An Analytical Framework to Reducing Hospital Readmissions

Descriptive, Predictive, and Prescriptive Analytics

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Outline

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1. **What is Readmission? Why Readmission is bad?**
2. **What causes Readmission?**
3. **What we can do to reduce avoidable Readmission.**
4. **Analytics in a nutshell: Descriptive, Predictive and Prescriptive.**
5. **How analytics can help in avoidable Readmission reduction.**

What is Readmission?

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Courtesy of the NYTimes.com

CMS
CENTERS FOR MEDICARE & MEDICAID SERVICES

Readmission is "an admission to a subsection(d) hospital within 30 days of a discharge from the same or another subsection(d) hospital"

'Rework', or a 'Recall'

What is Readmission?

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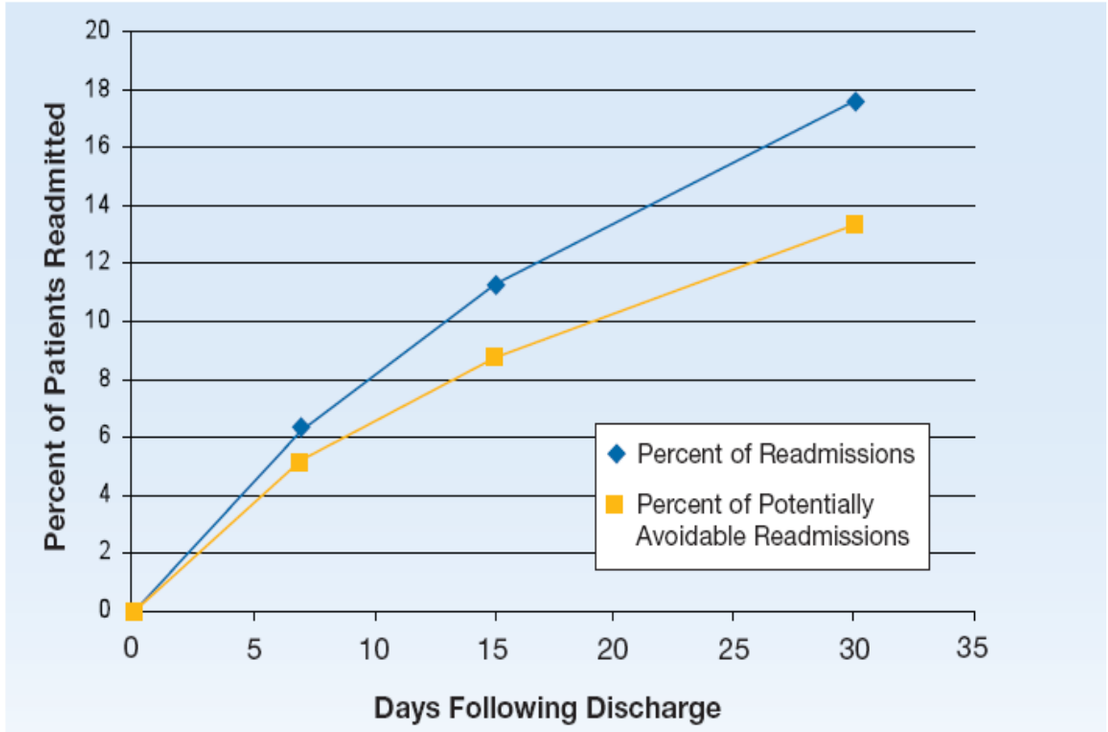
Definition

A return hospitalization to a same (or different) care unit within a specific time interval, following a prior admission and discharge.

Taxonomy

Readmission
- **Avoidable or Unnecessary**
- **Planned or Advised**



Source: Medicare Payment Advisory Commission. 2007. *Report to the Congress: Promoting Greater Efficiency in Medicare*. Washington, DC: Medicare Payment Advisory Commission, p. 107; the percent of potentially avoidable readmissions was estimated using 3M software and 2005 Medicare claims data.

Facts

- Readmission is influenced by *Quality of Care* and patient's health status (Miller, 2007).
- Section 3025 of the Obamacare established Hospital Readmission Reduction Program (2010)
- Readmission is influenced by *Access to Care* and patient socioeconomic status (Kangovi 2011).
- There is no single solution to address the issues contributing to readmission (Willaims 2013).

Why Readmission is Bad?

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INSTITUTE FOR HEALTHCARE IMPROVEMENT

Hospitalizations account for nearly one-third of the total $2 trillion spent on health care in the United States, and a substantial fraction of which are related to avoidable readmissions.

CMS
CENTERS FOR MEDICARE & MEDICAID SERVICES

In 2009, 19.6% of Medicare fee-for-service patients discharged from a hospital were readmitted within 30 days that accounts for $12 billion annually. In comparison to other European countries, the US has the highest readmission rate.

PPACA: about two-thirds (or 2,211) of US hospitals have been penalized a cumulative $280 million (1%) in Medicare funds because of excess readmissions starting Oct. 1, 2012. This is acted for 55 Michigan hospitals in FY 2013 and caused $14 million penalty.

Cost of Readmission

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Patient Readmission within 30 days, National Statistics 2011, AHRQ

Diagnosis	Number of index stays	No. of all-cause readmissions	Mean cost per readmission
Congestive Heart Failure	818,987	203,253	$13,966
Septicemia	794,760	164,379	$16,386
Pneumonia	931,532	145,720	$13,417
Mood Disorders	894,67	136,491	$7,320
COPD and Bronchiectasis	626,113	132,271	$11,670
…			
Diabetes	494,174	101,192	$11,725
…			
Acute Myocardial Infarction	509,756	82,964	$13,821
…			

Conditions received penalty from CMS by 2013: AMI, CHF, and Pneumonia

Conditions received penalty from CMS by 2015: COPD, Coronary Artery Bypass, Peripheral Vascular Disease

What Causes Readmission?

