THE UNIVERSITY OF CHICAGO MEDICINE

The Selection of Early Warning Scores

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Disclosures

Employment:

- The University of Chicago

Research support:

- National Heart Lung Blood Institute of NIH
- Philips Healthcare
- Early Sense

Ownership interests:

- Founder & CEO, QuantHC
- Patent pending, ARCD.P0535US.P2

Other:

- Immediate Past Chair, Systems of Care Subcommittee, American Heart Association
- Co-Chair, GWTG-R Adult Research Task Force
- Member, CDC Ward Sepsis Working Group

Hospitalization Time Course

Healthy

Physiologic State

Dead

Admitted

Each 1 hr delay in ICU transfer is associated with a 3% increased odds of mortality

Time

Cardiac arrest

Traditional RRT calling criteria

Call if any of these criteria are met:
Threatened airway*
Respiratory rate <5
Respiratory rate >36
Heart rate <40
Heart rate >140
Systolic Blood Pressure <90
Drop in Glasgow Coma Scale >2
Prolonged seizure activity*

Hillman, Lancet, 2005

WORLD SERIES CHAMPIONS

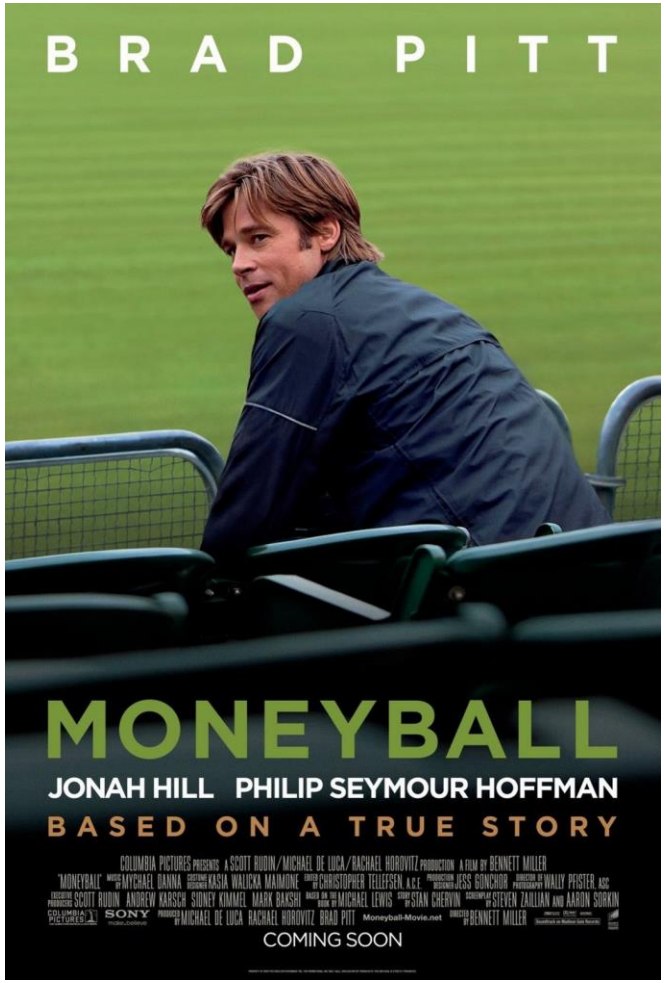
Chicago Tribune

THURSDAY, NOVEMBER 3, 2016 CHICAGOTRIBUNE.COM

Traditional Statistics: Baseball v. Healthcare

Rethinking baseball statistics

CALIBER OF PLAYER	WINS ABOVE REPLACEMENT
BENCH GUY	0-1 WAR
ROLE PLAYER	1-2 WAR
SOLID STARTER	2-3 WAR
ABOVE-AVERAGE	3-4 WAR
ALL-STAR	4-5 WAR
SUPERSTAR	5-6 WAR
MVP	6+ WAR



Modified Early Warning Score (MEWS)

Score	3	2	1	0	1	2	3
Respiratory rate (RPM)	—	≤ 8	—	9-14	15-20	21-29	≥ 30
Heart rate (BPM)	—	≤ 40	41-50	51-100	101-110	111-129	≥ 130
Systolic BP	≤ 70	71-80	81-100	101-199		≥ 200	
Temperature (°C)	—	≤35	—	35.0-38.4	—	>38.5	—
AVPU	—	—	—	Alert	React to Voice	React to Pain	Unresp

Churpek, Chest, 2013

National Early Warning Score (NEWS)

PHYSIOLOGICAL PARAMETERS	3	2	1	0	1	2	3
Respiration Rate	≤8		9 - 11	12 - 20		21 - 24	≥25
Oxygen Saturations	≤91	92 - 93	94 - 95	≥96			
Any Supplemental Oxygen		Yes		No			
Temperature	≤35.0		35.1 - 36.0	36.1 - 38.0	38.1 - 39.0	≥39.1	
Systolic BP	≤90	91 - 100	101 - 110	111 - 219			≥220
Heart Rate	≤40		41 - 50	51 - 90	91 - 110	111 - 130	≥131
Level of Consciousness				A			V, P, or U

Churpek, Chest, 2013

But health care has moved into the digital age

Running a paper-based tool on a computer is like …

Harnessing big data analytics for IHCA prevention

Introduction of eCART™ – linear logistic regression

Prior ICU stay (1 = Yes, 0 = No)	1.37
Heart rate (beats/min)	0.03
Diastolic blood pressure (mm Hg)	−0.02
Respiratory rate (breaths/min)	0.14
Oxygen saturation (%)	0.07
Temperature (°C)	−0.31
Mental status (alert, responsive to voice, responsive to pain, unresponsive)	0.43
On room air (1 = Yes, 0 = No)	−0.64
Age (yr)	0.03
Blood urea nitrogen (mg/dL)	0.01
Anion gap (mEq/L)	0.13
Hemoglobin (g/dL)	−0.17
Platelet count (K/μL)	−0.002
Potassium (mEq/L)	0.17
WBC count (K/μL)	0.01

n=56,649 admission from one hospital

Churpek, CCM 2014

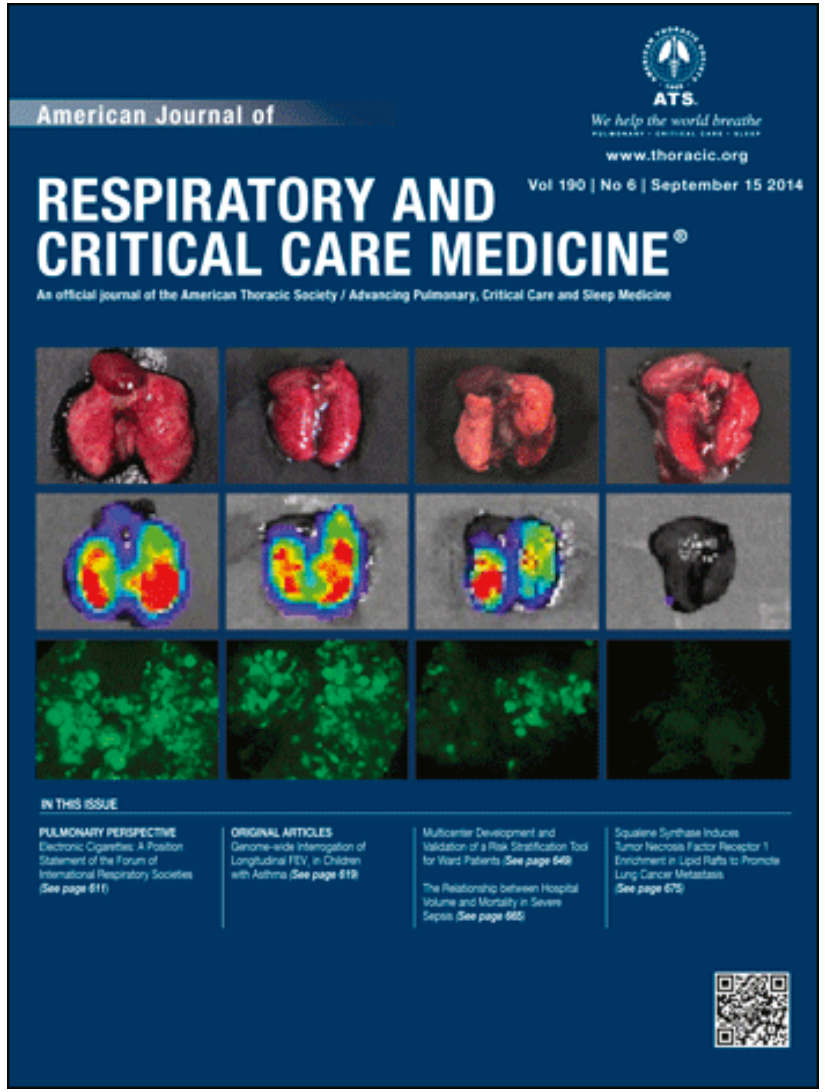
eCART™ 2

- Cubic spline logistic regression
- Utilizes 33 EHR variables: vitals, labs, demographics
- Derived and validated in >250,000 patients from five hospitals



