



# Estimating the Cost of Healthcare-Associated MRSA Infections in the VA

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# Acknowledgements

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  - VA Career Development Award (Nelson, CDA 11-120)
- Collaborators
  - Michael A. Rubin, MD, PhD (VA SLC)
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  - Vanessa Stevens, PhD (VA SLC)
  - Karim Khader, PhD (VA SLC)
  - Martin E. Evans, MD (VA Lexington)
  - Chuan-Fen Liu, PhD, MPH (VA Puget Sound)
  - Nicholas Graves, PhD (University of Queensland)

# Poll

- Are you an infectious disease researcher or clinician?
  - Yes
  - No

# Whiteboard Exercise

- How are estimates of the healthcare cost of a particular illness useful?

# HAI and MRSA

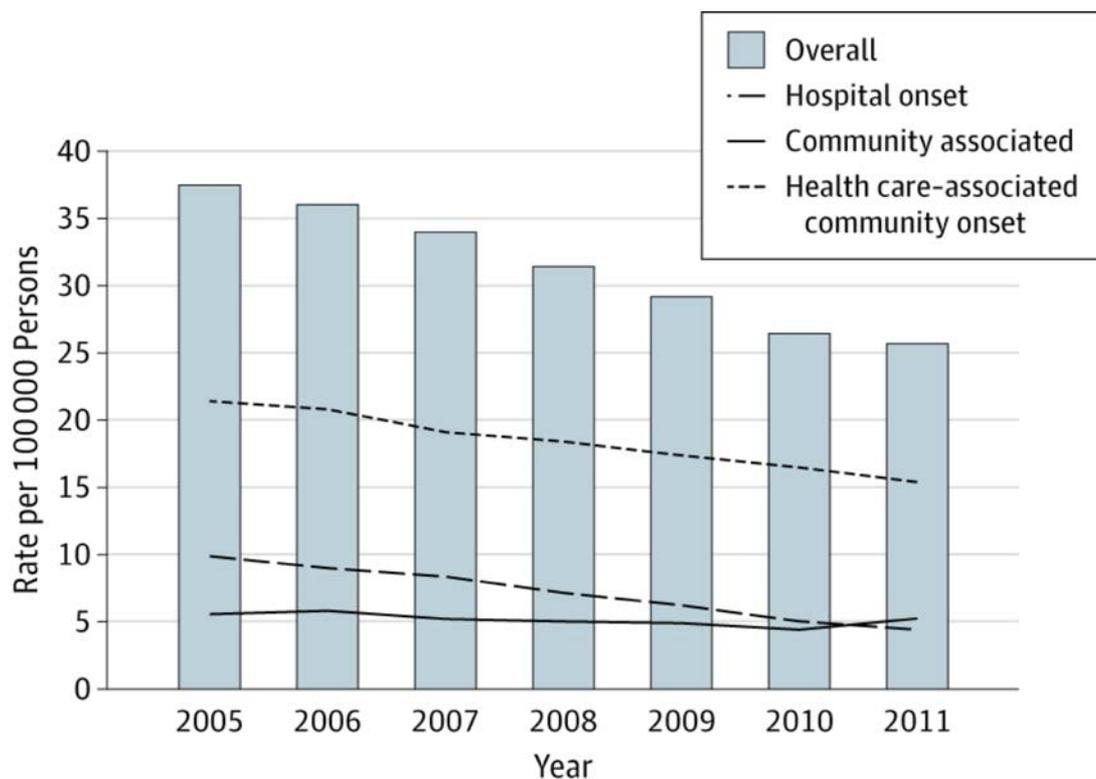
- Healthcare-associated infections (HAI)
  - Infections that result from encounters with healthcare system
  - About 440,000 in US adults per year<sup>1</sup>
  - NHSN definition = identified after 1<sup>st</sup> 48 hours during hospital stay
- Methicillin-resistant *Staphylococcus aureus* (MRSA)
  - Bacteria resistant to many antibiotics
  - One of the leading causes of invasive infections in healthcare settings<sup>2</sup>
    - Bloodstream, pneumonia, and surgical site infections

1. Zimlichman *JAMA Int Med* 2013

2. Hidron *Infect Control Hosp Epidemiol* 2008

# National Burden of Invasive Methicillin-Resistant *Staphylococcus aureus* Infections, United States, 2011

Raymund Dantes, MD, MPH; Yi Mu, PhD; Ruth Belflower, RN, MPH; Deborah Aragon, MSPH; Ghinwa Dumyati, MD; Lee H. Harrison, MD; Fernanda C. Lessa, MD; Ruth Lynfield, MD; Joelle Nadle, MPH; Susan Petit, MPH; Susan M. Ray, MD; William Schaffner, MD; John Townes, MD; Scott Fridkin, MD; for the Emerging Infections Program–Active Bacterial Core Surveillance MRSA Surveillance Investigators



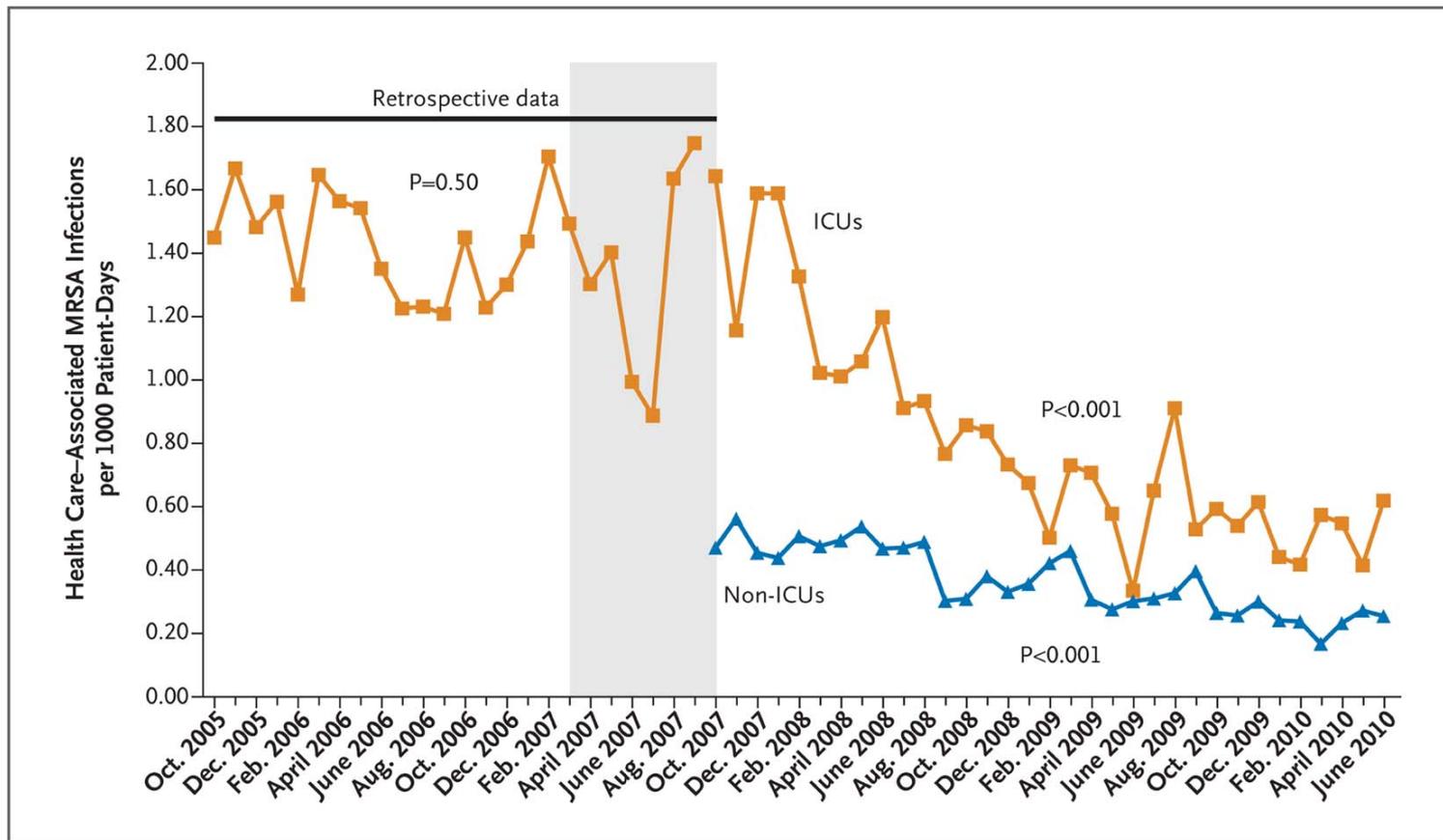
# Veterans Affairs

## MRSA Prevention Initiative

- Began October 2007
- Consisted of a “bundle” of prevention strategies
  - Universal nasal surveillance for MRSA
  - Contact precautions for patients colonized or infected with MRSA
  - Hand hygiene
  - Institutional change
    - HAI prevention is everyone’s responsibility

