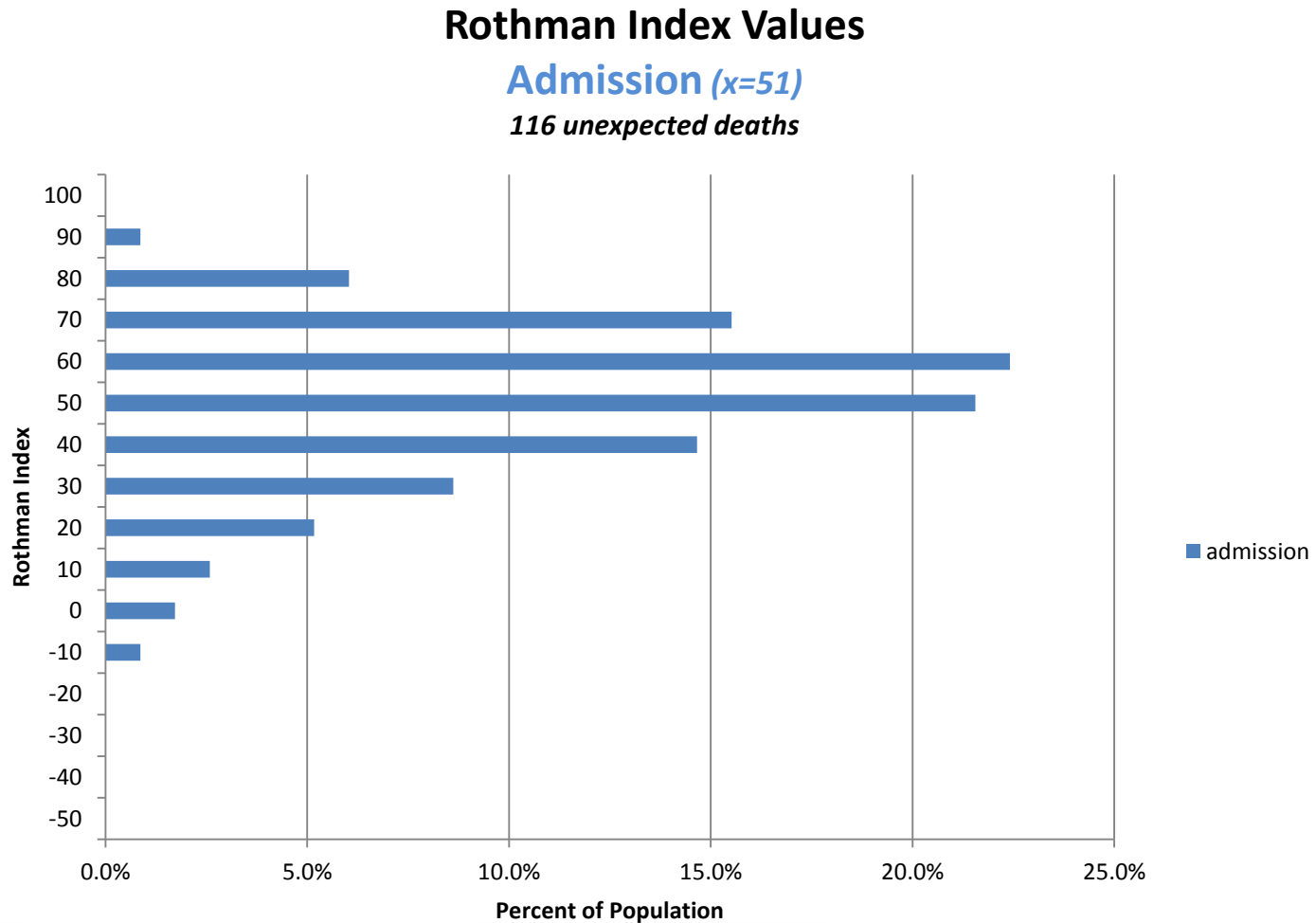
Max-rescaled R-Square: 0.64
c (ROC – AUC): 0.96