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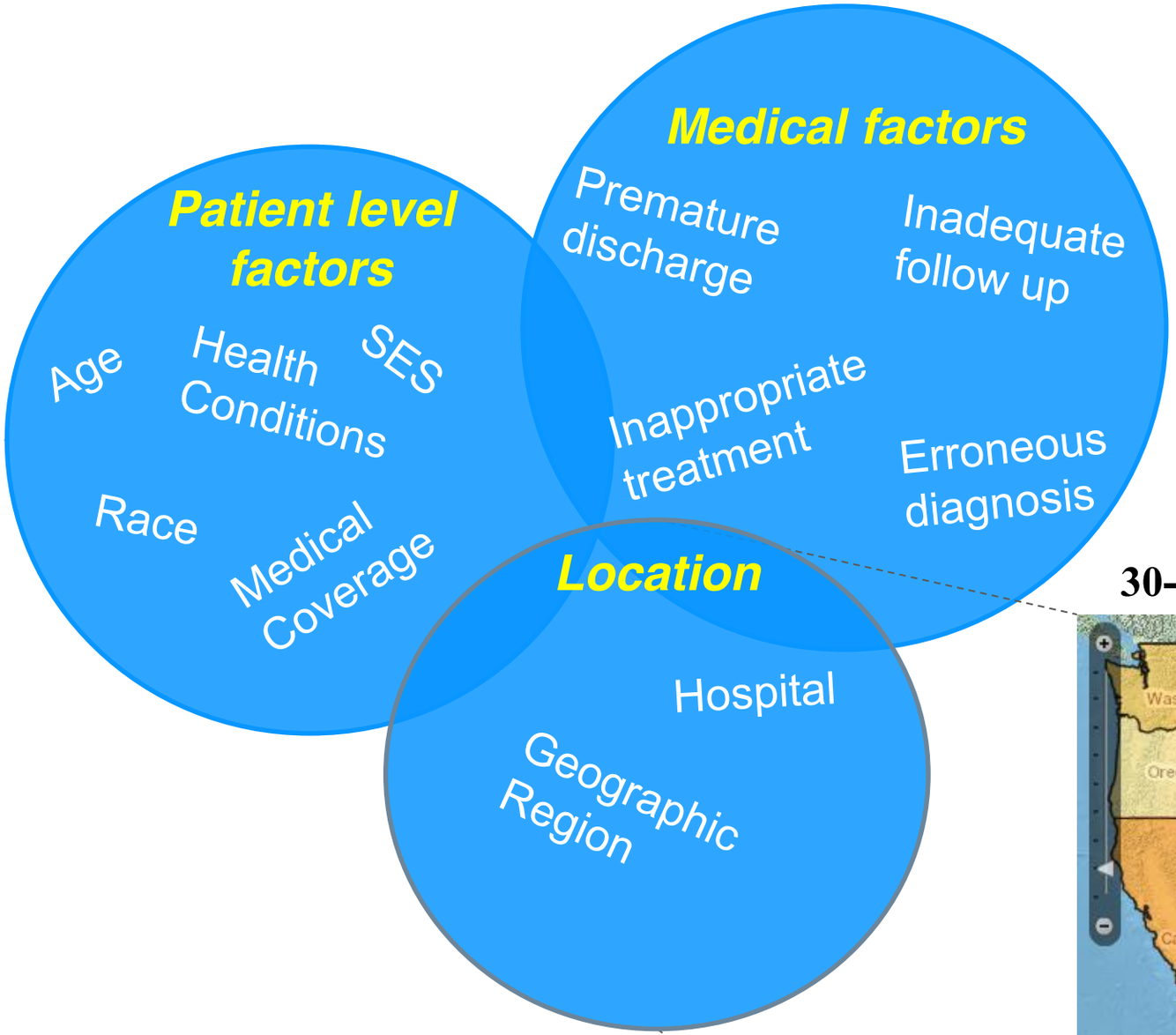
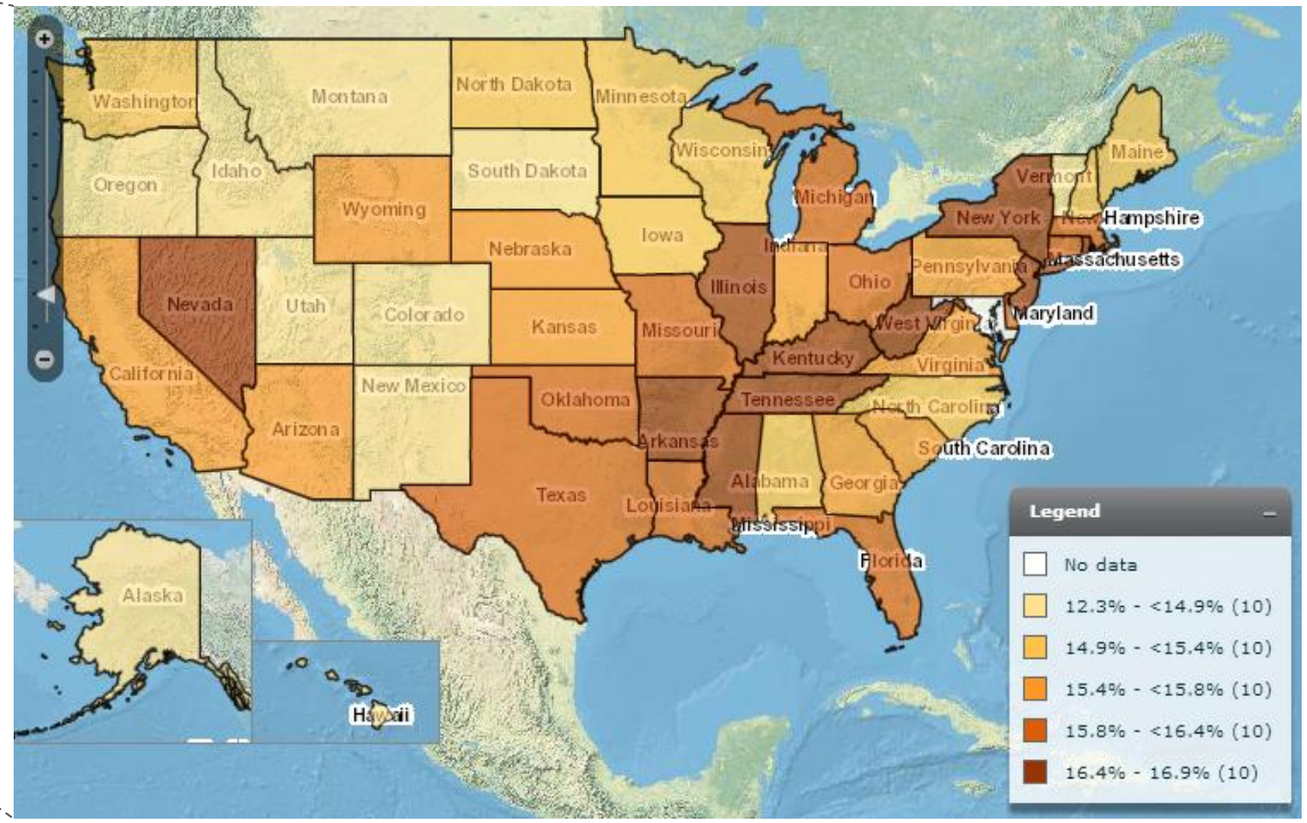


30-day readmission rate for Medicare beneficiaries in 2010



What Can be Done?

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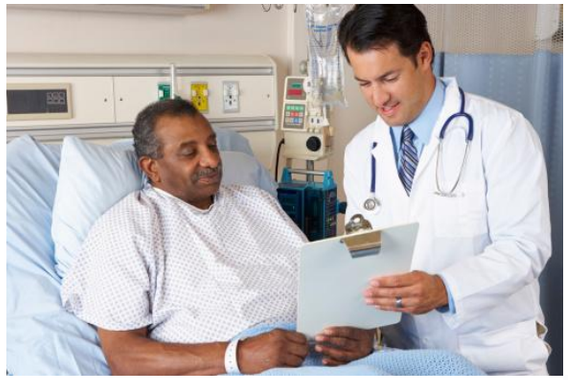
Manage practices and culture of medical facilities and medical neighborhood will affect Readmission rates.

Systematic Interventions through Healthcare Systems Engineering

- Care Coordination and Transition Planning
- Discharge Process Re-Engineering
- Care Access and Quality Improvement
- Patient, Family, and Community Support



Pre-discharge

Post-discharge

Readmission Intervention Roadmap

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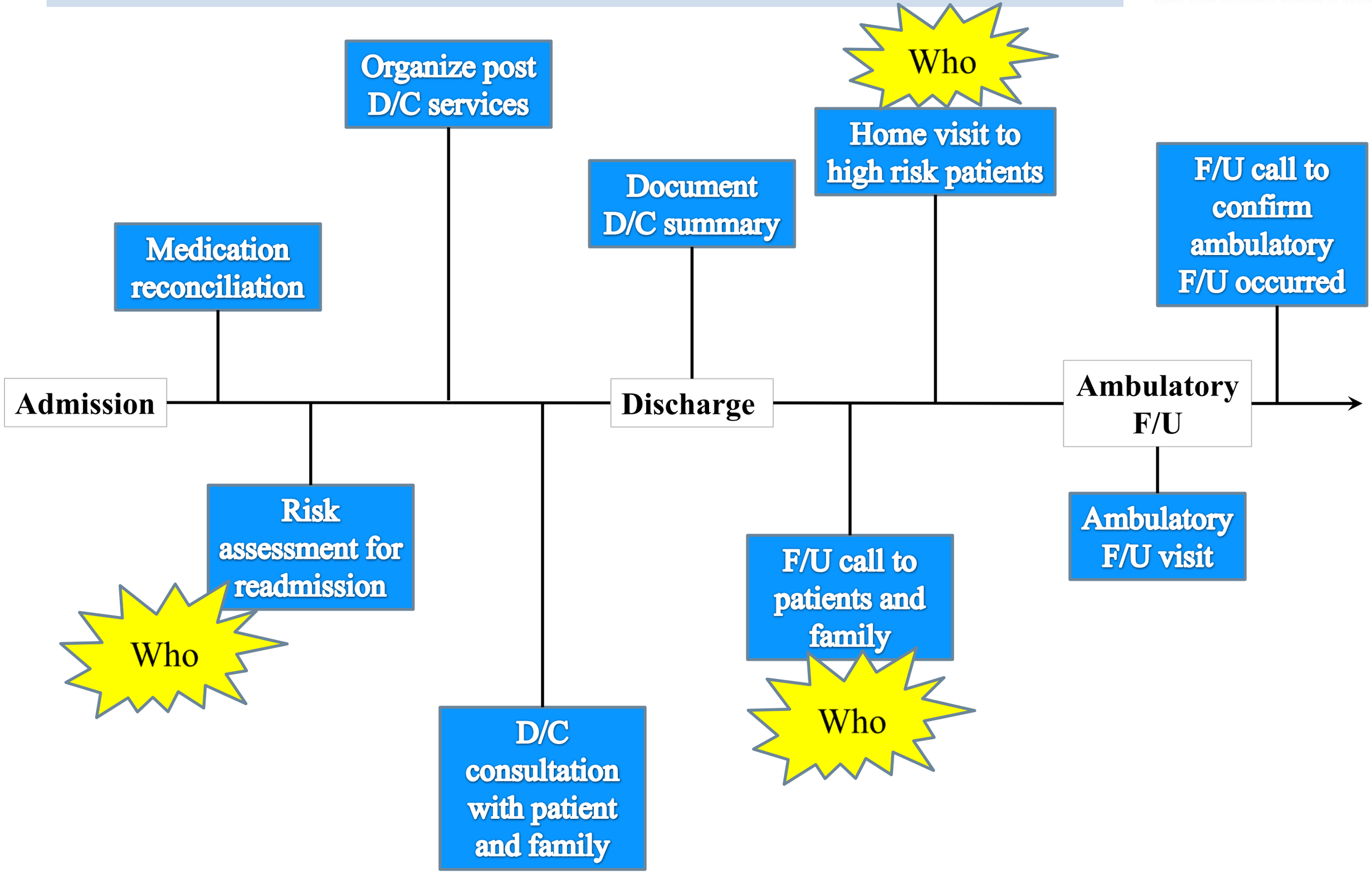