eCART 2™ – cubic spline logistic regression

Variable	Cut-off	Coeff	Cut-off	Coeff	Cut-off	Coeff
Age, years	18-40	0.042	>40	0.014		
Number of ICU stays	0-1	0.193	>1	0.112		
Respiratory rate, breaths per minute	≤20	-0.042	>20	0.109		
Heart rate, beats per minute	≤49	-0.044	50-100	0.014	>100	0.037
Systolic blood pressure, mm Hg	≤100	-0.034				
Diastolic blood pressure, mm Hg	≤49	-0.060				
Temperature, degrees Celsius	≤35.5	-0.850				
Pulse pressure index	≤0.249	3.030				
Oxygen saturation, %	≤92	-0.050				
Mental status (AVPU)	Voice	0.734				
Sodium, mEq/L	≤133	-0.038				
Potassium, mEq/L	≤3.4	-0.264				
Bicarbonate, mEq/L	≤22	-0.043				
Anion gap, mEq/L	≤12	0.062				
BUN, mg/dL	≤40	0.017	>40	-0.001		
Creatinine, mg/dL	≤1.4	0	>1.4	-0.024		
BUN-creatinine ratio	linear	0.002				
Glucose, mg/dL	≤59	-0.019	60-199	0.003	>199	-0.001
Calcium, mg/L	≤8	-0.146	>8	0		
WBC, K/μL	≤11	0.058	>11	0.002		
Hemoglobin, g/dL	≤13.4	-0.028	13.5-16	0	>16	0.291
Platelets, K/μL	≤149	-0.003	150-350	0	>350	-0.001
Total protein, g/dL	linear	0.059				
Albumin, g/dL	≤3.4	-0.113	3.5-4.4	-0.156	>4.4	0
Total bilirubin, mg/dL	≤1.9	0.237	>1.9	0.001		
AST, U/L	≤37	0.003	>37	0.0003		
Alkaline phosphatase, U/L	≤120	0.0001	>120	-0.0004		



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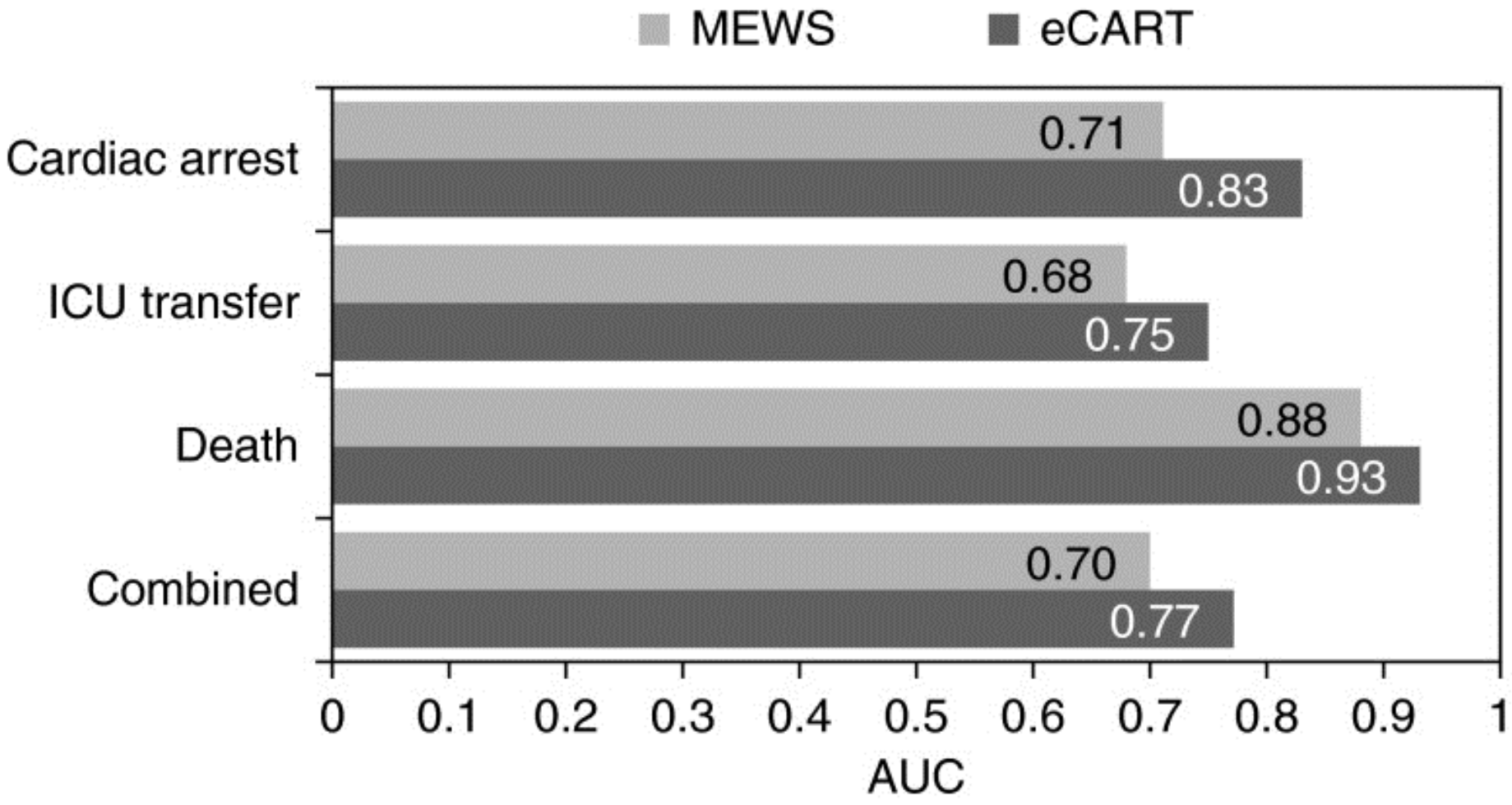
n=269,999 admission from five hospitals