# Veterans Affairs Initiative to Prevent Methicillin-Resistant *Staphylococcus aureus* Infections

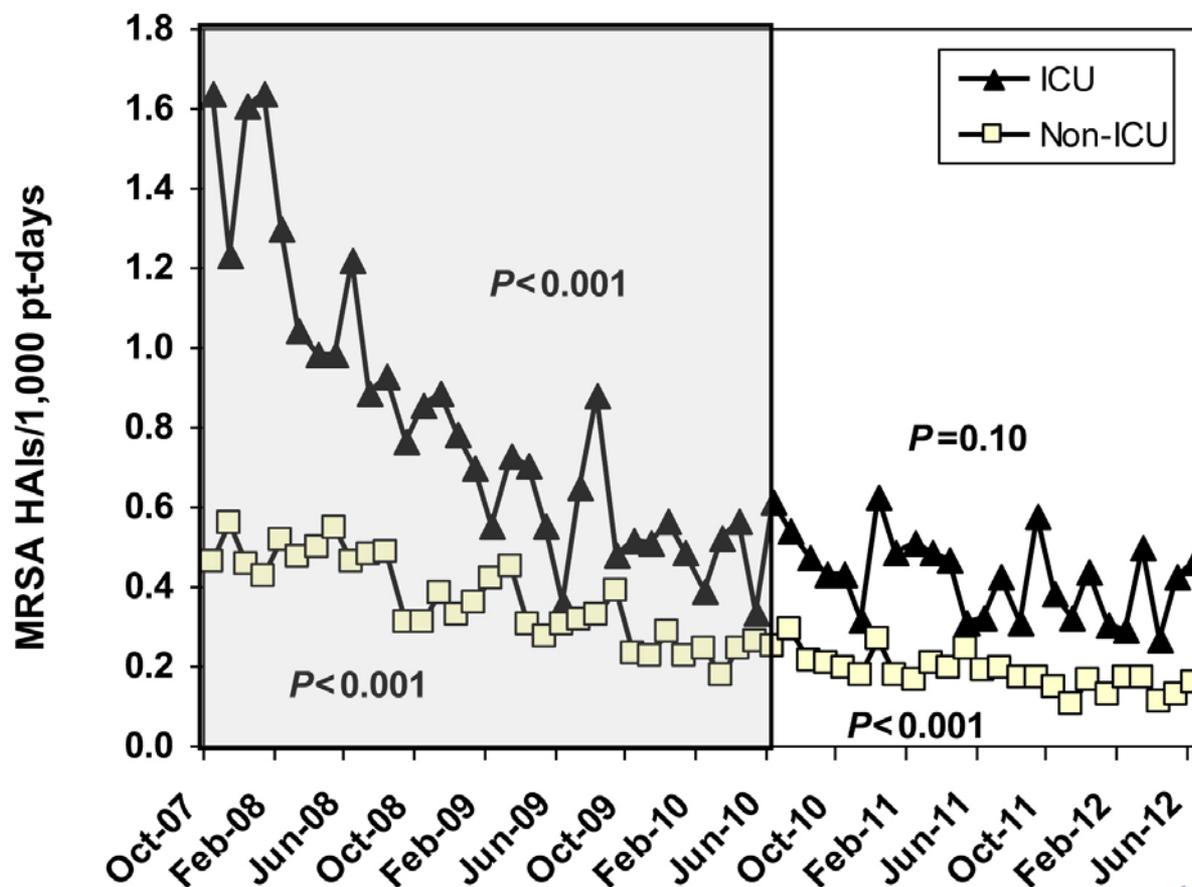
Rajiv Jain, M.D., Stephen M. Kralovic, M.D., M.P.H., Martin E. Evans, M.D.,  
 Meredith Ambrose, M.H.A., Loretta A. Simbartl, M.S., D. Scott Obrosky, M.S.,  
 Marta L. Render, M.D., Ron W. Freyberg, M.S., John A. Jernigan, M.D.,  
 Robert R. Muder, M.D., LaToya J. Miller, M.P.H., and Gary A. Roselle, M.D.



# Veterans Affairs methicillin-resistant *Staphylococcus aureus* prevention initiative associated with a sustained reduction in transmissions and health care-associated infections

Martin E. Evans MD<sup>a,b,\*</sup>, Stephen M. Kralovic MD, MPH<sup>c,d</sup>, Loretta A. Simbartl MS<sup>c</sup>, Ron W. Freyberg MS<sup>e</sup>, D. Scott Obrosky MS<sup>f</sup>, Gary A. Roselle MD<sup>c,d</sup>, Rajiv Jain MD<sup>g</sup>

## MRSA Healthcare-Associated Infections



# Long-Term Research Question

- What was budget impact of MRSA Prevention Initiative in VA?
  - Key component: cost of MRSA HAI in VA

# Conceptual model

Admission date	HAI date	Discharge date	
Healthcare services attributable to HAI		<ul style="list-style-type: none"> <li>• More inpatient days</li> <li>• More services on each day</li> </ul>	<ul style="list-style-type: none"> <li>• Number of outpatient visits</li> <li>• Number of prescriptions</li> <li>• Risk of readmission</li> <li>• More inpatient days on readmission</li> </ul>
Healthcare costs attributable to HAI		<ul style="list-style-type: none"> <li>• Cost per inpatient day</li> </ul>	<ul style="list-style-type: none"> <li>• Cost of outpatient visit</li> <li>• Cost per prescription</li> <li>• Cost of readmission</li> </ul>
Index hospitalization		Pre-discharge	Post-discharge

# Components of accurate cost of HAIs

## 1. Pre-discharge costs

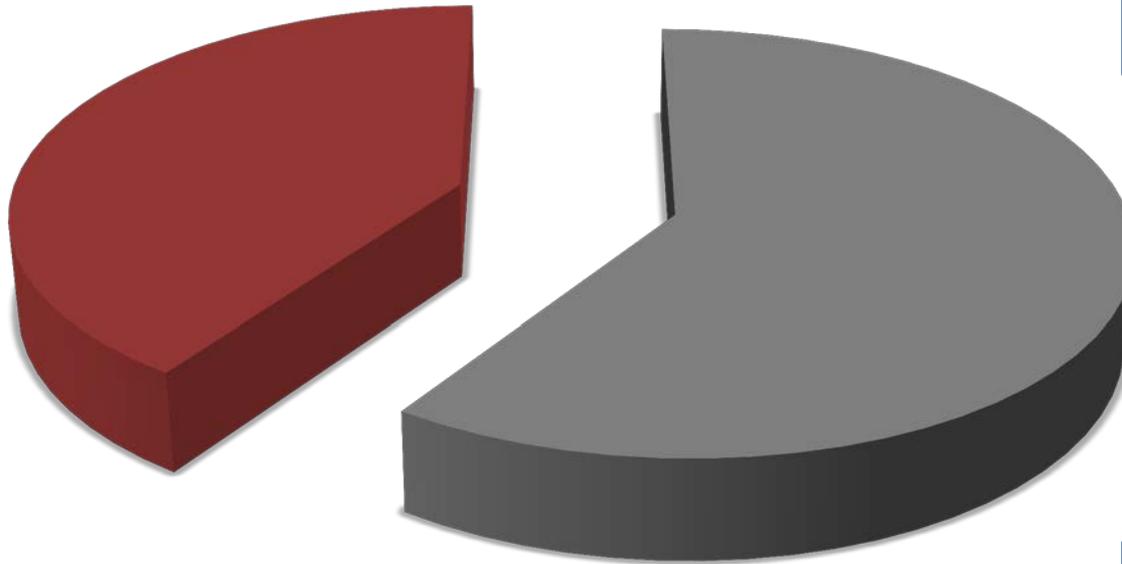
- Incorrect methods (overestimation)

## 2. Post-discharge costs

- Often neglected in cost of HAI estimates (underestimation)

# Which Costs Can be Avoided?

Cost of HAI



- Staff
- Buildings
- Equipment

- Fixed Cost
- Variable Cost

- Antibiotics
- Catheters
- Other consumables

# Estimating cost of MRSA HAI in VA

- Need way of identifying healthcare costs
  - VA DSS data
    - Activity-based accounting system in VA
    - Extracts information from general ledger and VA payroll system
    - Specific job categories, supplies or equipment
    - Costs are allocated to cost centers
      - Primary care clinics
      - Intensive care units
      - Administration
      - Environmental services
    - Costs are allocated based on employee activities

# Estimating cost of MRSA HAI in VA

- Need way of identifying MRSA infections
  - ICD-9 code (V09) is not good for MRSA HAIs
    - V09 = infection with drug-resistant microorganisms
  - Microbiology data
    - Unstructured

# VA Microbiology Data

Jones et al. *BMC Medical Informatics and Decision Making* 2012, **12**:34

<http://www.biomedcentral.com/1472-6947/12/34>



**RESEARCH ARTICLE**

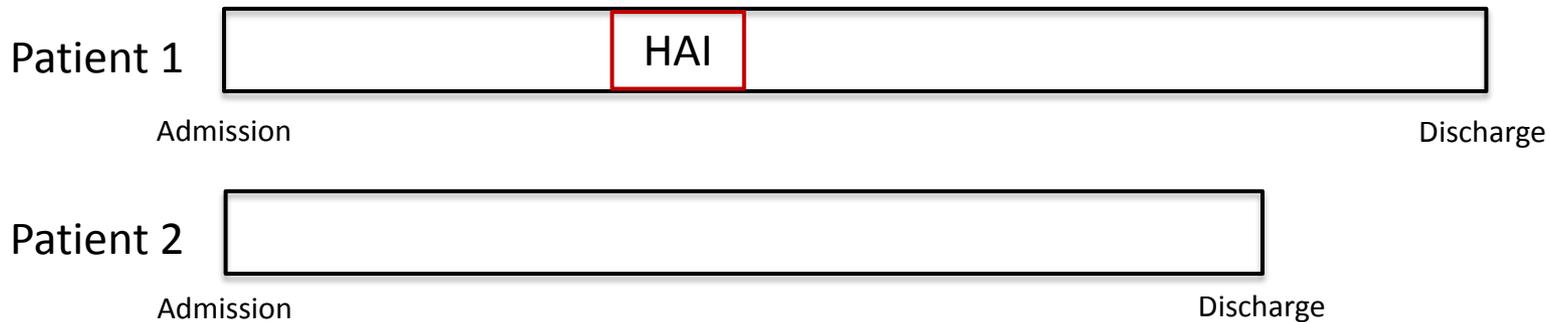
**Open Access**

## Identification of methicillin-resistant *Staphylococcus aureus* within the Nation's Veterans Affairs Medical Centers using natural language processing