Some Intervention Programs

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Project	Main Intervention	Result	Comments
Very Effective			
RED: Re-Engineered Discharge (Jack et al. 2009)	• Follow-up phone-call • Post-discharge services • Medication reconciliation • Patient education plan	• 30% decrease in hospital utilization in 30-day follow-up • 34% lower observed costs in RED group due to 32% lower use of hospital resources	• Decrease in both ED and readmissions • The method was most effective for patients with high utilization
The Care Transitions Program® (Coleman, 2004)	• A Personal Transition Coach meets the patient in hospital. • The PTC visits patients at their home. • The PTC arrange three phone calls within 28 days after discharge.	• Decreased readmission overall: 30 days = 4% 90 days = 6% 180 days = 5% • Decreased readmission for same diagnosis: 30 days = 2% 90 days = 5% 180 days = 5%	• Longer time to the next readmission (225 days vs. 217 days, $p < 0.001$) • Use RN, NP, APN as transition coach
Transitional Care Model (TCM) (Naylor, 2004)	• A Transitional Care Nurse conducts home visits 24h after discharge helping on patient and family education • A TCN accompanies the patient on the first post-discharge visits	• 17% decrease in 180-day readmission rate for the intervention group • Significantly fewer number of readmissions at one year for HF elderly (65+) patients.	• Advanced Practice Nurses (APN) provide transitions among care settings

Some Intervention Programs

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Project	Main Intervention	Result	Comments
Effective			
Community Care North Carolina (2004)	• Coordinate care through developing local networks of PCPs • Makes care deliverers responsible for performance	• 23% cut in Pediatrics asthma hospitalization • Diabetes hospitalizations decreased by 9%	• Designed for Medicaid and low-income patients • Covered initiatives such as asthma, HF, diabetes, ED, and pharmacy
Commonwealth Care Alliance Brightwood Clininc (2008)	• Multidisciplinary clinical team model with own authorities • Reminders calls for preventive care • Enhanced behavioral health care	• Unspecified readmission rates • Cost saving of $204 PMPM compared to fee-for-service • ED utilization decrease from 0.109 visits PMPM to 0.097 visits PMPM.	• Intensive resources for highly coordinated teams with close individual outreach and follow-ups
Home Healthcare Telemedicine (Naylor, 2004)	• Visit the patient remotely via video 1-3 times per week • Telemonitor patient blood pressure and pulse oximeter	• 5% cut in rate of readmission for CHF patients	• Designed for CHF and COPD patients • Cost of telemedicine unit ($5,500) is less than one hospital admission

Some Intervention Programs

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Project	Main Intervention	Result	Comments
Promising but requiring additional data			
BOOST: Better Outcomes for Older adults through Safe Transition (2008)	• General Assessment of Preparedness (GAP) tools • Nurse training of 'teach-back' process • Standard forms and methods to transmit information to PCPs	• 8.5 % cut in all-cause 30-day readmission for patients (70-) • 22 % cut in all-cause 30-day readmission for patients (70+)	• Results are from one site (Atlanta Piedmont Hospital) • It covers 24 medical facilities in Michigan
STAAR: STate Action on Avoidable Readmissions (2009)	• Customized education for patient and caregivers at discharge • In-person visit for high-risk patients and phone calls for moderate-risk ones 48h after discharge	• No published results; it launched in 2009 for a 4-year cycle	• It covers states of MA, MI, OH, and WA • It conducts real-time patient- and family-centered communications
Hospital at Home (Leff et al. 2005)	• Web-based community to share tool kits and best practices • Post-discharge medication management, early follow-up, and symptom management	• No results have been published	• Focused on patients (65+) with HF or AMI diagnosis discharges

Readmission Rate and Risk Adjustment

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What is Risk Adjustment?

The process by which the health status of a population is taken into account when evaluating outcomes of care or setting capitation rates.

Rationale for Risk-Adjustment

Hospital A
affluent suburb

Patients	System
- Few comorbidities - Younger - Insured	- Good access to outpatient care - Care coordination

Hospital B
urban tertiary center

Patients	System
- Multiple comorbidities - Older - Uninsured	- Limited access to outpatient care - Limited pre-discharge services

Is it Fair to Compare These Hospitals?

Readmission Rate and Risk Adjustment

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How to do Risk Adjustment?

Compare a hospital's performance, given clinical status of its patients (Case Mix), with the average hospital's performance, given the same Case Mix.

Risk-Adjusted Readmission Rate

$$\frac{\text{Number of 30-day Readmission Predicted Based on the Hospital's Performance with its Observed Case Mix}}{\text{Number of 30-day Readmission Expected Based on the Nation's Performance with that Hospital's Case Mix}} \times \text{US National Readmission Rate}$$

Both Fixed Effects and Hospital Random Effect

Only Fixed Effects

Does this hospital have more or fewer readmission than would be expected from a typical hospital?

Readmission Rate as a Quality Metric

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Risk-Adjusted Readmission Rates (RARR) are publicly reported on CMS and VA Hospital Compare websites.

CMS Hospital Compare

30-Day Outcomes Readmission and Deaths Details - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Medicare Hospital Comparison | 30-Day Outcomes Readmission and Deat...

www.medicare.gov/HospitalCompare/details.aspx?msrCd=prnt3grp1&ID=220031,220071,22010F&stsltd=MA

Yahoo

The U.S. National Rate of readmission for heart attack patients = 19.7%

Hospital Name	Better Than U.S. National Rate (Adjusted readmission is lower than U.S. National Rate)	No Different Than U.S. National Rate (Adjusted readmission is about the same as U.S. National Rate or difference is uncertain)	Worse Than U.S. National Rate (Adjusted readmission is higher than U.S. National Rate)
BOSTON MEDICAL CENTER CORPORATION			X
MASSACHUSETTS GENERAL HOSPITAL		X	
VA BOSTON HEALTHCARE SYSTEM - JAMAICA PLAIN		X	

The 'total number' of hospitals in the table below is the total number of hospitals that had eligible admissions for this measure. See 30-Day Death and Readmission Measures for additional information about the data collection for the readmission measures.

Out of 4519 in the United States →	**30** hospitals in the United States were Better than U.S. National Rate	**2338** hospitals in the United States were No different than U.S. National Rate	**41** hospitals in the United States were Worse than U.S. National Rate
	2110 hospitals in the United States did not have enough cases to reliably tell how well they are performing		