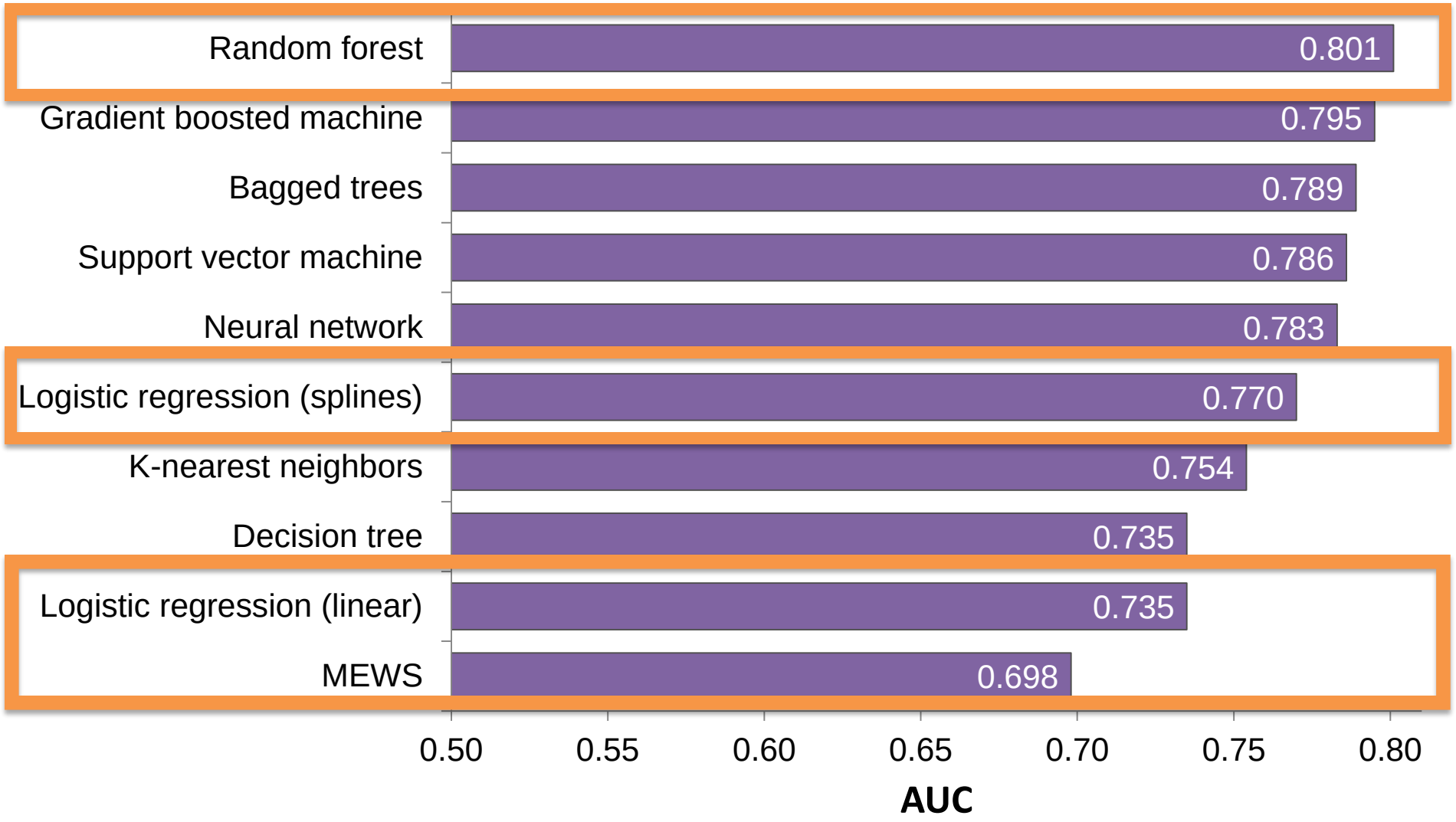
Churpek, AJRCCM 2014

Accuracy: eCART vs MEWS



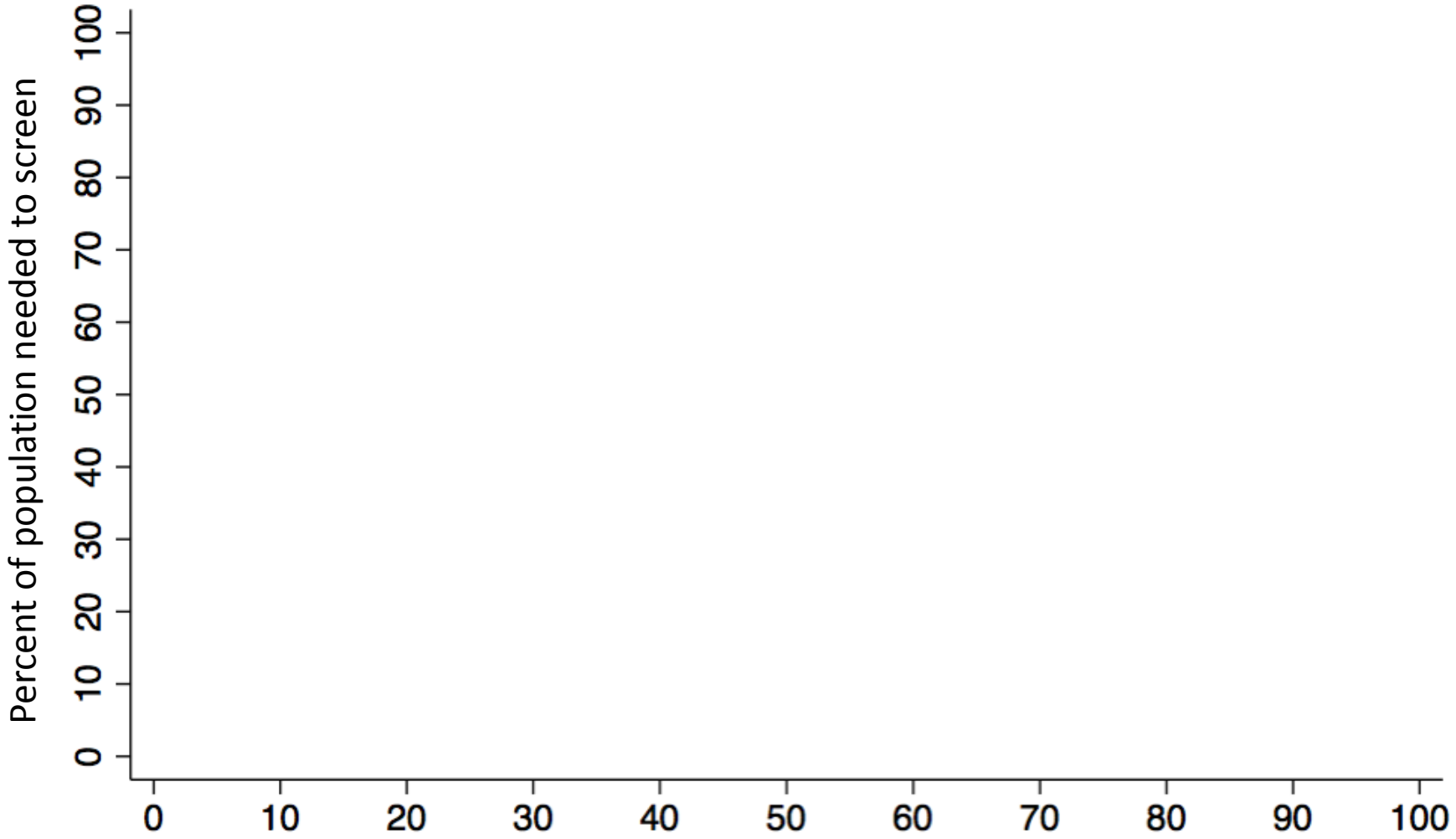
Challenge: $1,000,000 to improve rental suggestions