Makoto Jones<sup>1,2\*</sup>, Scott L DuVall<sup>1,2\*</sup>, Joshua Spuhl<sup>1</sup>, Matthew H Samore<sup>1,2</sup>, Christopher Nielson<sup>3,4</sup> and Michael Rubin<sup>1,2</sup>

# Aside: Impact of HAI on Excess LOS

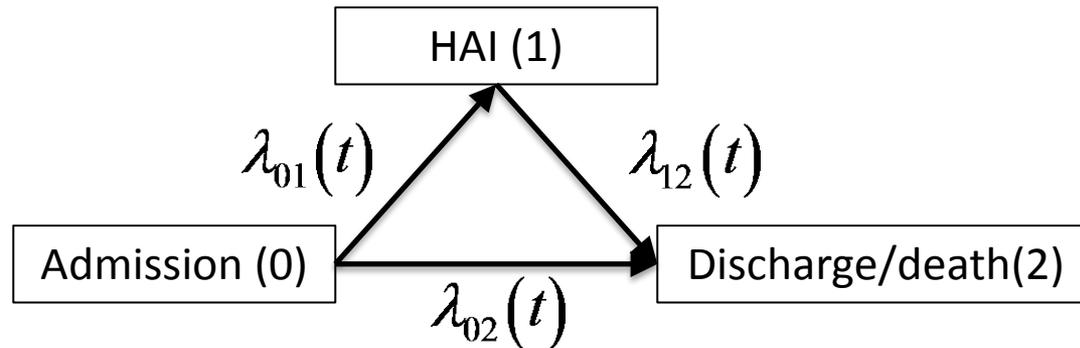
- Important because each extra bed-day taken up by a patient with HAI represents opportunity cost for hospital
- Many studies compare total LOS between patients with HAI and those without



- But not all of the days are attributable to the HAI
- This leads to “time-dependent bias”

# Aside: Impact of HAI on Excess LOS

- Multi-state models



$$\lambda_{ij} = \frac{\text{number of } i \rightarrow j \text{ transitions}}{\text{person-time in state } i}$$

- Match patients with HAI with those without HAI on timing of infection

# Estimates of the Magnitude of Time-Dependent Bias

## Multistate model

Study	HAI type	Excess LOS (HAI non-time-varying)	Excess LOS (HAI time-varying)	Absolute difference (days)	Relative difference
Schulgen (2000) - Study I	Postoperative wound	18.8	9.8	9.0	91.8%
Schulgen (2000) - Study II	Pneumonia	13.4	3.4	10.0	292.6%
Roberts (2010)	Many	8.1	5.9	2.2	37.3%
Barnett (2011)	CLABSI, CAUTI, VAP	11.2	1.4	9.9	731.9%
Schumacher (2013)	Pneumonia	21.9	6.2	15.7	253.2%
Wolkewitz (2013)	MRSA	24.5	6.0	18.6	312.3%

<b>Mean</b>	<b>10.9</b>	<b>286.5%</b>
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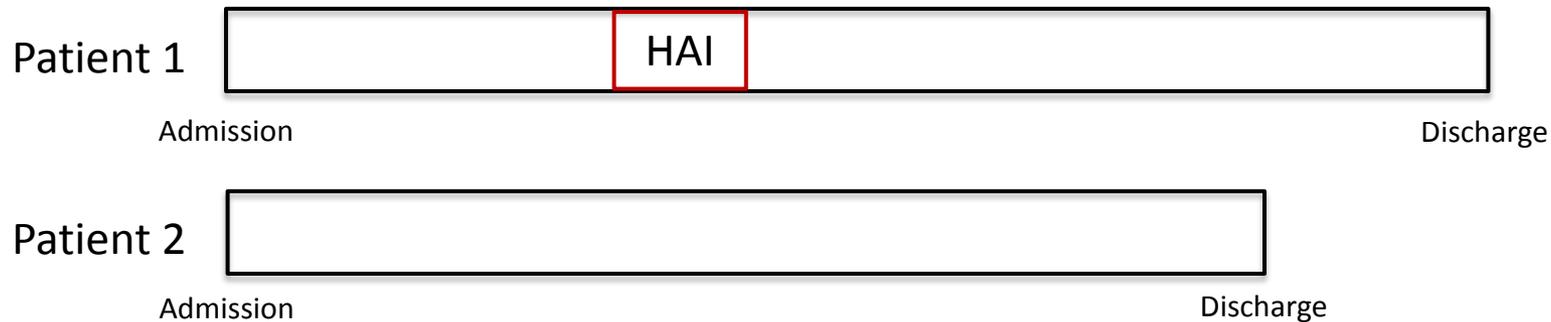
## Matching on timing of infection

Study	HAI type	Excess LOS (HAI non-time-varying)	Excess LOS (HAI time-varying)	Absolute difference (days)	Relative difference
Schulgen (2000) - Study I	Postoperative wound	18.8	11.4	7.4	64.9%
Schulgen (2000) - Study II	Pneumonia	13.4	8.2	5.2	62.8%
Vrijens (2010)	Bloodstream	21.0	6.7	14.3	213.4%
Schumacher (2013)	Pneumonia	21.9	11.3	10.6	93.8%
Nelson (2014)	MRSA	18.7	12.9	5.8	45.4%

<b>Mean</b>	<b>8.7</b>	<b>96.1%</b>
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# Impact of HAI on Pre-Discharge Costs

- All previous studies compare total inpatient costs between patients with HAI and those without



- But not all of the costs are attributable to the HAI
- This leads to “time-dependent bias”

# Impact of HAI on Pre-Discharge Costs

- Can we differentiate between costs that occur before and after HAI with VA data?
- DSS Daily Cost Resource (DCR)
  - Daily inpatient costs
    - DSS Production-Level Data