Readmission Rate as a Quality Metric

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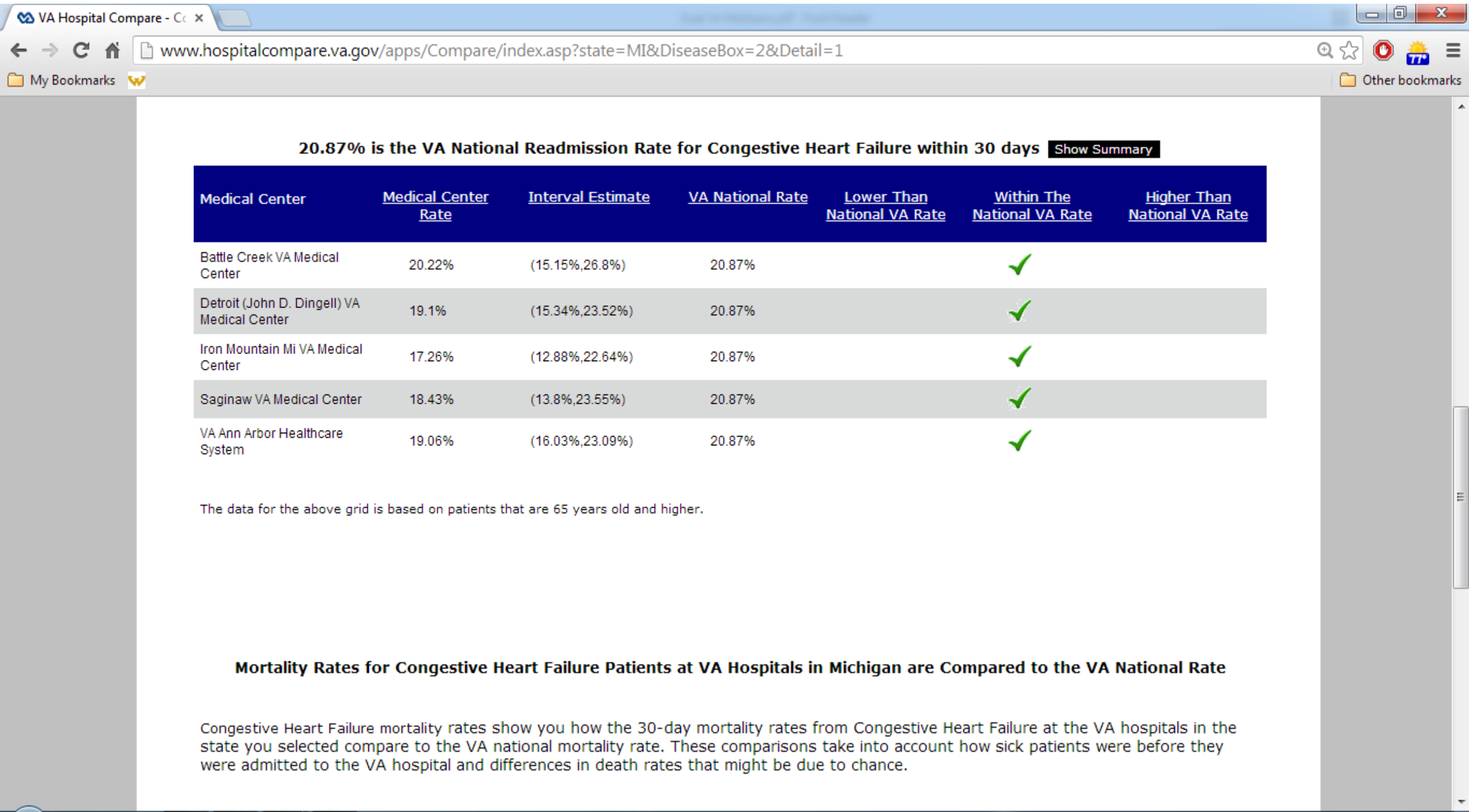
Risk-Adjusted Readmission Rates (RARR) are publicly reported on CMS and VA Hospital Compare websites.

VA Hospital Compare



Readmission Rate as a Quality Metric

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Risk-Adjusted Readmission Rates (RARR) are used for Financial Penalties.

Readmissions PUF-FY 2013 IPPS Correction-March 2013.xlsx - Microsoft Excel

Home Insert Page Layout Formulas Data Review View

K14

	A	B	C	D	E	F	G	H
5	PROV	FY 2013 Readmission Payment Adjustment Factor	Number of Pneumonia Cases	Excess Readmission Ratio for Pneumonia	Number of Heart Failure Cases	Excess Readmission Ratio for Heart Failur	Number of Acute Myocardial Infarction Cases	Acute Myocardial Infarction Excess Readmission Ratio
6	010001	1.0000	400	0.9137	894	0.9406	728	0.9664
7	010005	1.0000	374	0.9547	264	0.9126	21	0.0000
8	010006	1.0000	842	0.9134	614	0.8033	342	0.9021
9	010007	0.9929	254	1.0439	135	1.0942	1	0.0000
10	010008	1.0000	56	0.9767	59	0.9981	4	0.0000
11	010009	1.0000	110	0.9929	133	0.9561	9	0.0000
12	010010	0.9994	326	1.0106	173	0.9664	13	0.0000
13	010011	0.9952	452	0.9540	417	0.8641	213	1.1661
14	010012	0.9972	210	0.9585	160	1.0674	79	1.0140
15	010015	1.0000	67	0.9343	117	0.9914	2	0.0000
16	010016	0.9978	332	0.9199	323	1.0164	199	1.0432
17	010018	1.0000	0	0.0000	0	0.0000	0	0.0000
18	010019	0.9982	336	1.0401	289	0.8763	43	1.0699
19	010021	1.0000	183	0.9585	128	0.9167	15	0.0000
20	010022	0.9969	112	0.9325	77	1.0548	5	0.0000
21	010023	0.9925	214	1.1577	531	0.9716	379	1.1247
22	010024	0.9981	358	1.0852	533	0.9625	208	0.9708

File Layout | FINAL FY 2013-Aug 1, 2012 | Correction FY 2013

Ready 100%

http://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/Readmissions-Reduction-Program.html

Current Problems in Readmission Reduction

- **Diversity of Medical Facilities, Management Practices, and Cultures. Lack of Comparative Outcome Studies.**
- **Variations in Readmission Causes (Risk Factors) among Different Healthcare Settings and among Different Patient Population**
- **Deficiency in Current Risk Prediction Models and Lack of Consensus on Readmission Timeframe.**
- **Cost and Resources related to Readmission Intervention Programs. Absence of Optimal Mechanism to Allocate Interventions to a Given Patient Population.**

Analytics in a Nutshell

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Prescriptive Analytics: What we should do?

$$\text{Max } Z = \sum_i p_i x_i - c_0 Q$$

subject to:

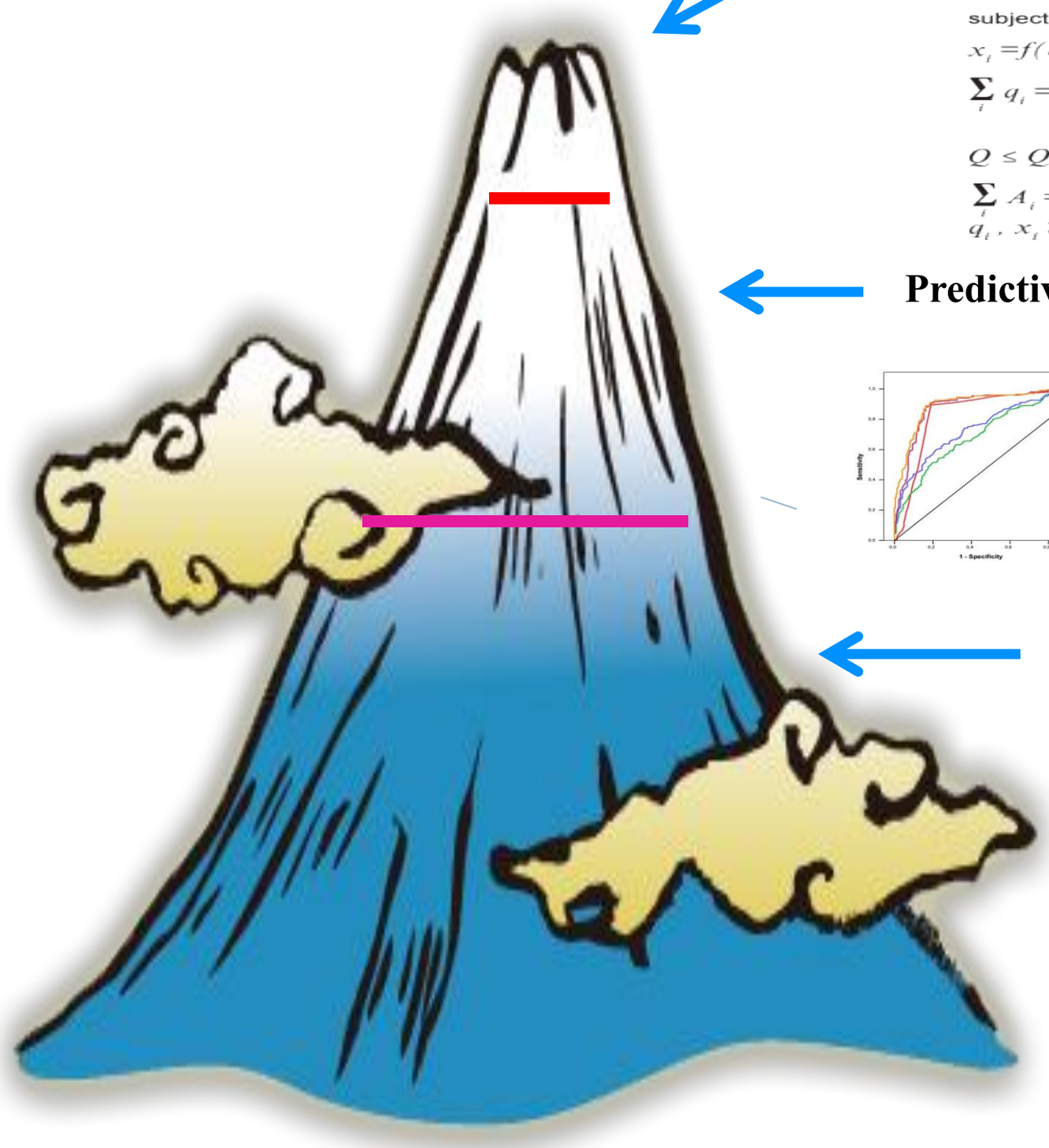
$$x_i = f(q_i) \times A_i$$

$$\sum_i q_i = Q$$

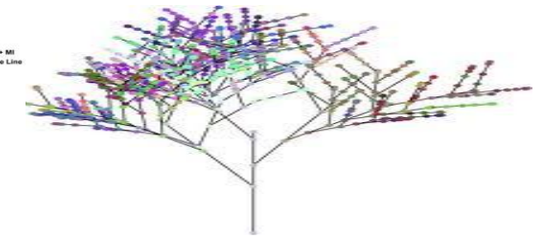
$$Q \le Q^{max}$$

$$\sum_i A_i = A^{max}$$

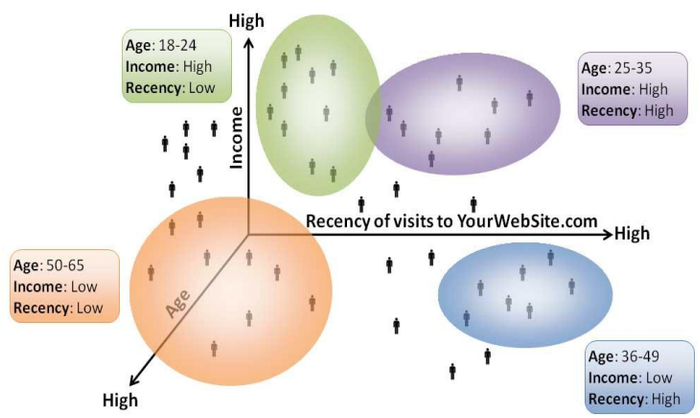
$$q_i, x_i \ge 0$$



Predictive Analytics: Predict what will happen



Descriptive Analytics: Understand what happened in the past.



Descriptive Analytics at Work

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Data

4 VA Michigan facilities , FY 2008 to 2012, contained near 4724 records from 1852 patients

76.8% were readmitted once, 14.8% were readmitted twice, and 8.4% were readmitted 3 times or more.

Patient Factors

Demographics: Gender (Male ~86%), Age (60+ about 76%), Race …

SES: Income, Insurance (Insured about 62%) …

Utilization: Ward, Length of stay…

Risk and comorbidities: Treatment Specialty, Principal Diagnosis, …

War-connected: POW, Radiation status, …

Descriptive Analytics at Work

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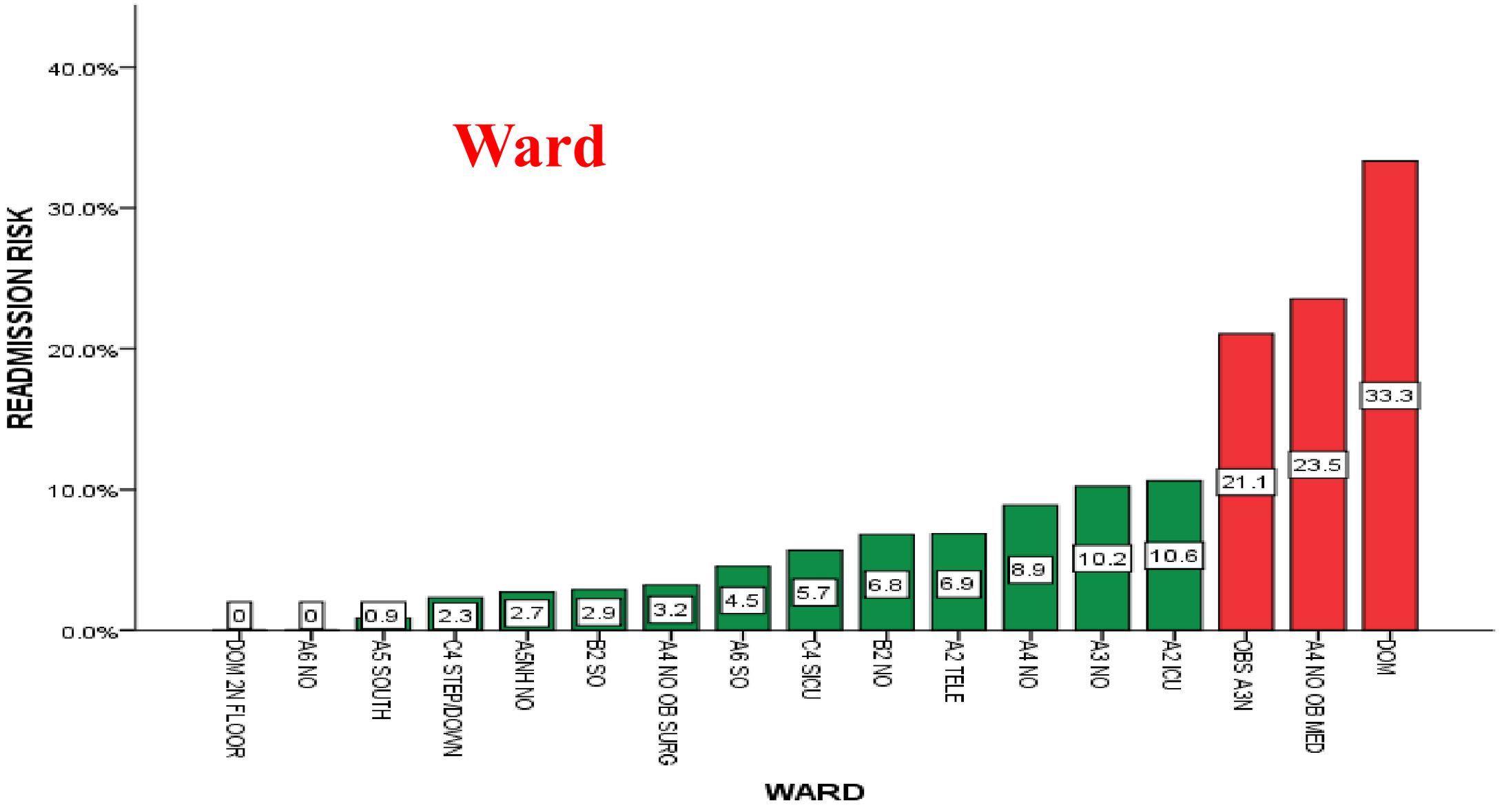
Ward



DOM – Mental Health Domiciliary (Offsite)

OBS A3N – Acute Medicine (Observation for <24 hours

A4 NO OB MED – Acute Medicine (Observation for <24 hours)

Descriptive Analytics at Work

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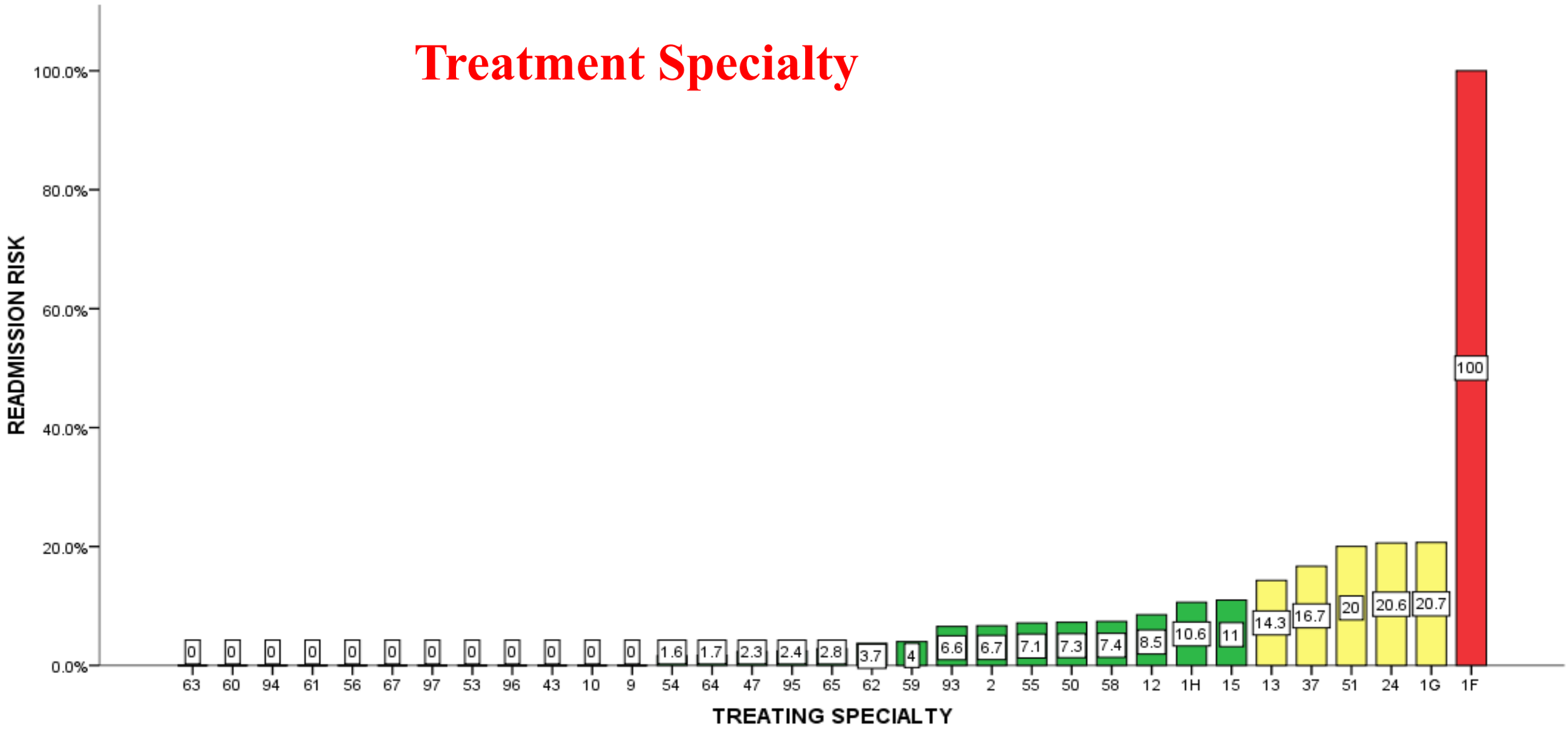
Treatment Specialty