Machine learning models are more accurate



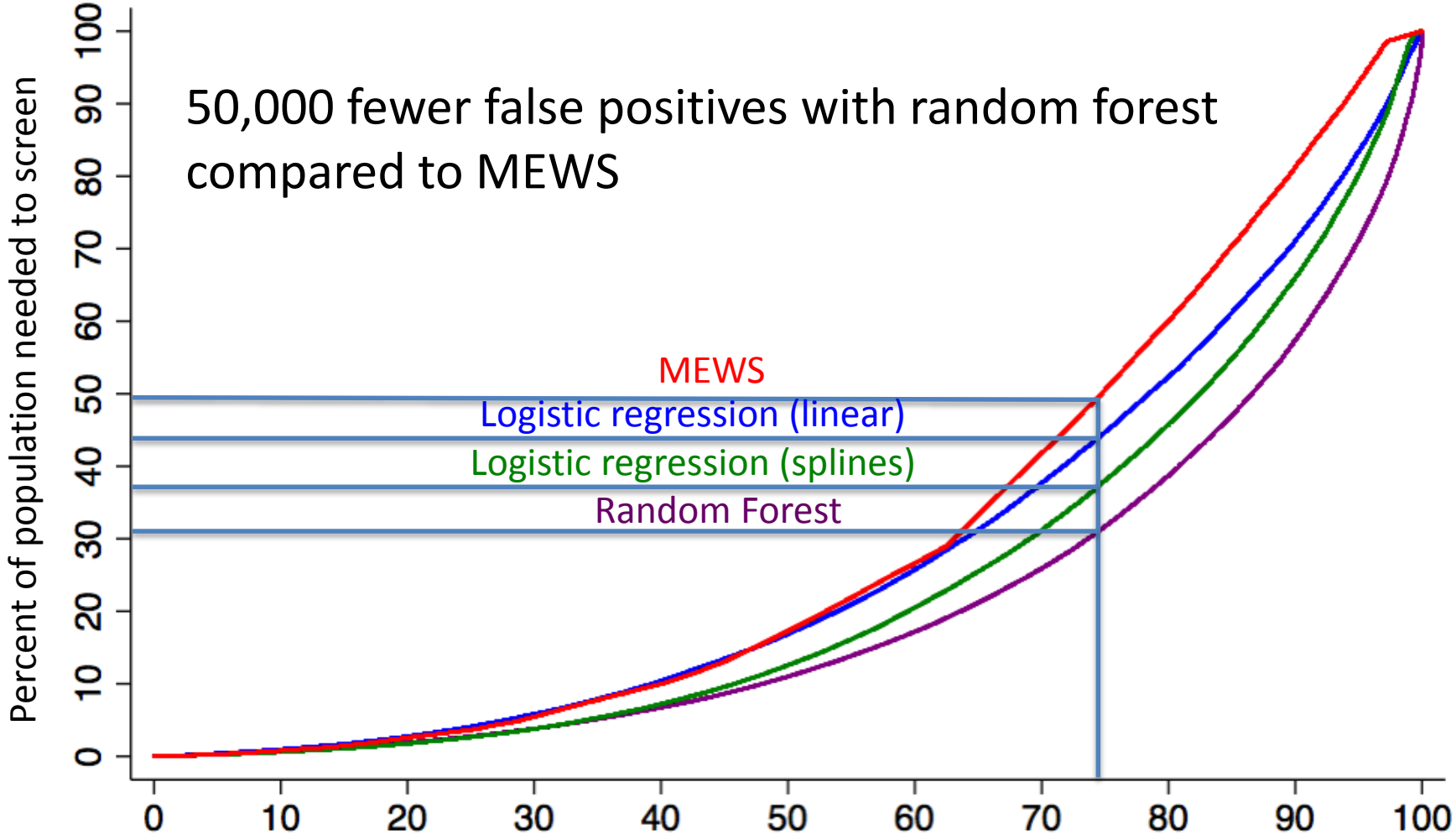
Churpek, CCM, 2016

Model accuracy comparisons



Churpek, CCM, 2016

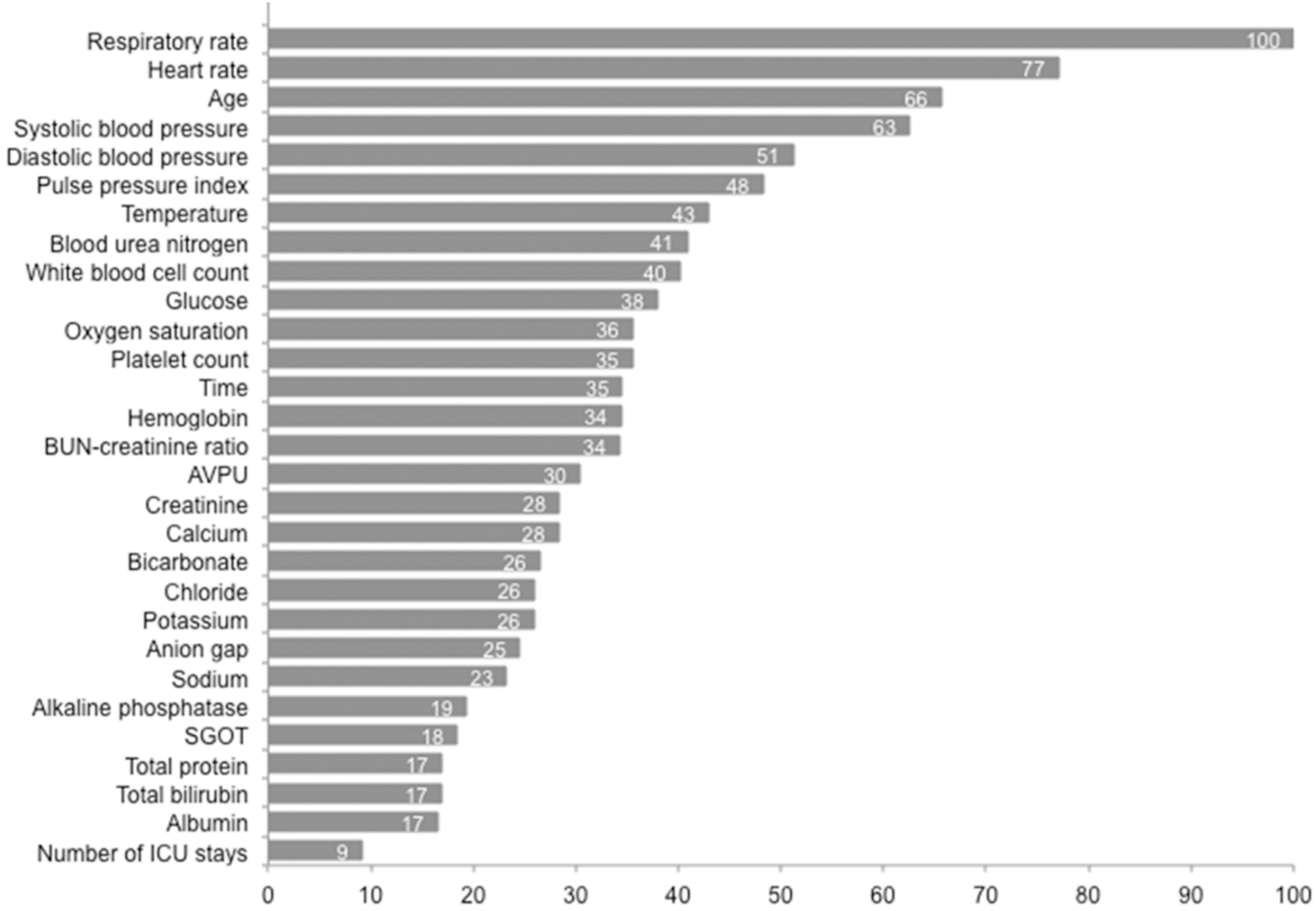
Model accuracy comparisons



Churpek, CCM, 2016

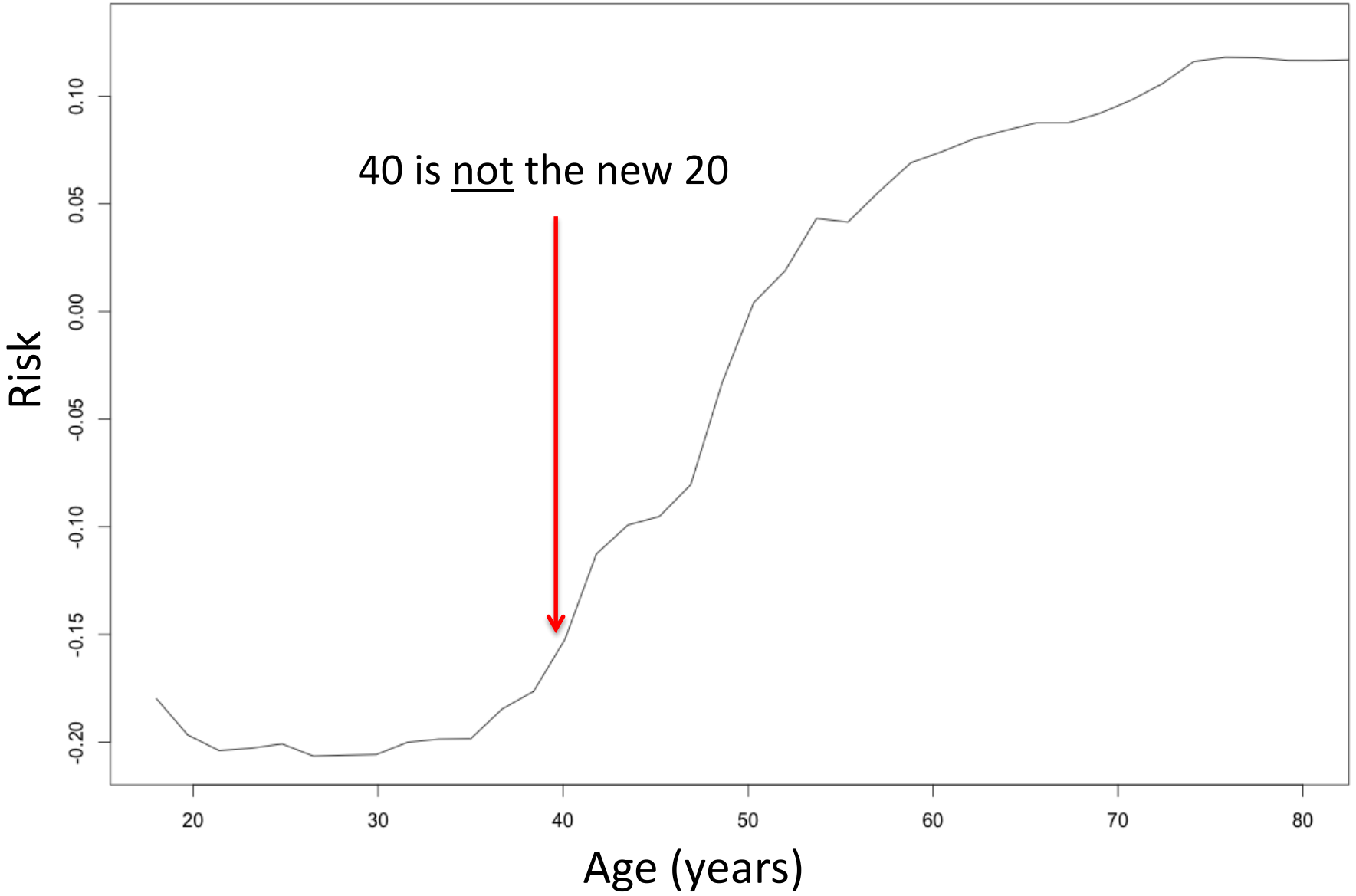
50,000 Fewer False Alarms With Random Forest over MEWS