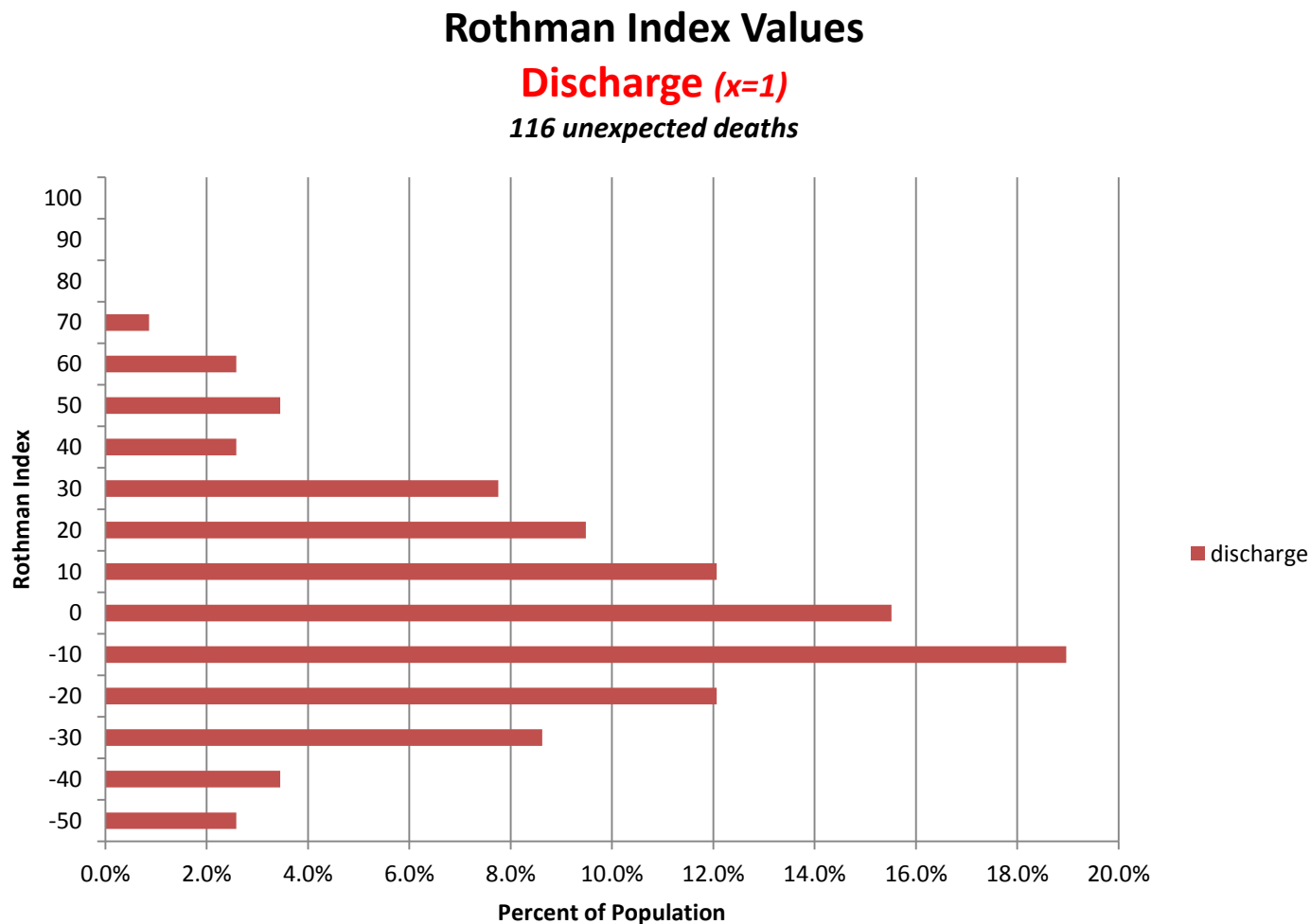
Max-rescaled R-Square: 0.35
c (ROC – AUC): 0.82