1F – Hospice for Acute Care

13 – Cardiac Intensive Care Unit
37 – Domiciliary CHV
51 – OB/GYN
24 – Medicine

Descriptive Analytics at Work

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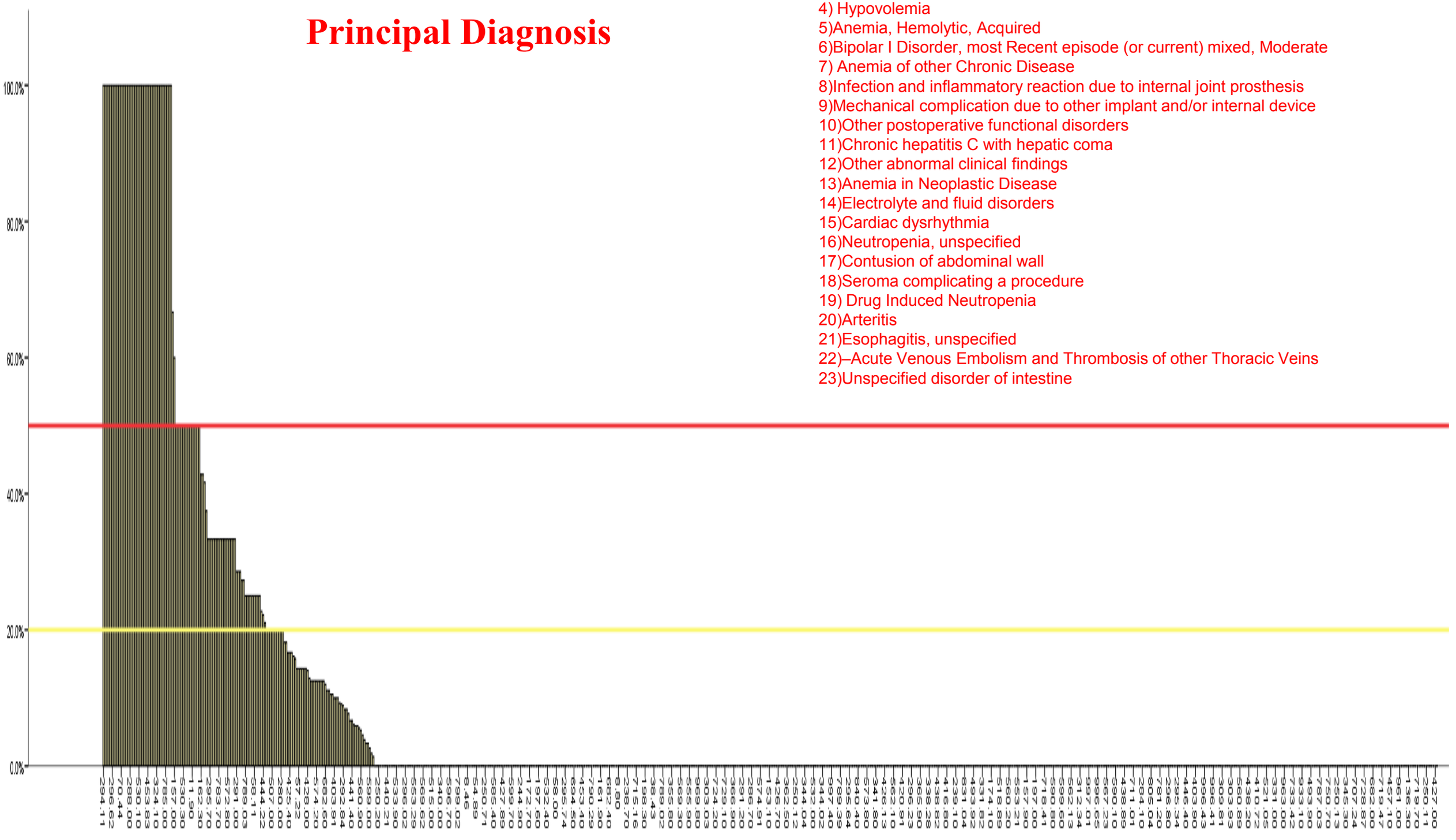
Principal Diagnosis



1)Dementia in conditions classified elsewhere with Behavioral disturbance
2) Leiomyoma of uterus
3) Dysphasia causing late effects in cerebrovascular disease
4) Hypovolemia
5)Anemia, Hemolytic, Acquired
6)Bipolar I Disorder, most Recent episode (or current) mixed, Moderate
7) Anemia of other Chronic Disease
8)Infection and inflammatory reaction due to internal joint prosthesis
9)Mechanical complication due to other implant and/or internal device
10)Other postoperative functional disorders
11)Chronic hepatitis C with hepatic coma
12)Other abnormal clinical findings
13)Anemia in Neoplastic Disease
14)Electrolyte and fluid disorders
15)Cardiac dysrhythmia
16)Neutropenia, unspecified
17)Contusion of abdominal wall
18)Seroma complicating a procedure
19) Drug Induced Neutropenia
20)Arteritis
21)Esophagitis, unspecified
22)–Acute Venous Embolism and Thrombosis of other Thoracic Veins
23)Unspecified disorder of intestine

What We Can Get from Descriptive Analytics?

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- **Understand What Patients Look Like?**
- **Identify Vulnerable Areas and Wards.**
- **Pinpoint High Risk Disease Types and Patient Groups.**
- **Develop Customized Readmission Intervention Approaches.**

Predictive Analytics

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- **Predict Readmission Risk for Individual Patients**
- **Classify Patients into High, Medium, and Low Risk Groups.**

Objective

Develop a Risk Prediction Model that:

1. Can capture the timing of readmission
2. Be able to incorporate patient's past history of readmission
3. Produce better discriminative results comparing to the literature (c-Statistics > 0.7)

Predictive Analytics (Goal 1)