Variable importance in the random forest model



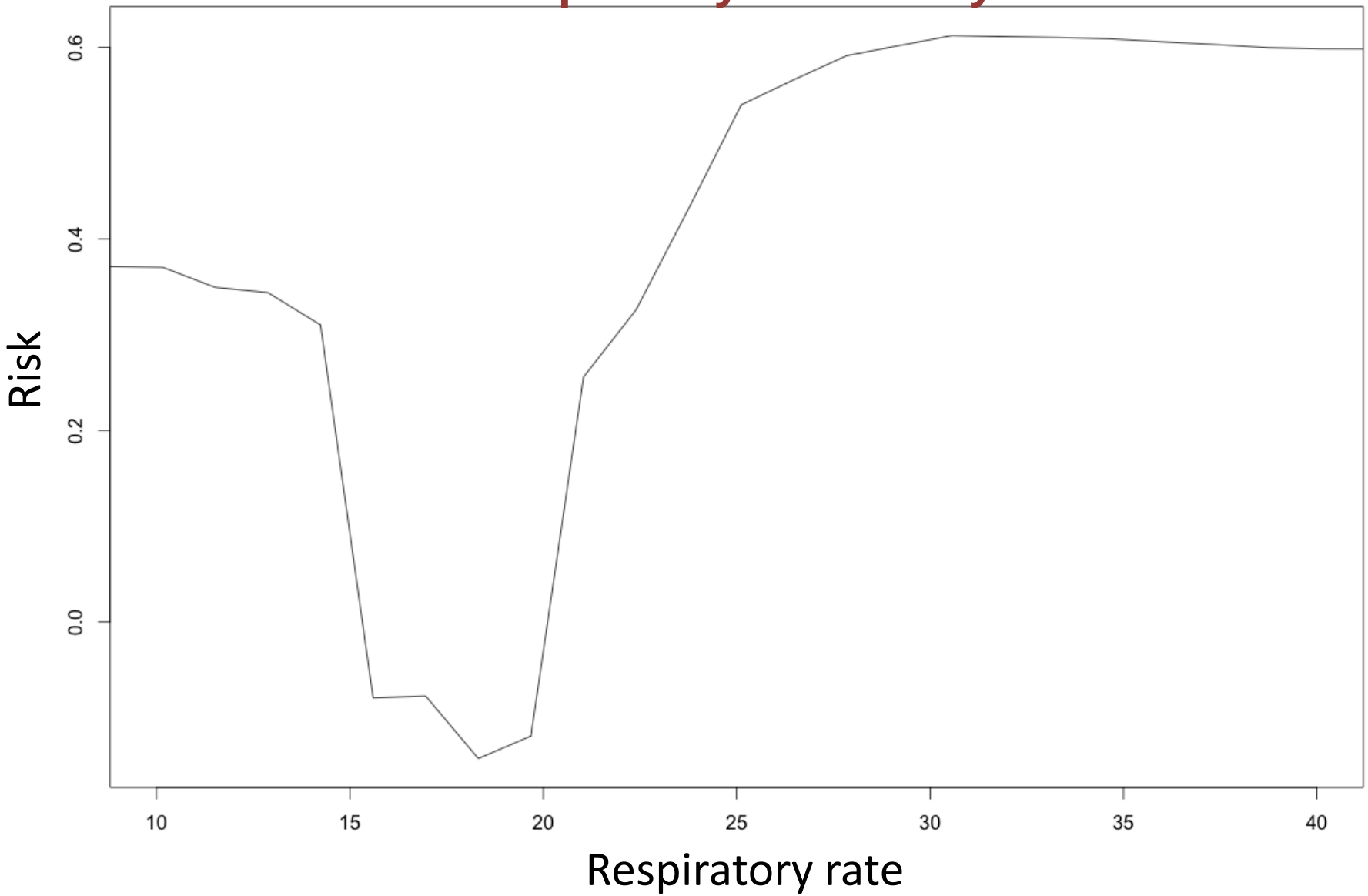
Churpek, CCM, 2016

Random forest visualization: Getting old is bad



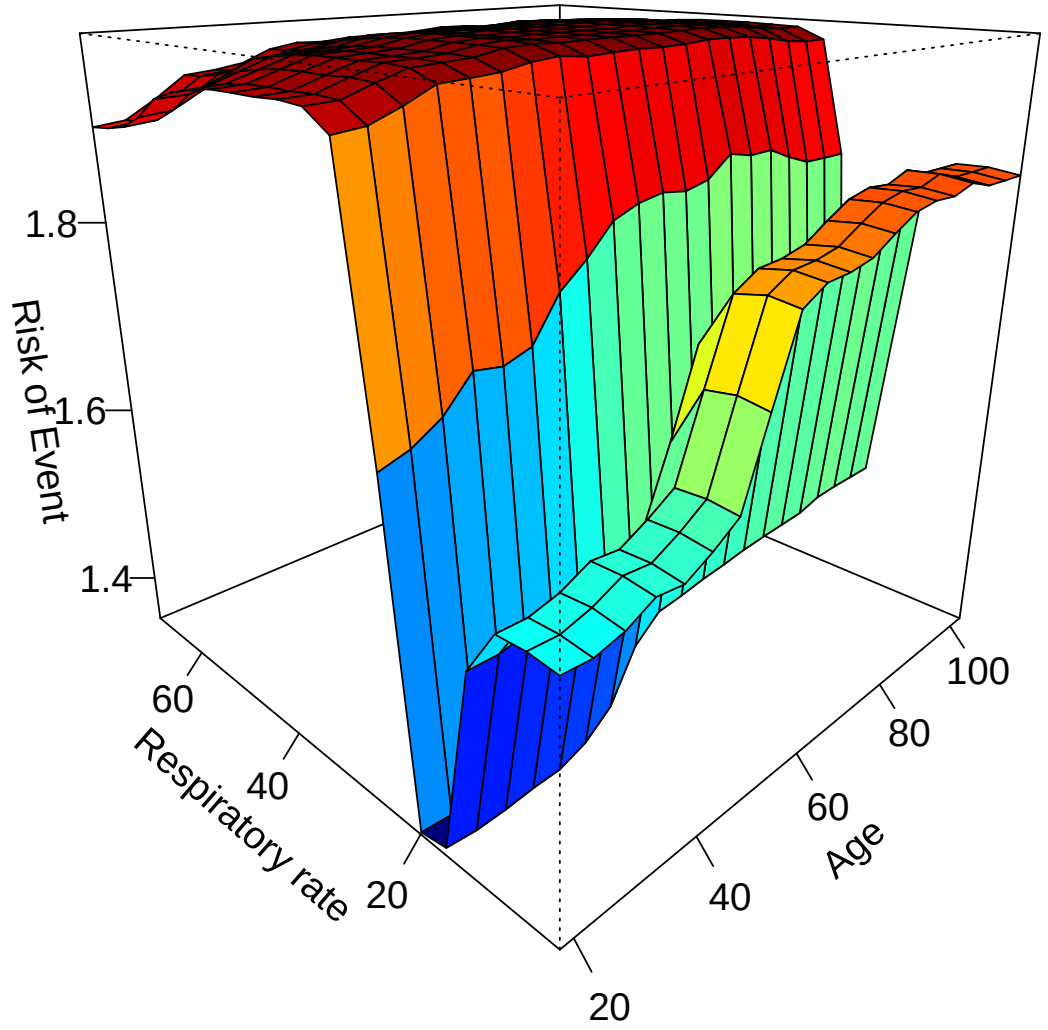
Churpek, CCM, 2016

Random forest visualization: respiratory rate is key



Churpek, CCM, 2016

Random forest visualization: predictors interaction




SEPSIS
SIRS
death
DRG 871
#1 cause of ICU deaths
time sensitivity
virus
severe
bacteria
blood chemicals
DRG 870
death
infection
organ failure
toxic response
fungi
shock
inflammation
top billed DRG
reimbursement
mortality
50%
unnecessary
severe
parasite
No dedicated drug tx
increased LOS
death
difficult
diagnosis