Admitdt

HAI

Dischdt

Patient 1

Day 1

Day 2

Day 3

Day 4

Day 5

Day 6

Day 7

Day 8

Day 9

Day 10

Day 11

Admitdt

HAI

Dischdt

Patient 2

Day 1

Day 2

Day 3

Day 4

Day 5

Day 6

Day 7

Day 8

Day 9

Day 10

Day 11

Day 12

Admitdt

Dischdt

No HAI

Patient 3

Day 1

Day 2

Day 3

Day 4

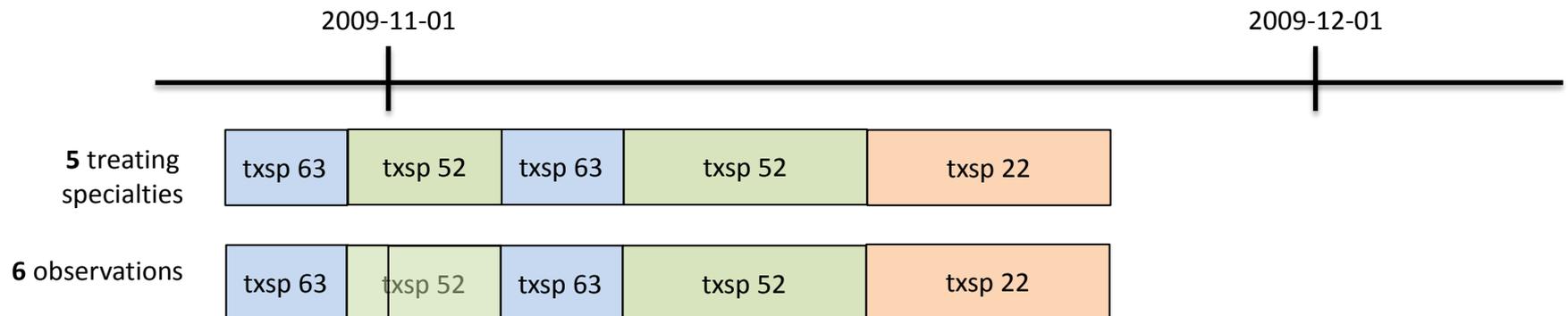
Day 5

Day 6

# Impact of HAI on Pre-Discharge Costs

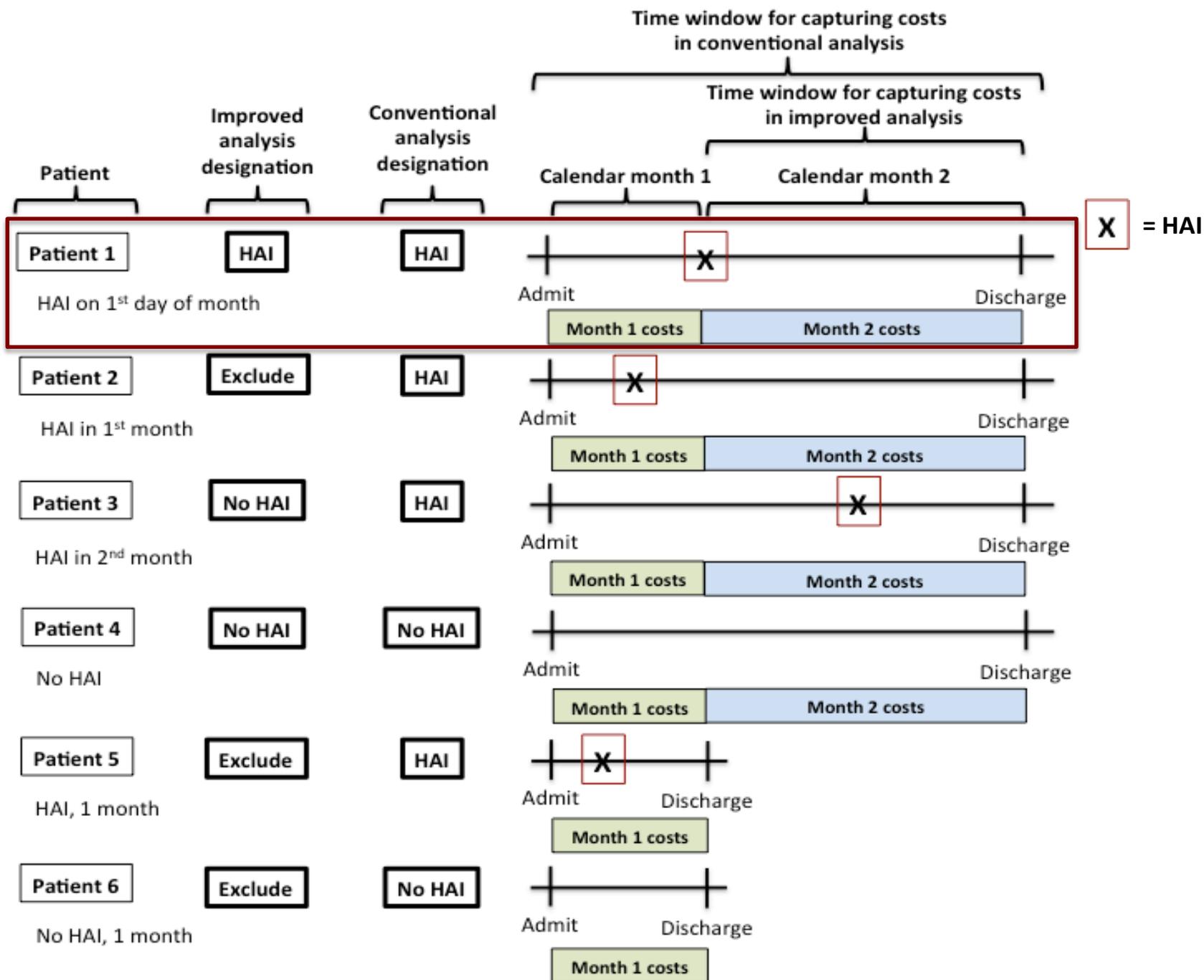
- Can we differentiate between costs that occur before and after HAI with VA data?
  - Separate observations for each patient-treating specialty-calendar month

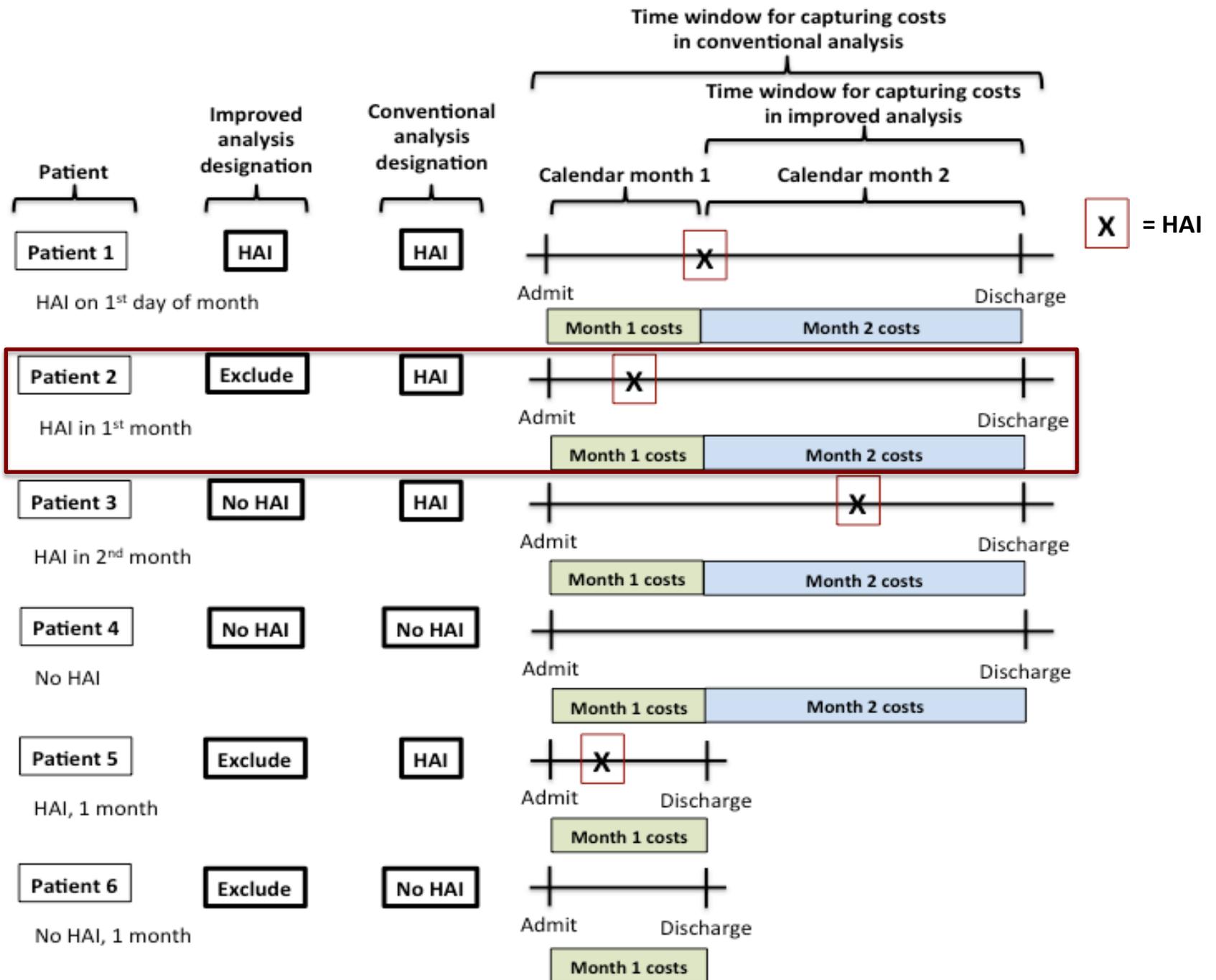
admitday	txspsdt	txspedt	txsp	fy	fp	TotFD	TotFI	TotVD	TotCost
2009-10-29	2009-10-29	2009-10-31	63	2010	1	\$1270.52	\$17,767.53	\$38,508.67	\$57,546.72
2009-10-29	2009-10-31	2009-10-31	52	2010	1	\$13.83	\$195.31	\$282.38	\$491.52
2009-10-29	2009-11-01	2009-11-04	52	2010	2	\$63.47	\$1560.92	\$1966.30	\$3590.69
2009-10-29	2009-11-04	2009-11-05	63	2010	2	\$225.60	\$1882.73	\$2480.43	\$4588.76
2009-10-29	2009-11-05	2009-11-12	52	2010	2	\$401.53	\$7290.23	\$9183.70	\$16,875.45
2009-10-29	2009-11-12	2009-11-21	22	2010	2	\$1089.92	\$12,469.61	\$15,273.73	\$28,833.26