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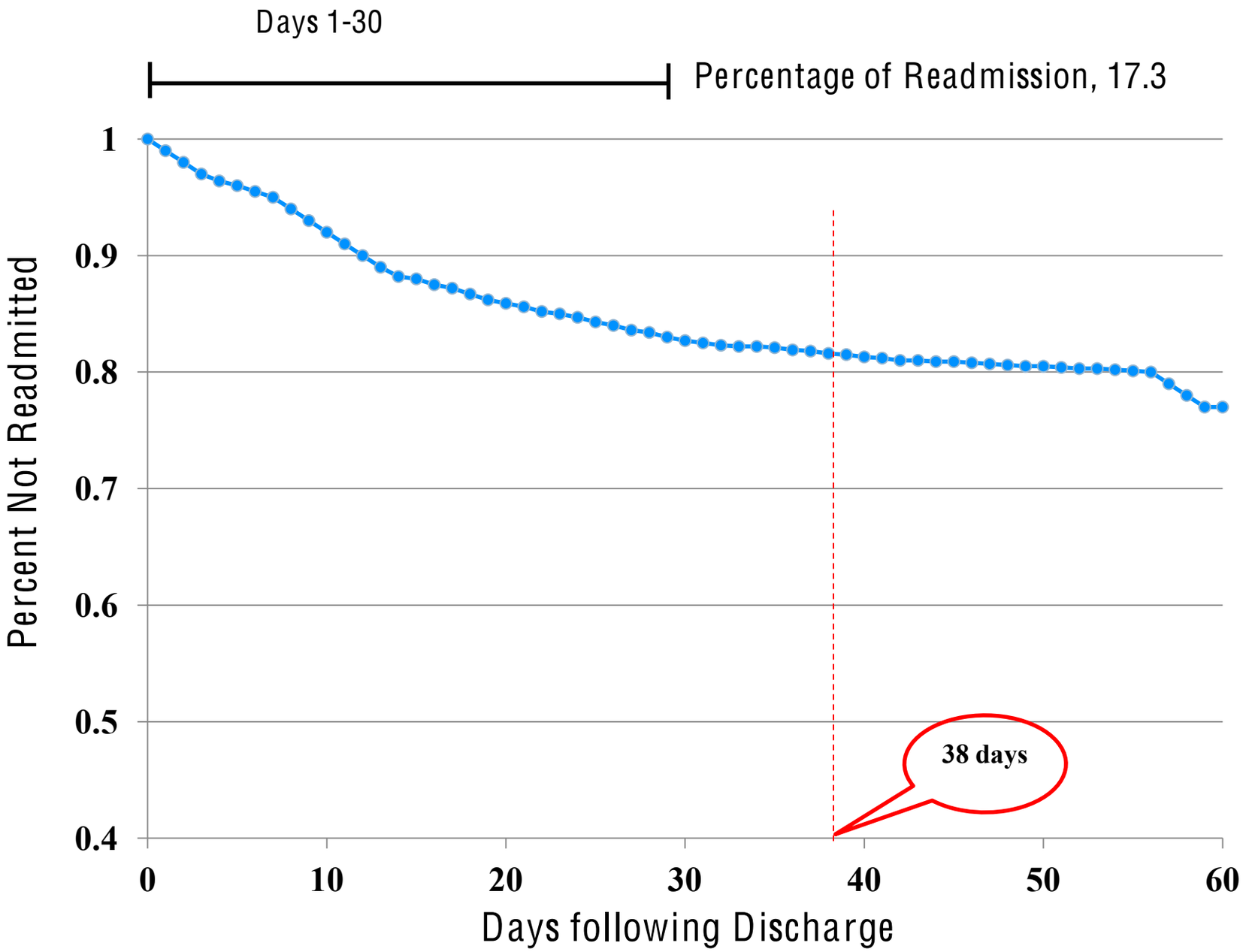
Timing to Readmission for COPD Patients



Predictive Analytics (Goal 1)

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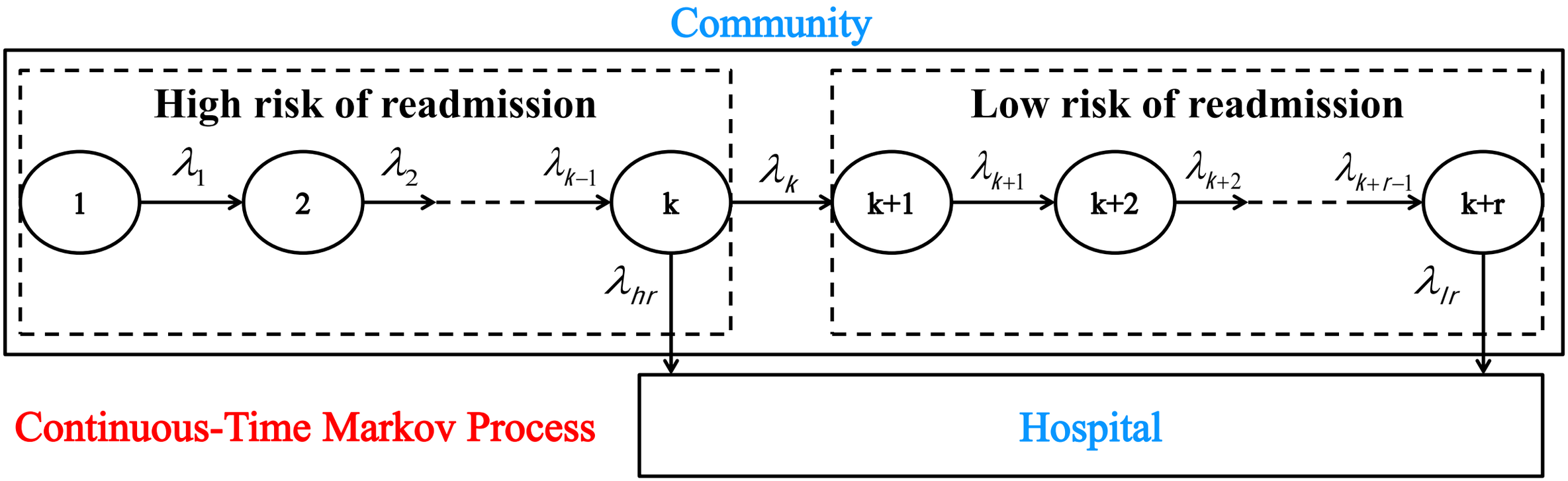
Modeling Time to Readmission with Patient Flow Approach

Shams et al., Working paper 2013



Continuous-Time Markov Process

$$\Psi = \begin{matrix} -\lambda_1 & \lambda_1 & 0 & 0 & 0 & 0 & \cdots & 0 \\ 0 & -\lambda_2 & \lambda_2 & 0 & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & -\lambda_k + \lambda_{hr} & \lambda_k & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & -\lambda_{k+r-1} & \lambda_{k+r-1} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\lambda_{lr} \end{matrix}$$

Time to Readmission

=

Time from the starting state until absorption in the absorbing state.

Predictive Analytics (Goal 1)

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Inference

Shams et al., Working paper 2013

The model can be seen as a CTMP with k+r transient state and one absorbing state. The initial probability is **P**=(1 0 0 ⋯ 0 0) and the transition matrix is given by **Ψ**.

If t presents the time to absorption (Readmission Time), we have:

$$f(t) = \mathbf{P}\exp(\mathbf{\Psi} x)\boldsymbol{\alpha}; \qquad \boldsymbol{\alpha} = -\mathbf{\Psi}\mathbf{1} = \begin{pmatrix} 0 & 0 & \cdots & \lambda_{hr} & 0 & \cdots & \lambda_{lr} \end{pmatrix}^{\mathrm{T}}$$

$$S(t) = \Pr(T > t) = \mathbf{P}\exp(\mathbf{\Psi} x)\mathbf{1}$$

The time spent in each phase follows an exponential distribution. Hence, the pdf can be viewed as a mixture of two generalized Erlang distribution (k, k+r) like:

$$f(t) = pf_k(t) + (1-p)g_{k+r}(t)$$

where p is the probability of being in the high-risk group and can be estimated as

$$p = \frac{\lambda_{hr}}{\lambda_{hr} + \lambda_k}$$

Predictive Analytics (Goal 1)

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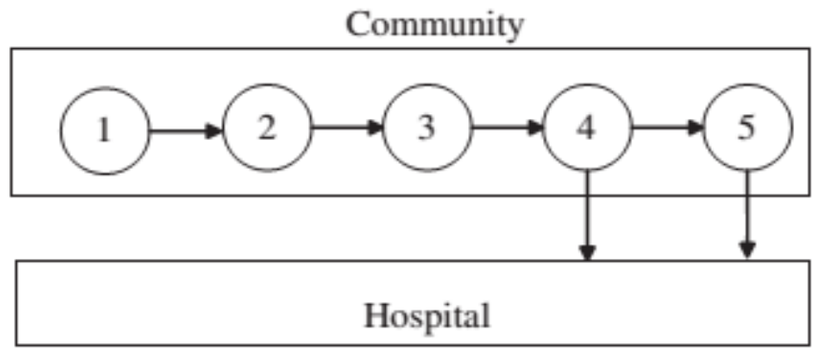
Results

Shams et al., Working paper 2013

Parameter	Estimate	St. Error
λ_1	0.04	0.003
λ_2	3.62	0.12
λ_3	5.87	0.23
λ_4	1.25	0.05
λ_{40}	1.04	0.03
λ_{50}	0.07	0.006



COPD

Proposal

In order to minimize the classification error between high-risk and low-risk group, we use Bayesian classification argument which yields to the cut-off readmission time where

$$p f_k(t) = (1-p)\, g_r(t)$$

simply where the two corresponding curves intersect

Optimal Time Window = 42 Days

Predictive Analytics (Goal 2, 3)

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Risk Prediction Model to study the Effects of Patient Factors

Shams et al., Working paper 2013

Let h_{ij} be the risk of j^{th} readmission for patient i $(j = 1, \dots, n_i)$, then we propose

$$h_{ij}(t|x,z) = h_0(t)\exp\left(\beta' x_{ij} + z'_{ij}\boldsymbol{w}_{ij}\right)$$

Where $\boldsymbol{w}_{ij}$ accounts for the correlation among patients within a cluster.