Systemic Inflammatory Response Syndrome (SIRS) criteria

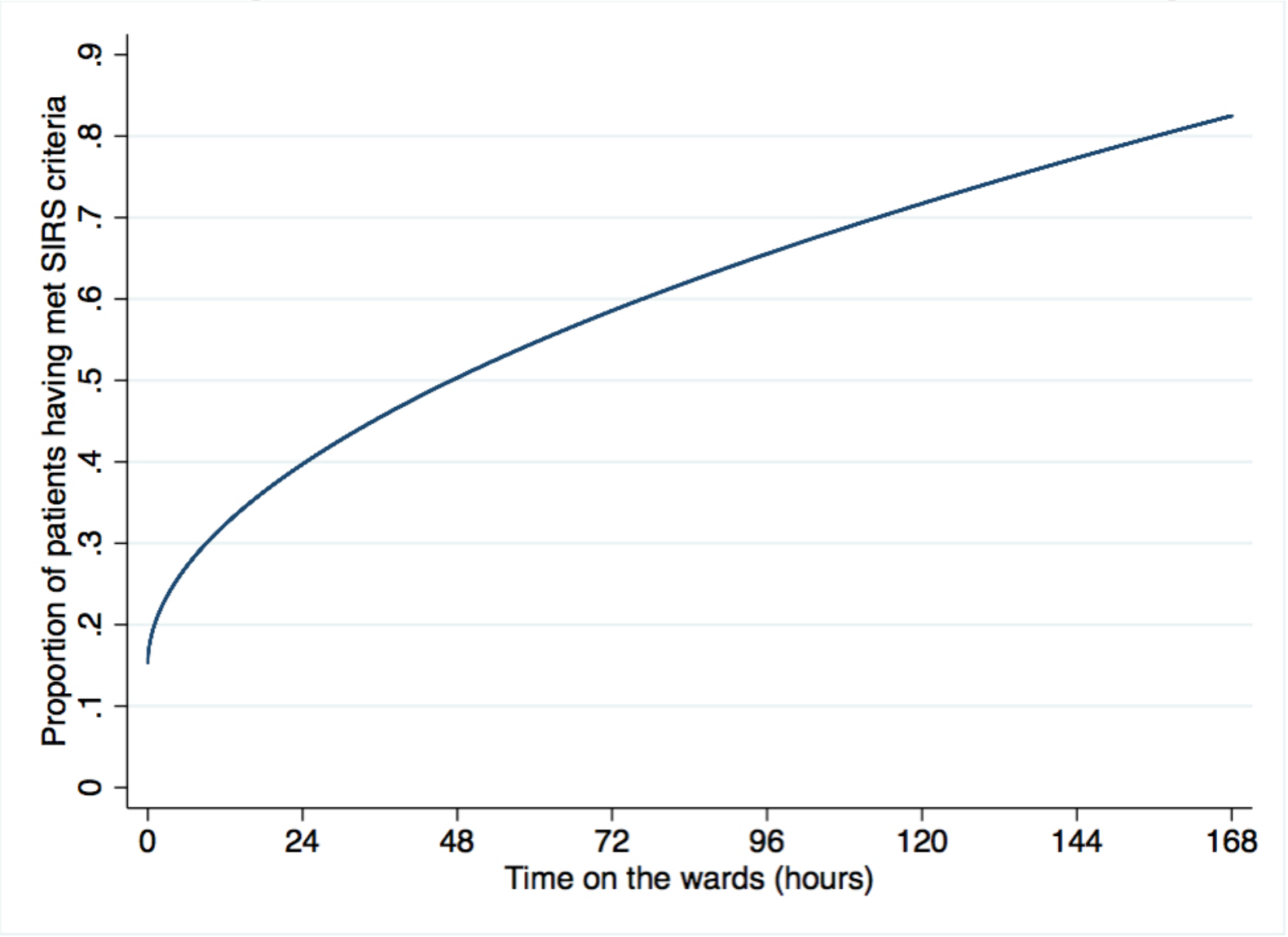
Body temperature: >38°C or <36°C

Heart rate: >90 beats per minute

Tachypnea: manifested by a respiratory rate >20 breaths per minute or a $PaCO_2$ of <32 mmHg

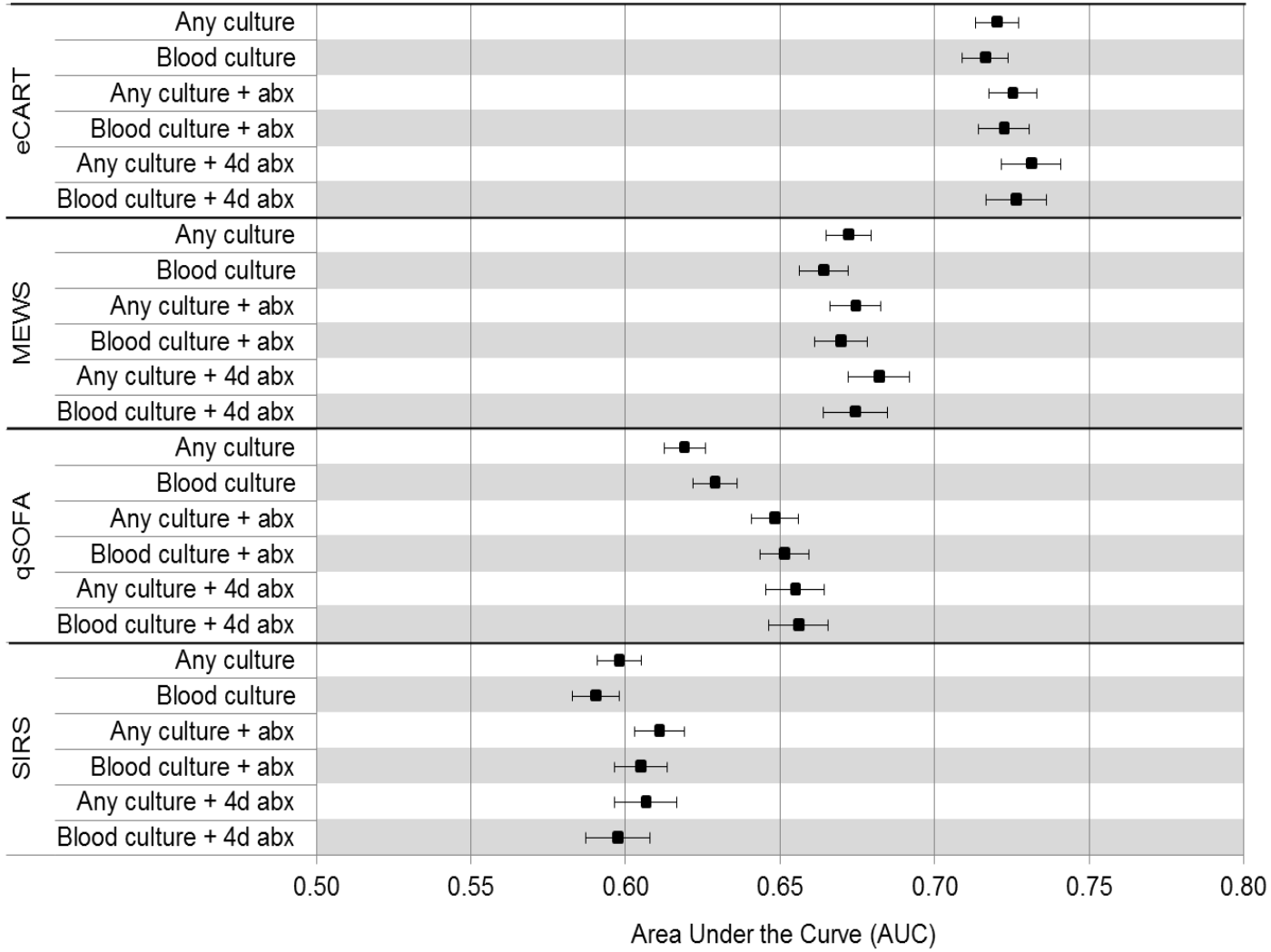
White blood cell count: >12,000/mm^3 or <4,000/mm^3, or the presence of >10% immature neutrophils

Most ward patients meets SIRS criteria at some point



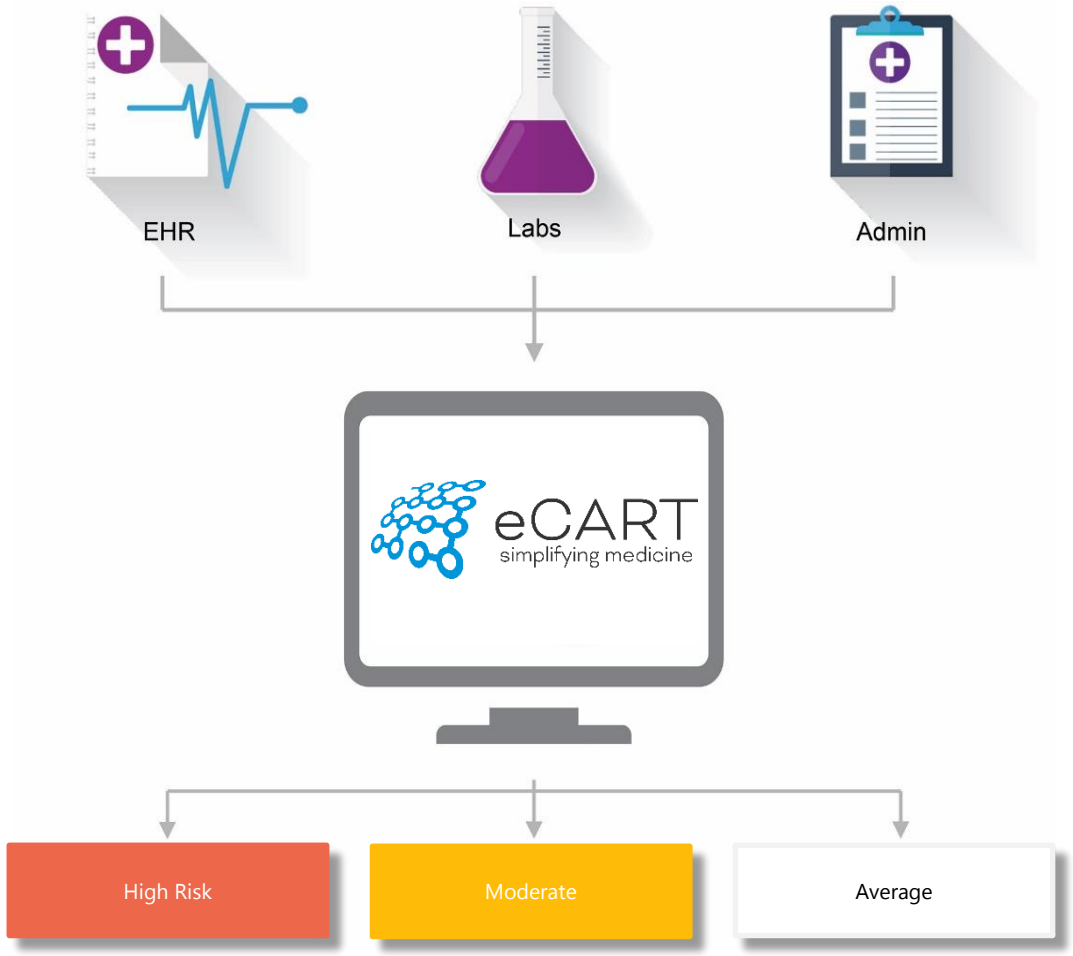
More specific than SIRS but less sensitive