Progression of Rothman Index Values from Admission to Discharge



Progression of Rothman Index Values from Admission to Discharge



Early warning of death

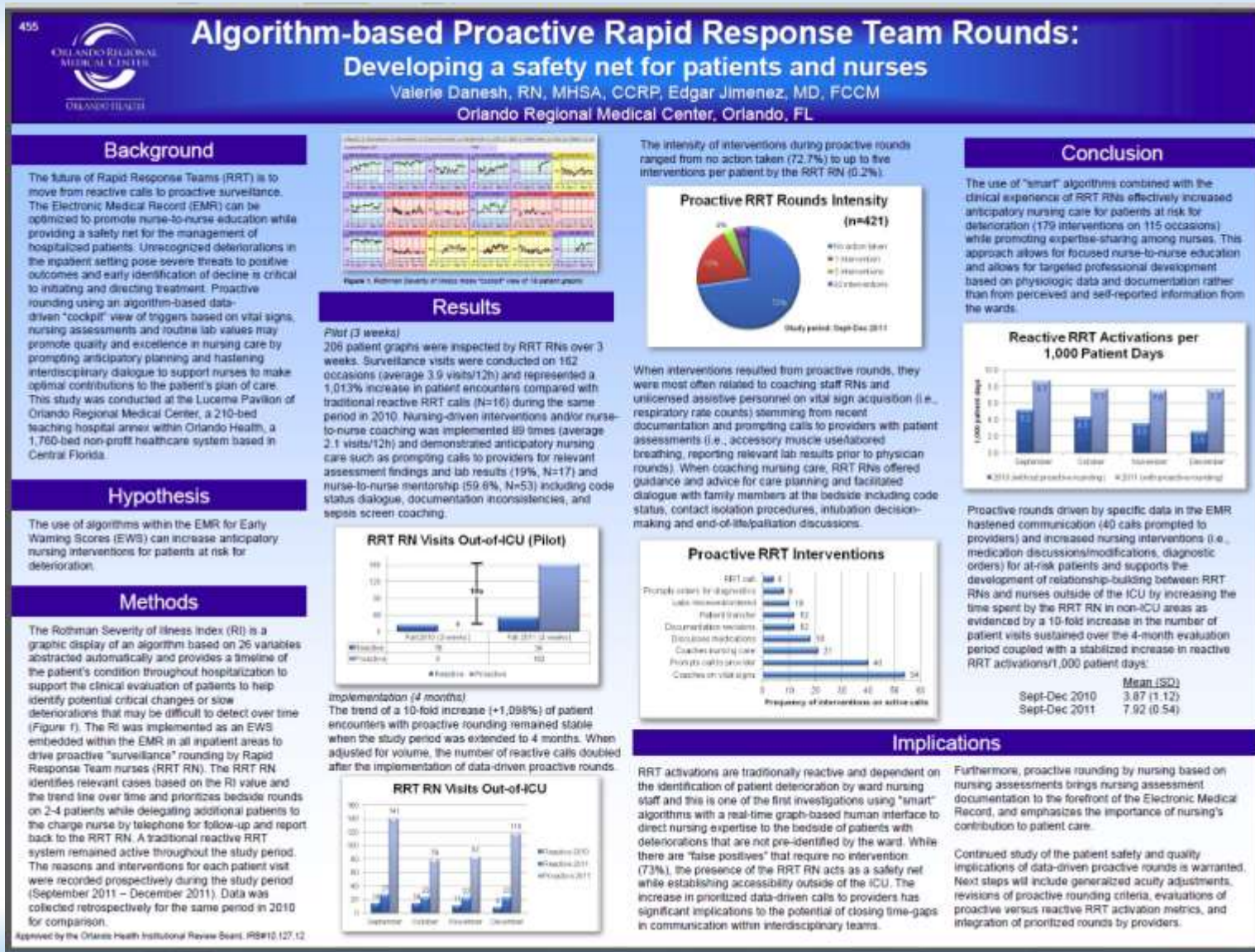
- At admission these patients were quite ill, mean RI=51
 - But 19% failed no vital sign test, 28% failed just one
 - In contrast, 91% failed at least 6 nursing assessments
- The low Rothman Index values at admission are largely driven by the failed nursing assessments
- RI continued to fall (an average of 50 points) during the mean 9.6 day LOS
- RI, driven by nursing assessments, is an early warning of death

How are we doing in achieving effective communication?