Both inter- and intra-patient variability of readmission can be captured (i and j indices).

Results

Method	MPSE	AUC_{ROC}	PPV	NPV
Our proposal	2.36	0.84	0.89	0.92
Logistic R	3.14	0.67	0.82	0.93

$$\text{MPSE} := \frac{1}{n}\sum_{i=1}^{n}\left(y_i^* - y_{o,i}\right)^2$$

PPV = TP / (TP + FP)

NPV = TN / (TN + FN)

		actual value		
		p	*n*	total
prediction outcome	*p'*	True Positive	False Positive	P'
	n'	False Negative	True Negative	N'
	total	P	N	

Predictive Analytics (Goal 3)

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Shams et al., Working paper 2013

Association of Patient Factors with 42-day Hazard Ratio

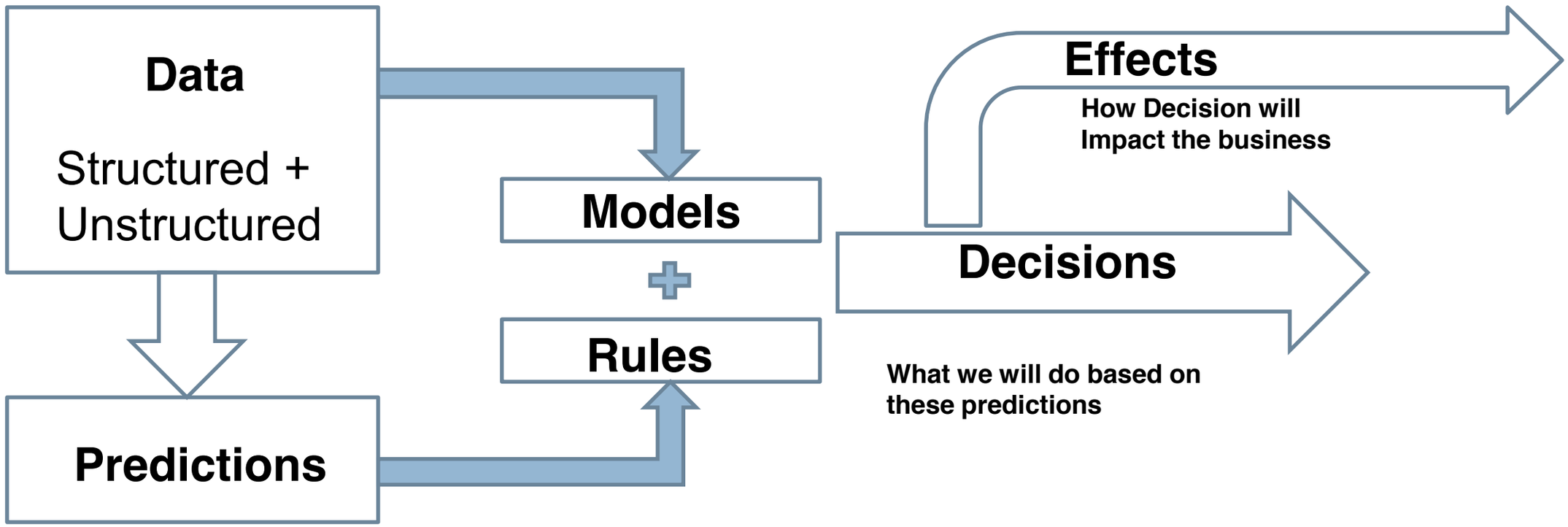
Patient Risk Factor	Hazard Ratio (95% CI)
Age, 40-60	1 [Reference]
Age, 65+	1.07 (1.03-1.08)
Sex, Male	1 [Reference]
Sex, Female	0.97 (0.94-0.99)
Race, White	1 [Reference]
Race, Black	1.04 (1.02-1.06)
Race, Other	0.96 (0.93-0.99)
POW, Yes	1.8 (1.7-2.1)
Radiation Status, Yes	2.6 (2.4-2.8)

Patient Risk Factor	Hazard Ratio (95% CI)
Priority 1, service connected >50%	2.4 (2.1-2.6)
Priority 2, service connected 30–50%	1.6 (1.4-1.8)
Priority 3, service connected 20–30%	1.3 (1.1-1.4)
Priority 4, severely disabling injury	1.8 (1.6-1.9)
Priority 5, low income or Medicaid	1.2 (1.1-1.3)
Priority 6, Agent Orange or Gulf War	2.8 (2.6-3)
Priority 7, non-service connected, income below HUD	1.2 (1.1-1.3)
Priority 8, non-service connected, income above HUD	1 [Reference]

Prescriptive Analytics

industrial & systems engineering
WAYNE STATE UNIVERSITY COLLEGE OF ENGINEERING

General Framework



Application in Readmission

- **Individualized Readmission Intervention Programs**
- **Assign Right Patients to Right Intervention Programs with Resource Constraints**

DISCHARGE CRITERIA

✔ CHECK ALL THAT APPLY

LOW RISK DISCHARGE

- ☐ Independent in ADL's
- ☐ Caregivers in the home and available to assist
- ☐ Lives alone with community support
- ☐ Independent with management of chronic disease/meds
- ☐ Adherent to treatment plan
- ☐ Able to direct medical care
- ☐ Consistently followed by MD/Practitioner

Discharge to Community

Refer to home care services (Including patients who reside in Adult Home or Assisted Living Facility)

MODERATE RISK DISCHARGE

- ☐ Lives alone with limited community support
- ☐ Requires assistance with medications
- ☐ Issues of health literacy
- ☐ History of mental illness
- ☐ Polypharmacy (greater than 7 meds)
- ☐ Requires temporary assistance with IADL's and ADL's
- ☐ Requires assistance in:
  - Ambulating
  - Transferring
  - Wound Care
  - Management of oxygen and/or nebulizer

If ≥ 2 then refer to home health agency

Refer to home care services for:

Patient received services from home care prior to hospitalization?

☐ Yes ☐ No If Yes, name of agency:

Skilled Nursing

- *Observation and assessment*
- *Teaching and training*
- *Performance of skilled treatment or procedure*
- *Management and evaluation of a client care plan*

AND/OR

- *Physical, occupational and/or speech therapy*
- *Medical social work*
- *Home health aide service for personal care and/or therapeutic exercises*
- *Telehealth Care Management*

HIGH RISK DISCHARGE

- ☐ Lives alone with no community support
- ☐ Lives with family that is not actively involved in care
- ☐ Clinically complex
  (multiple co-morbidities, repeat hospitalizations or ED visits, needs considerable assistance to manage or is unable to manage medical needs independently)
- ☐ History of falls
- ☐ Acute/chronic wound or pressure ulcer
- ☐ Incontinent
- ☐ Cognitive impairment
- ☐ History of mental illness
- ☐ CHF and/or COPD and/or diabetes and/or HIV/AIDS
- ☐ End stage condition
- ☐ Requires considerable assistance in:
  - Transferring
  - Ambulating
  - Medication management (greater than 7 meds)
  - Management of oxygen and/or nebulizer

If ≥ 4 then refer to home health agency upon patient admission to hospital

THIS PATIENT IS HIGH RISK FOR REHOSPITALIZATION REFER TO HOME CARE SERVICES IMMEDIATELY

Other Outpatient Referrals

Services not provided by home care agencies: ☐ Outpatient mental health ☐ Medicaid/Public Assistance ☐ Social Security Office

This information is provided as guidance and should not be considered to be an all inclusive list of discharge planning options. Providers need to select and/or develop protocols that apply to their specific patient population and region.

IPRO Experts in Defining and Improving the Quality of Health Care

This material was prepared by IPRO, the Medicare Quality Improvement Organization for New York State, under contract with the Centers for Medicare & Medicaid Services (CMS), an agency of the U.S. Department of Health and Human Services. The contents presented do not necessarily reflect CMS policy.
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Modeling within an Optimization Framework

Shams et al., Working paper 2013

Assuming C_j be the cost of readmission for disease type j, and $C'_{i(j)}$ be the cost of intervention program for patient i having illness j, an assignment can be formulated as:

$$\max \sum_j c_j \sum_{i(j)} \left[1 - S_{i(j)}(T_j)\right] x_{i(j)}$$

T_j could be 30 days or be estimated

$$s.t. \quad \sum_{i(j)} c'_j \, x_{i(j)} \le B_j \quad \forall j$$

Budget constraints

$$x_{i(j)} = \{0,1\}$$

Generalized Assignment Problem

Further improvements can be made by making difference between pre- and post-discharge intervention costs (and budgets).

Thanks for your patience

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