When infection is suspected: eCART>MEWS>qSOFA>SIRS



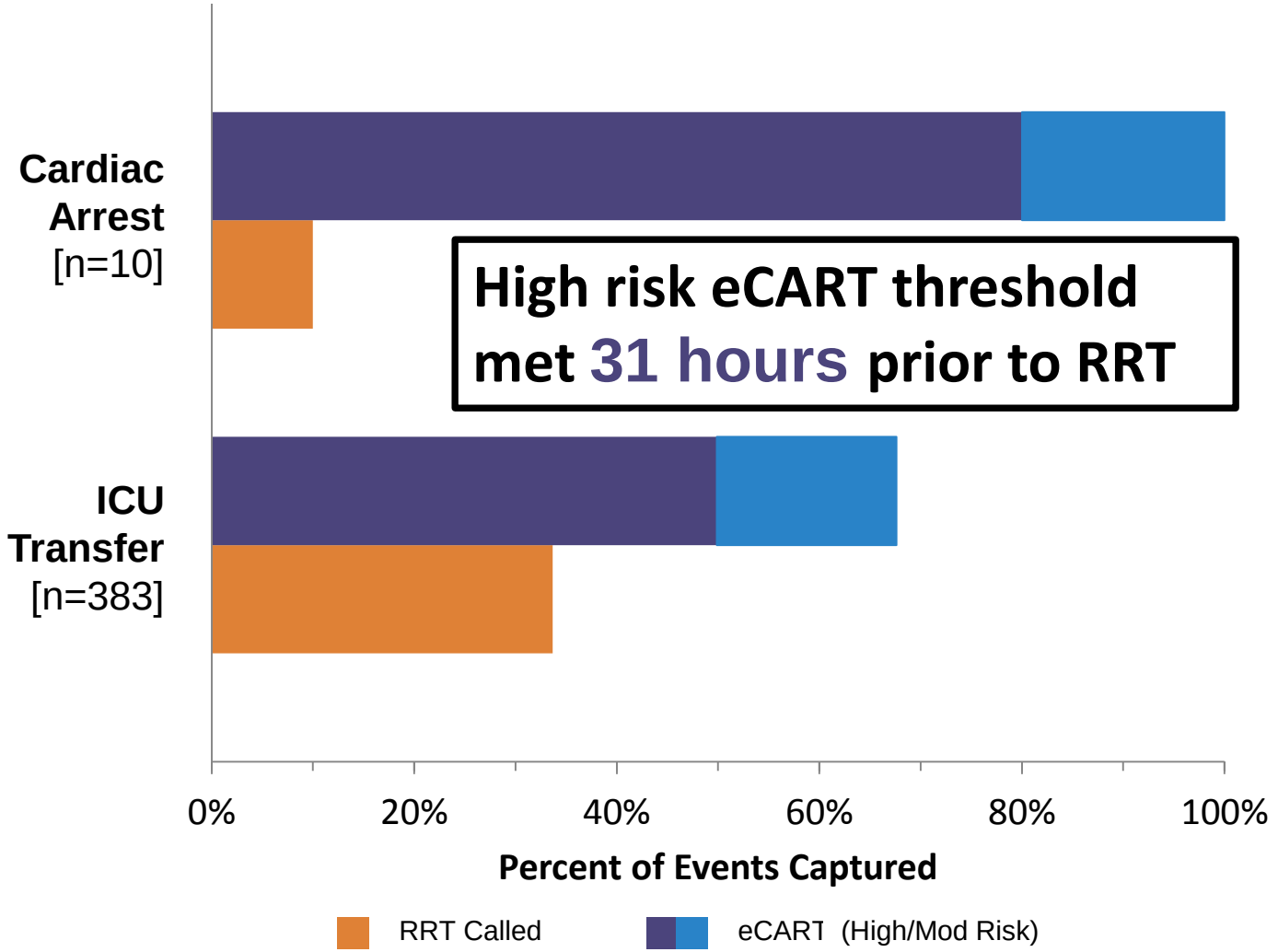
ATS, 2017

Real-time data-driven decision support in action



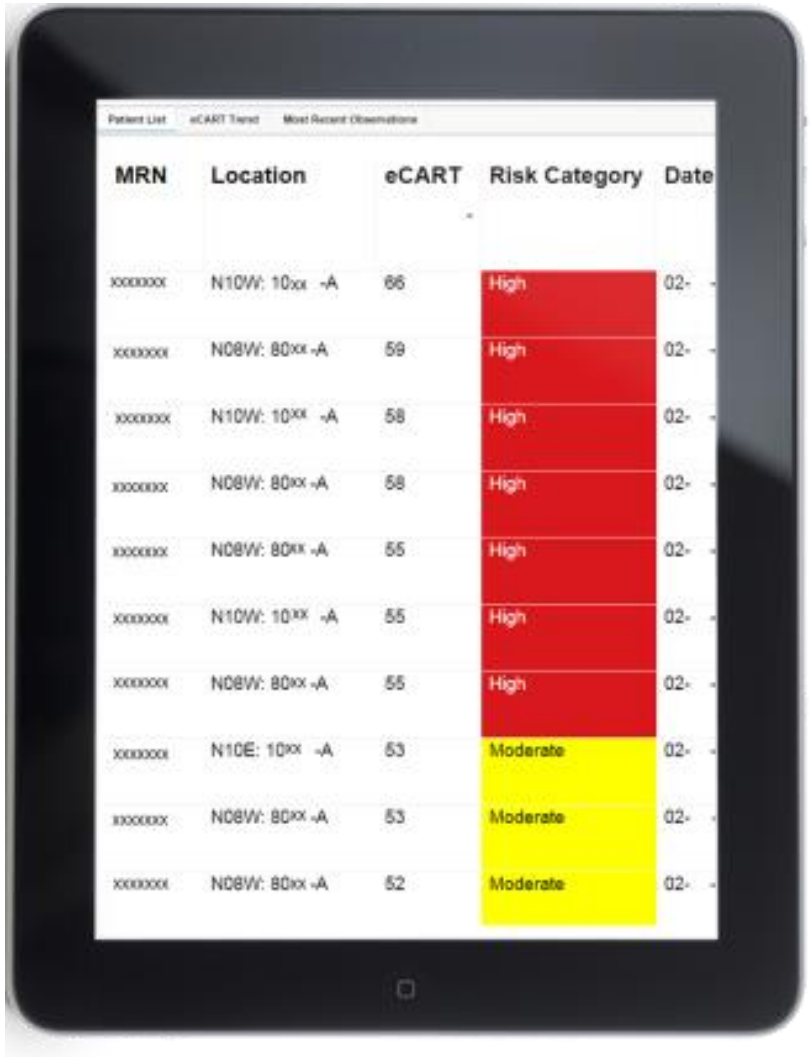

The University of Chicago Medical Center
617 beds
28,726 inpatient admissions

Silent phase eCART implementation



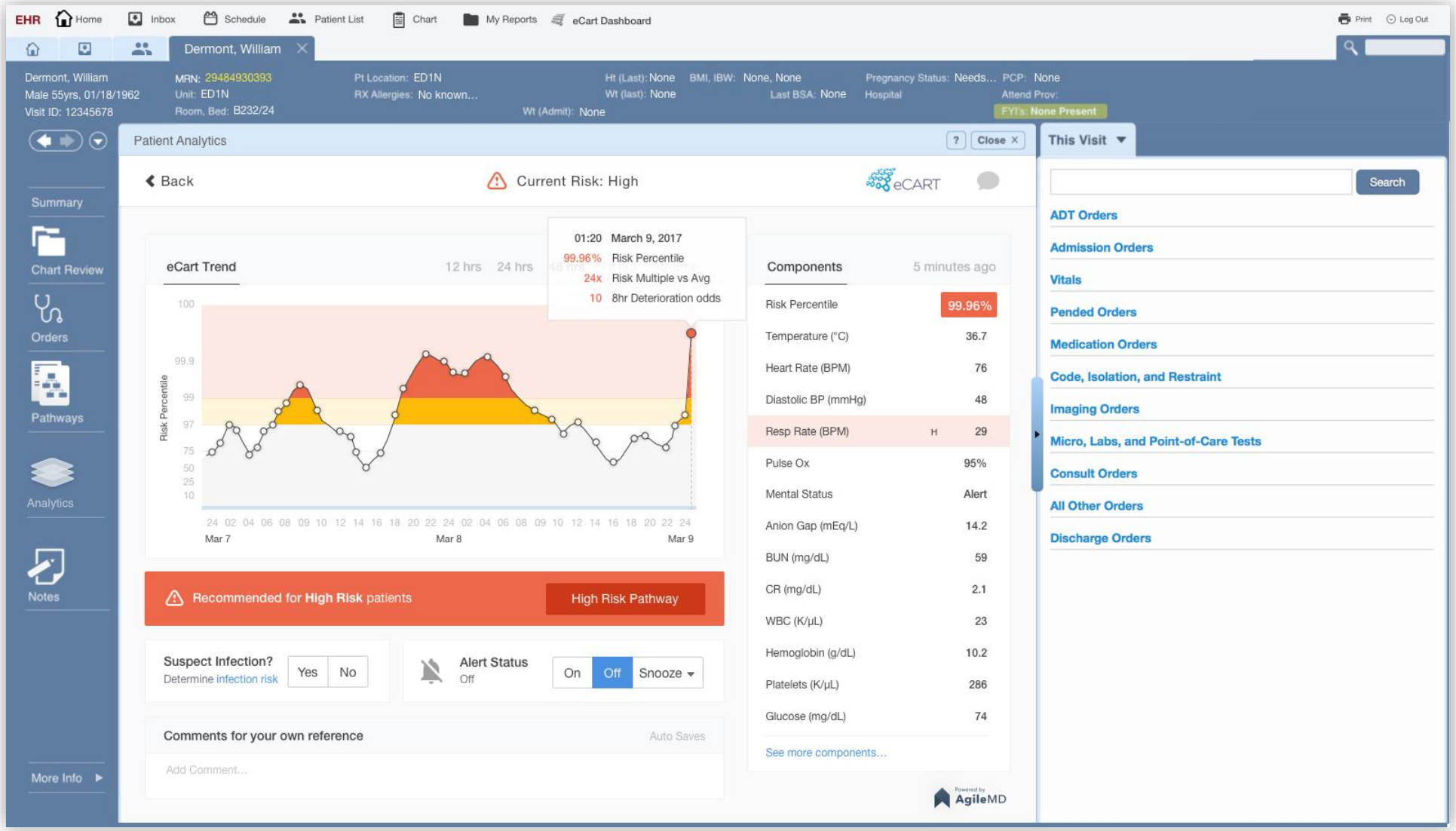
Kang, CCM, 2016

Custom implementation at the University of Chicago

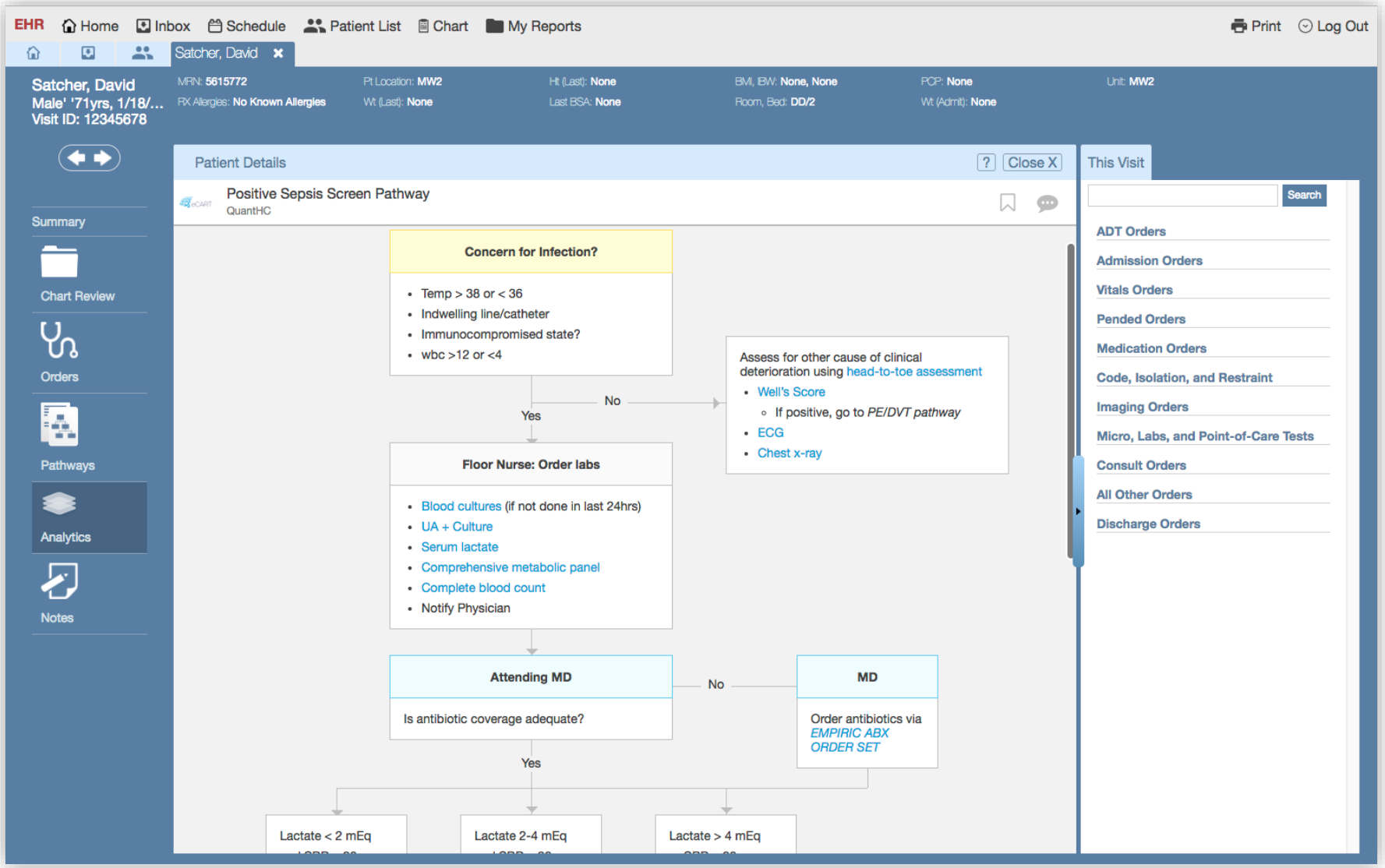


MRN	Location	eCART	Risk Category	Date
xxxxxxx	N10W: 10xx -A	66	High	02-
xxxxxxx	N08W: 80xx -A	59	High	02-
xxxxxxx	N10W: 10xx -A	58	High	02-
xxxxxxx	N08W: 80xx -A	58	High	02-
xxxxxxx	N08W: 80xx -A	55	High	02-
xxxxxxx	N10W: 10xx -A	55	High	02-
xxxxxxx	N08W: 80xx -A	55	High	02-
xxxxxxx	N10E: 10xx -A	53	Moderate	02-
xxxxxxx	N08W: 80xx -A	53	Moderate	02-
xxxxxxx	N08W: 80xx -A	52	Moderate	02-

eCART imbedded within the EHR



Building in clinical decision support



eCART Imbedded in the Philips Guardian Platform

Philips IntelliVue GuardianSoftware - [My Institution - My Unit] - This is not an alarming system