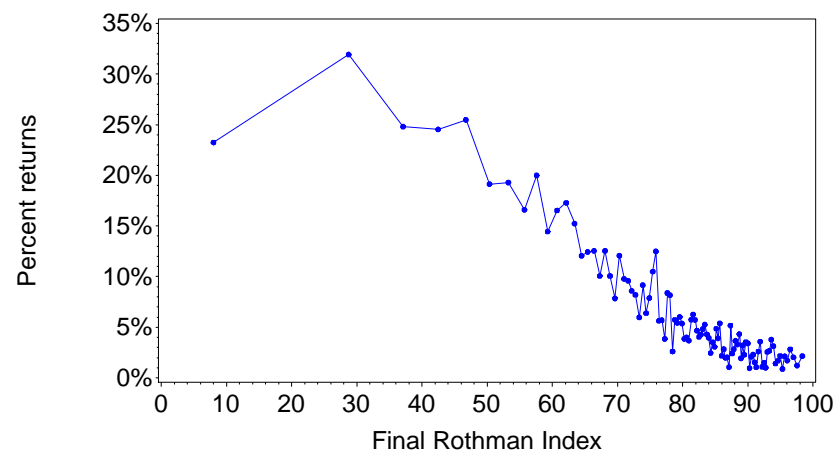
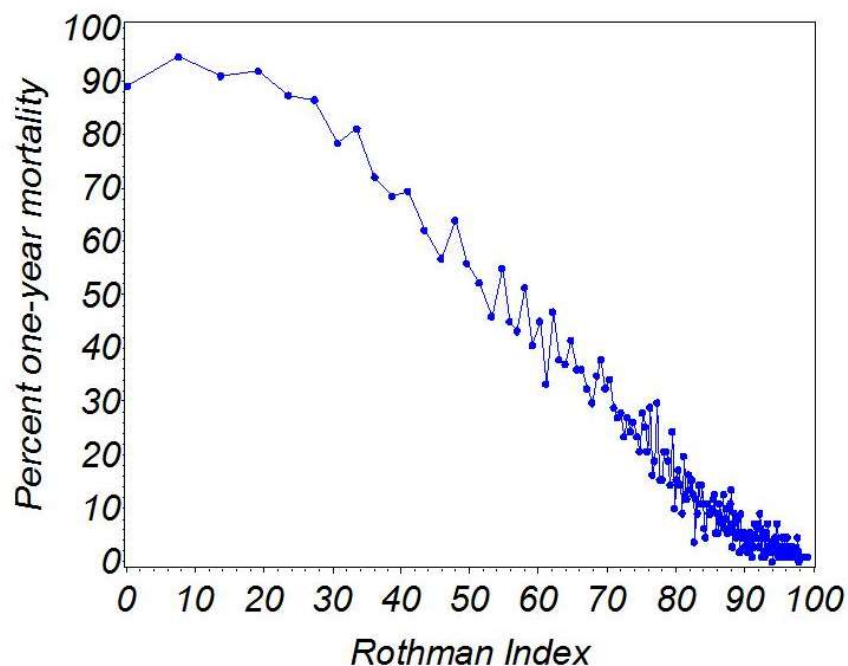
- 80% of adverse events involve **communication problems between healthcare professionals**, often in the form of a fumbled handoff.
- 60% of sentinel events reported to the Joint Commission were related to **failures in communication**
- **37% of handoffs were defective** and didn't allow the receiver to care for the patient safely (4)

- About you and how you got to where you are
 - What your company does and what you do there
 - Your challenges and thoughts on the industry
 - Your view of informatics and how it fits into the healthcare/life sciences ecosystem
 - What you see happening in the healthcare/life sciences 5-10 yrs down the road
 - What you'd like to see folks in the audience do/work on
 - Science is the focus
 - View good science also happens in industry
 - Challenges in taking it to market
-
- Other notes: The audience tends to be a mix of grad students, med students and business school students. What's worked well is painting the big picture and then talking about a specific project as a microcosm of what happens.