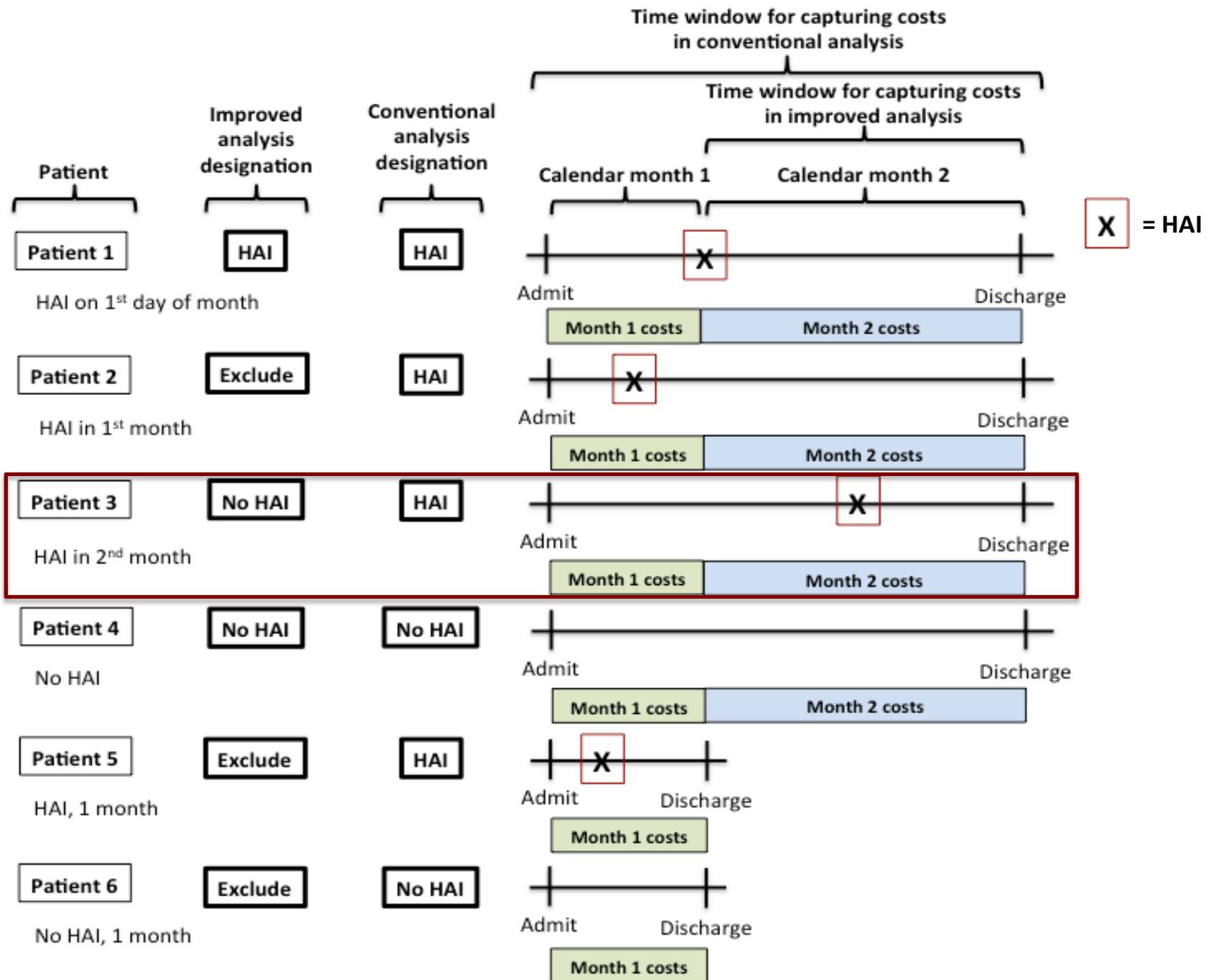


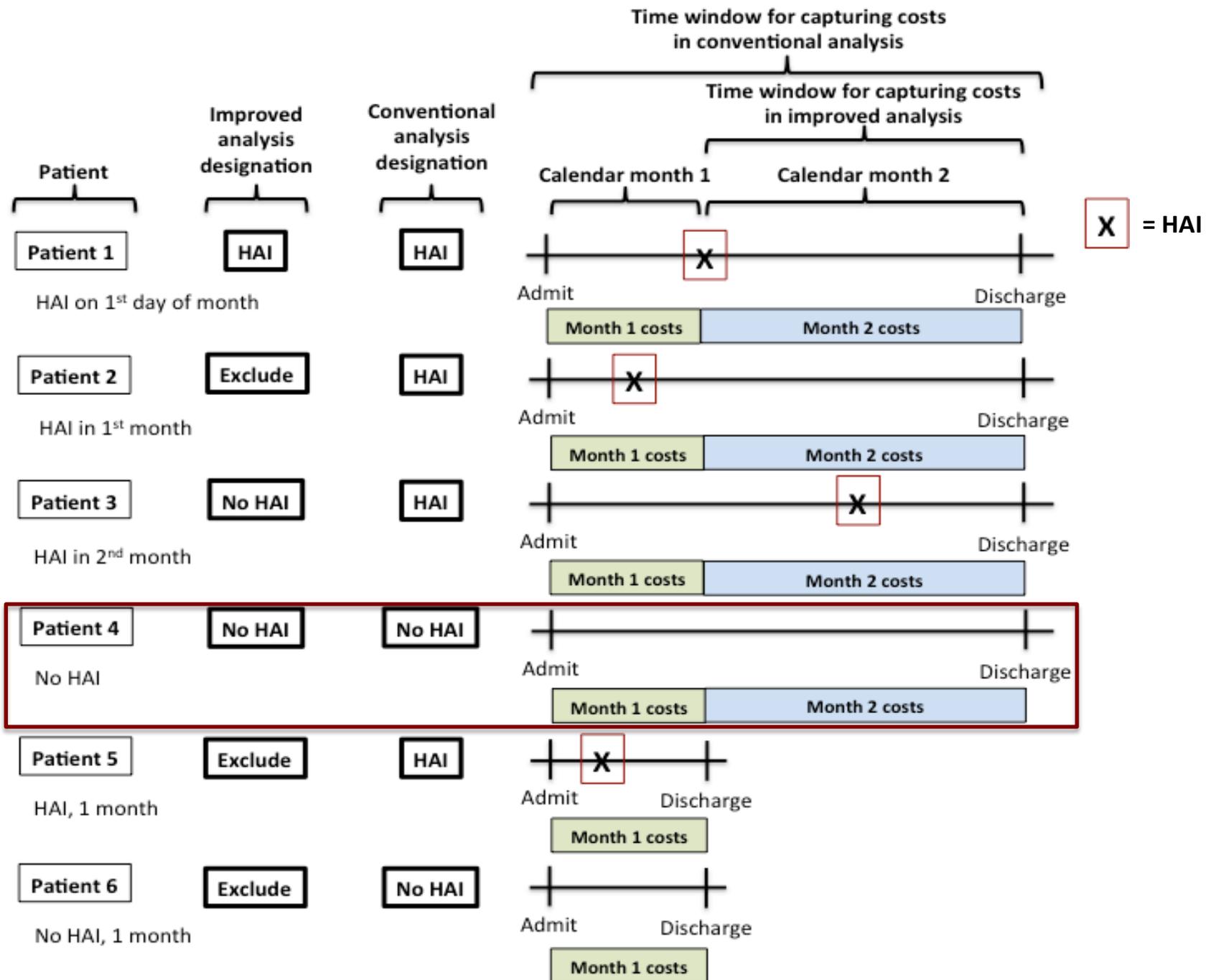
# Impact of HAI on Pre-Discharge Costs

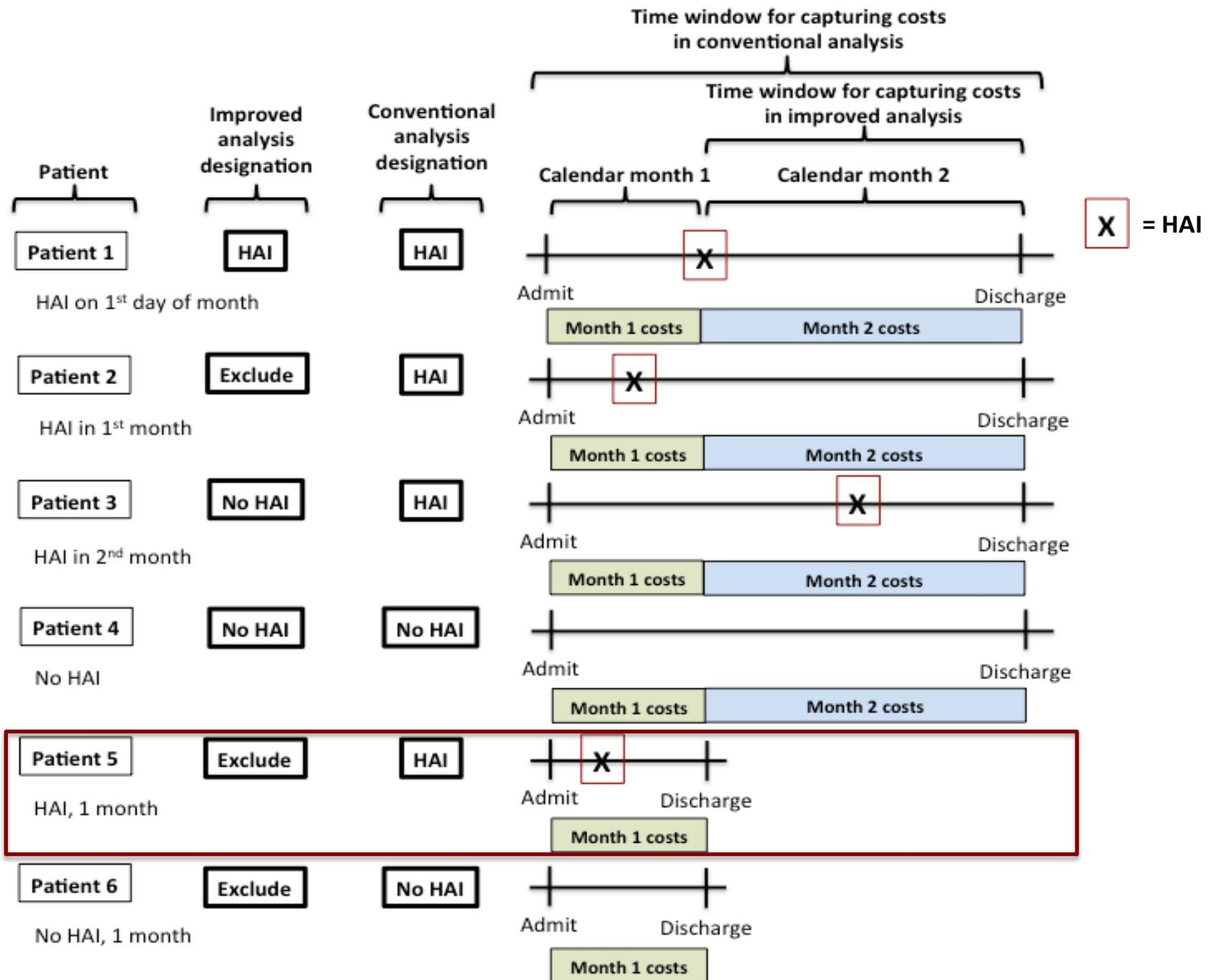
- Conventional analysis
  - Compare cost over entire LOS for patients with and without MRSA HAI
- Improved analysis
  - Utilize the quirk of the DSS TRT file to identify costs occurring after MRSA HAI