Super User

PHILIPS

Patient Overview

Patient	MRN	Age	Location	eCART	Time Since Last eCART	Trend
C. Smith	MRN001	66 Years	601		42min	
W. Petersen	MRN002	55 Years	602		12min	
M. Helgenberger	MRN003	65 Years	603		11min	
P. Guifoyle	MRN005	44 Years	604		10min	
J. Fox	MRN007	51 Years	605		9min	
E. Szmanda	MRN008	54 Years	606		5min	
R. Hall	MRN009	66 Years	607		42min	
L. Lombard	MRN010	55 Years	608		12min	
C. Boyce	MRN049	65 Years	609		11min	
C. Giovinazzo	MRN038	44 Years	610		10min	
S. Gomez	MRN082	51 Years	611		9min	
A. Grande	MRN097	54 Years	612		5min	
E. Harnois	MRN016	66 Years	613		42min	
H. Harper	MRN039	55 Years	614		12min	
M. Jackson	MRN048	65 Years	615		11min	
S. Jackson	MRN095	44 Years	616		10min	

Summary

Data-driven early warning scores outperform traditional expert consensus

Machine learning algorithms further improve detection and reduce false alarms

Pick the best early warning score you can and skip the sepsis screening tool

Imbed it into your workflow at the point of care


PHILIPS