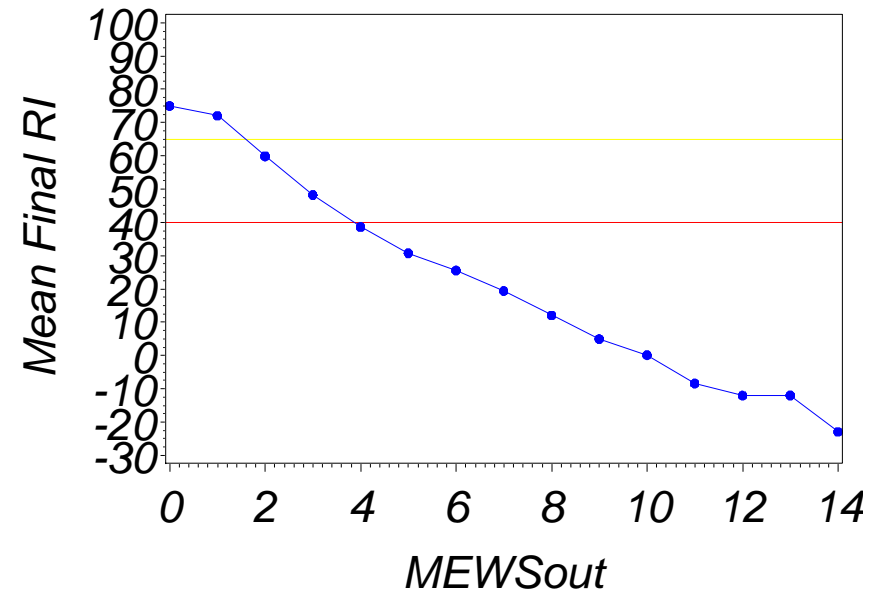
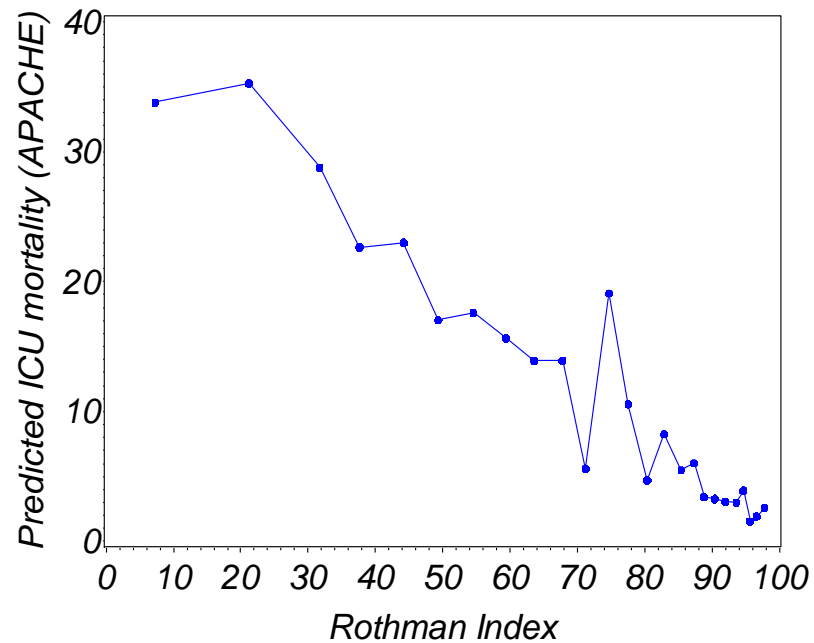
Initial report from Orlando – proactive rounding doubled RRT calls



Correlation with 1-year mortality and 30-day return to hospital



Correlation with APACHE III and MEWS



A hospital in Philadelphia - detailed review of 30 medical records

- *All 30 graphs were valid and correlated extremely well with the documentation in the medical records.*
- *26 Charts were MET cases*
 - *35% revealed a decline in status 2-11 hours (or more) prior to the MET call.*
 - *8% were of patients who had been doing poorly in critical care, transferred out... back within 8-24 hours (bounce back).*