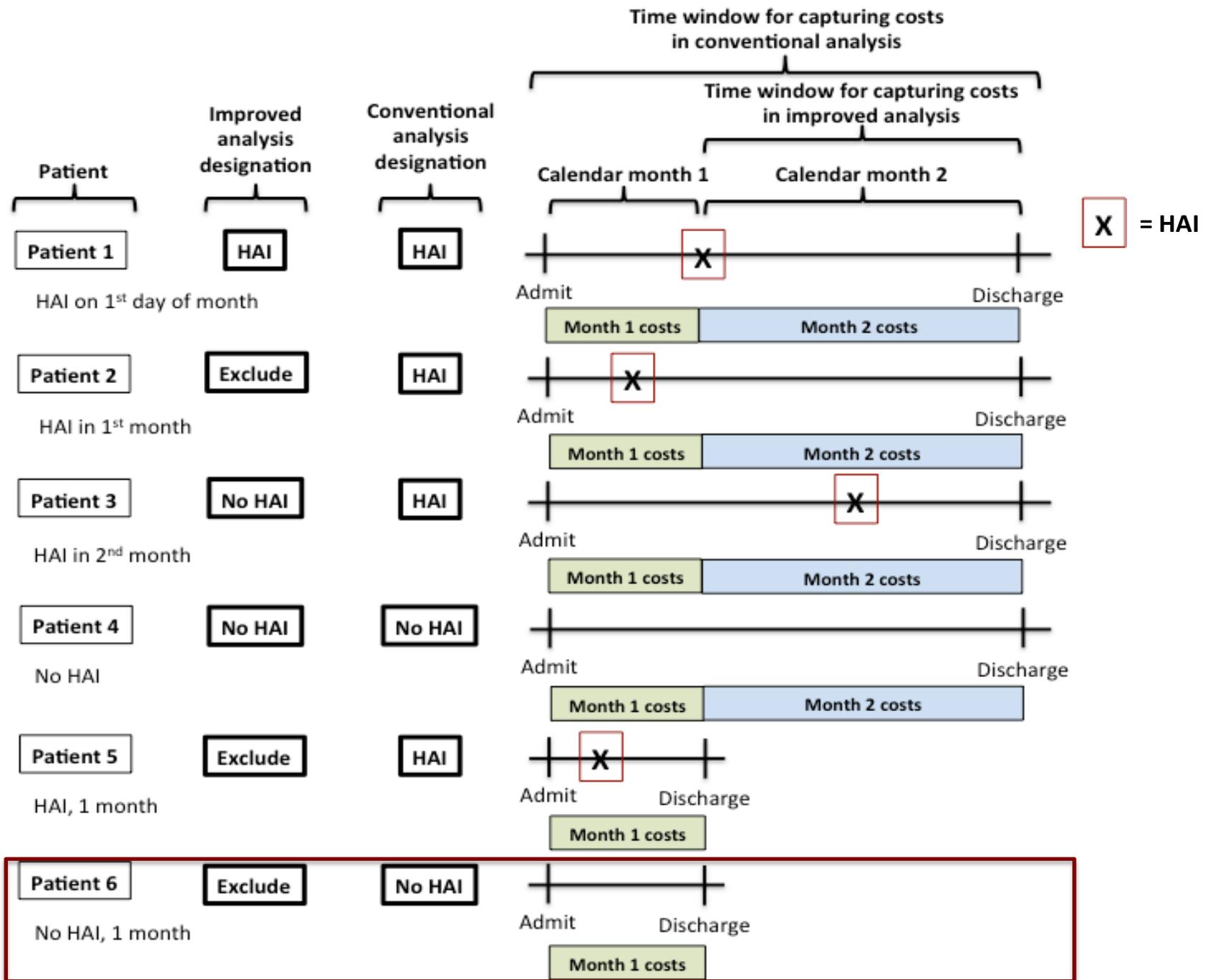










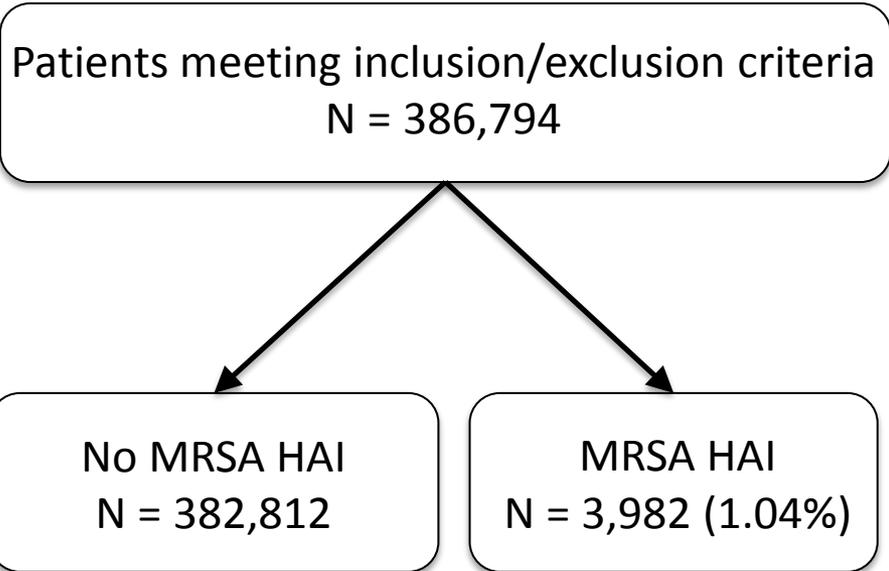


# Impact of HAI on Pre-Discharge Costs

- Patient selection
  - Inclusion criteria
    - Patients admitted to 1 of 123 VA hospitals nationwide
      - 1<sup>st</sup> hospitalization
    - Between Oct 1, 2007 – Sept 30, 2010
    - 365 days prior to admission
  - Exclusion criteria
    - Patients with inpatient stays < 48 hours
    - Patients with MRSA positive culture in 365 days prior to admission
    - Patients with MRSA positive surveillance test on index admission

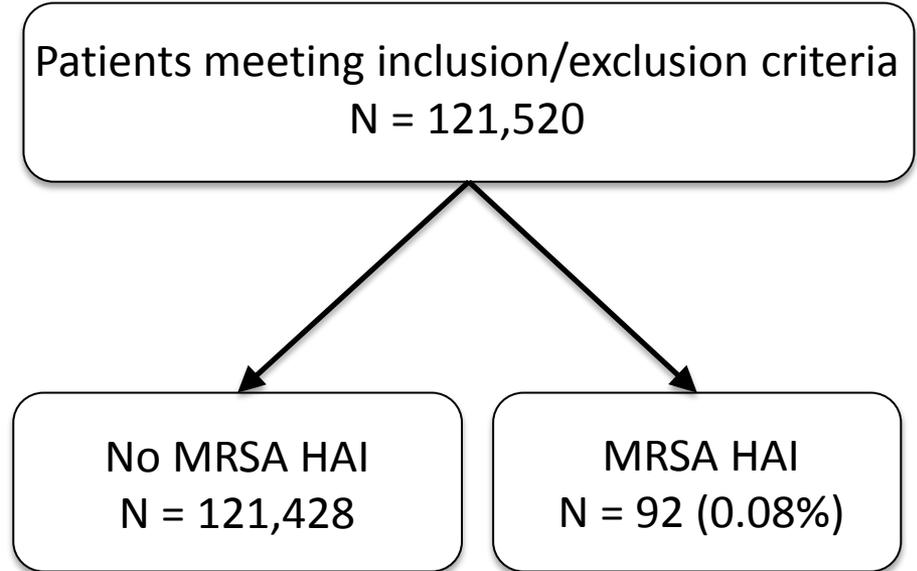
# Conventional Analysis

Include all patients who survived initial inclusion exclusion criteria



# Improved Analysis

Exclude patients with < 2 calendar months and with MRSA HAI during month 1

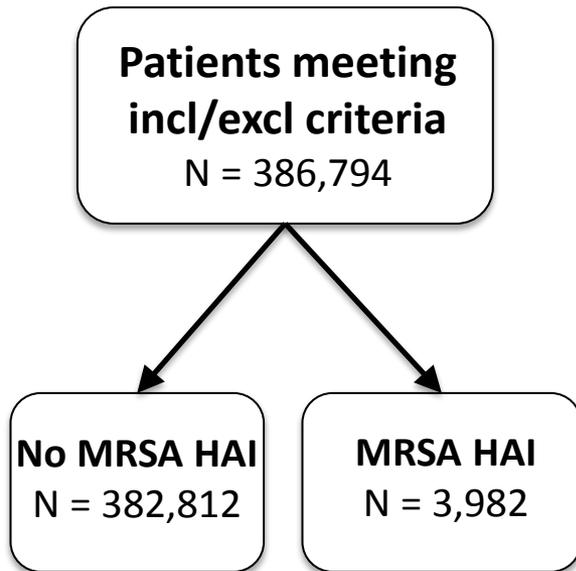


# Impact of HAI on Pre-Discharge Costs

- Approximation of improved method on data more widely available
  - “Almost as good” method
  - If have date of HAI but not cost data that separates cost by calendar month
  - Propensity score match 4 non-MRSA HAI patients for every MRSA HAI patient
    - For each MRSA HAI patient, the potential matches were those still at risk for MRSA HAI on the day that the infected patient was infected
    - Did separate PS matching for HAIs occurring on days 3-40

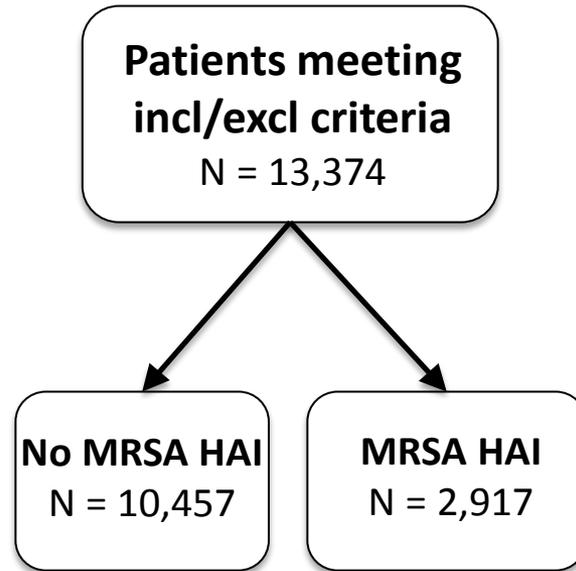
# Conventional Analysis

Include all patients who survived initial inclusion exclusion criteria



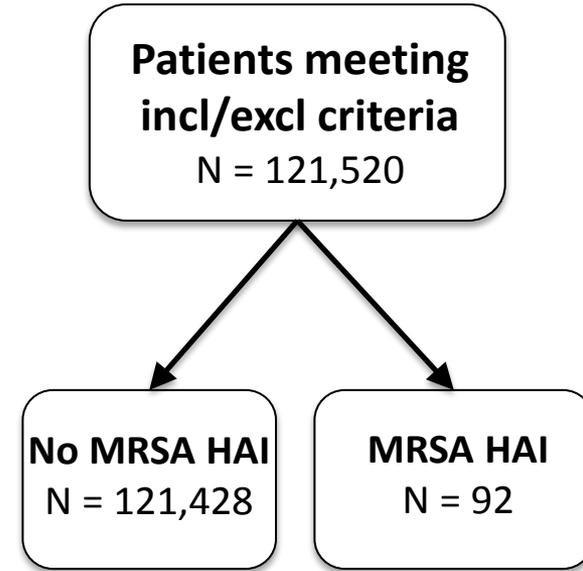
# Almost as Good Analysis

PS match MRSA HAI patients with 4 controls without MRSA HAI up to that point



# Improved Analysis

Exclude patients with < 2 calendar months and with MRSA HAI during month 1



# Impact of HAI on Pre-Discharge Costs

- Methods
  - Dependent variables
    - Total cost
    - Variable cost
    - LOS
  - Generalized linear model (GLM)
    - Gamma distribution for costs
    - Poisson distribution for LOS

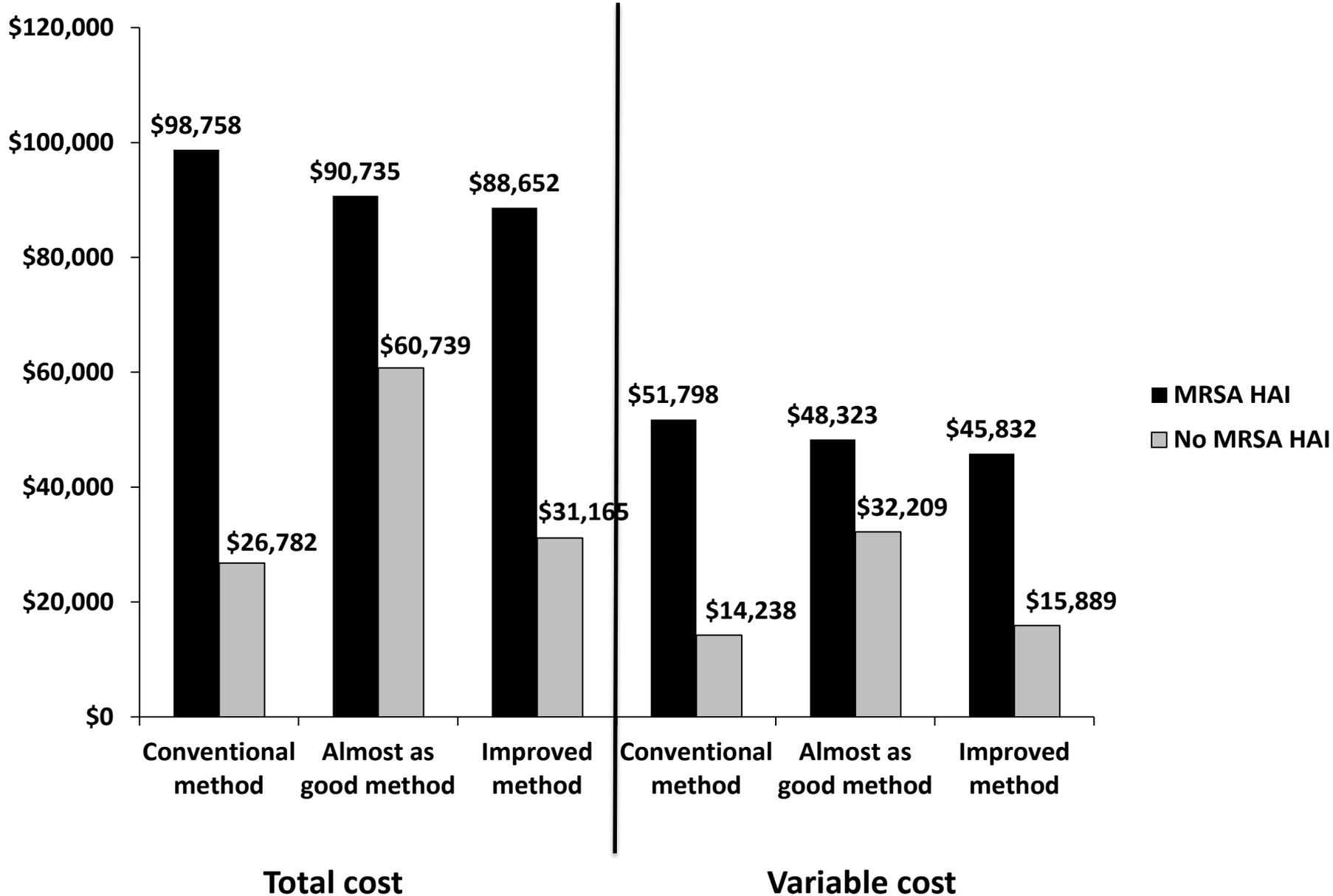
# Impact of HAI on Pre-Discharge Costs

- Methods
  - Independent variables
    - Improved method
      - MSRA HAI
      - Demographics
      - Comorbid conditions
        - » Principle ICD-9
        - » CCI/Elixhauser comorbidity index
      - Prior healthcare utilization
        - » Surgery within 1<sup>st</sup> 48 hours
        - » Outpatient costs in 365 days prior to admission
        - » LOS during 1<sup>st</sup> calendar month
      - Facility

# Impact of HAI on Pre-Discharge Costs

- Methods
  - Independent variables
    - Conventional method
      - MSRA HAI
      - Demographics
      - Comorbid conditions
        - » Principle ICD-9
        - » CCI/Elixhauser comorbidity index
      - Prior healthcare utilization
        - » Surgery within 1<sup>st</sup> 48 hours
        - » Outpatient costs in 365 days prior to admission
      - Facility

# Mean per-patient unadjusted inpatient costs



# Impact of HAI on Pre-Discharge Costs

## Results: Multivariable Cost Regressions

- Model = GLM, gamma/Poisson distribution, log link
- Dependent variable = inpatient cost, LOS
- Key independent variable = MRSA HAI

	Improved method <sup>a</sup> N=121,520			Almost as good method <sup>a</sup> N=13,374			Conventional method <sup>b</sup> N=443,856		
	Effect	95% CI		Effect	95% CI		Effect	95% CI	
<b>Variable</b>	\$12,272	\$5,501	\$19,044	\$13,816	\$11,680	\$15,953	\$18,003	\$17,178	\$18,827
<b>Total</b>	\$23,733	\$10,497	\$36,969	\$25,517	\$21,480	\$29,554	\$33,885	\$32,317	\$35,453
<b>LOS</b>	12.85	11.86	13.85	12.10	11.86	12.34	18.68	18.62	18.75

<sup>a</sup>Improved method regressions controlled for the following variables: demographic characteristics, comorbid conditions, surgery during 1<sup>st</sup> 48 hours, primary ICD-9 code, length of stay during 1<sup>st</sup> calendar month, and facility

<sup>c</sup>Almost as good method regressions controlled for the following variables: demographic characteristics, comorbid conditions, surgery during 1<sup>st</sup> 48 hours, primary ICD-9 code, and facility

<sup>c</sup>Conventional method regressions controlled for the following variables: demographic characteristics, comorbid conditions, primary ICD-9 code, and facility

# Impact of HAI on Pre-Discharge Costs

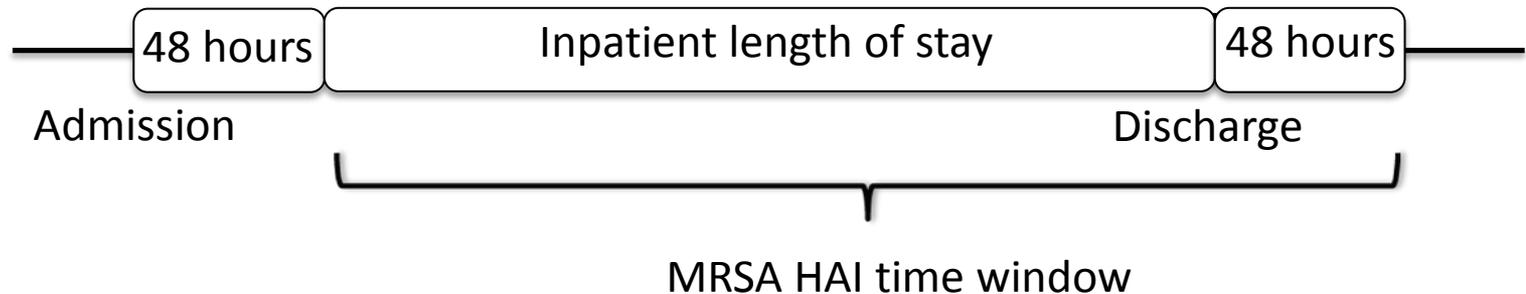
- “Conventional” method
  - 46.7% higher than “improved” method
  - \$18,003 vs. \$12,272
- “Almost as good” method
  - 4.8% higher than “improved” method
  - \$13,816 vs. \$12,272

# Impact of HAI on post-discharge costs

- Patient selection
  - Inclusion criteria
    - Patients admitted to 1 of 123 VA hospitals nationwide
      - 1<sup>st</sup> hospitalization
    - Between Oct 1, 2007 – Sept 30, 2010
    - 365 days prior to admission
  - Exclusion criteria
    - Patients with inpatient stays < 48 hours
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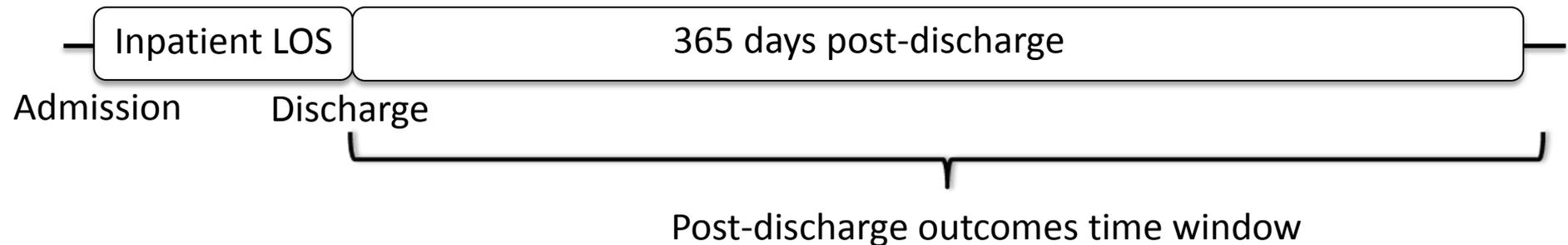
# Impact of HAI on post-discharge costs

- Exposure
  - MRSA HAI
    - MRSA positive clinical culture between 48 hours after admission and 48 hours after discharge

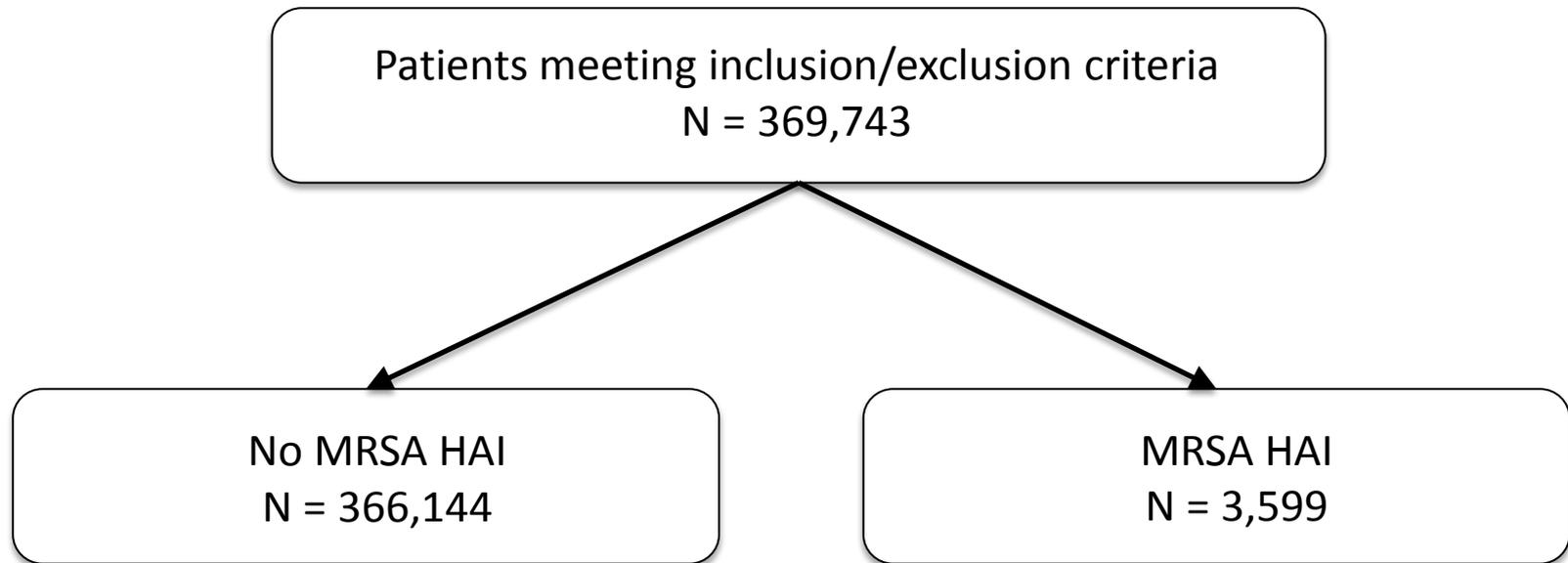


# Impact of HAI on post-discharge costs

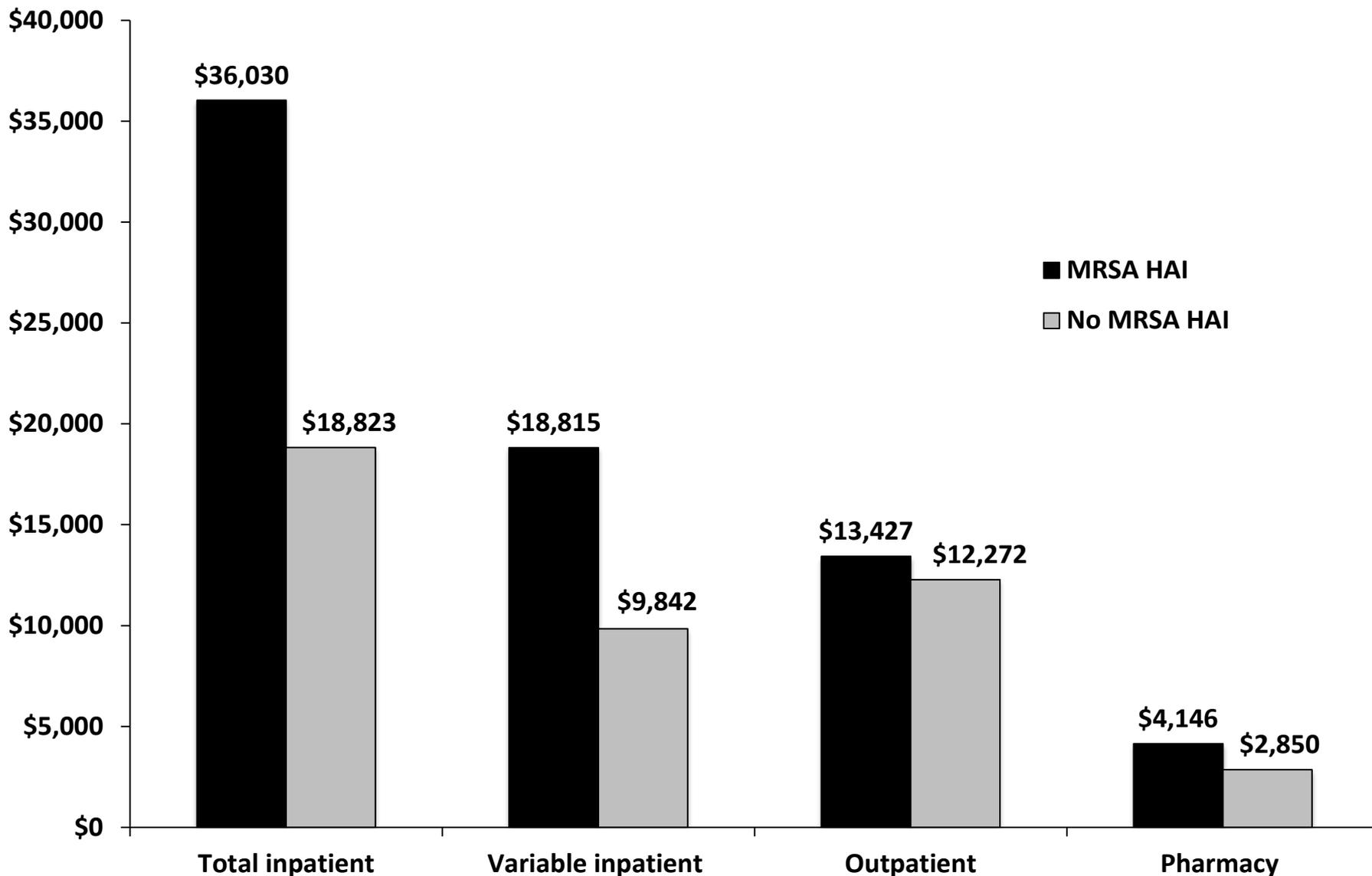
- Post-discharge outcomes
  - Inpatient costs
    - Variable costs
    - Total costs
  - Outpatient costs
  - Pharmacy costs



# Impact of HAI on post-discharge costs



# Unadjusted post-discharge costs



# Results – Multivariable Cost Regressions

- Model = GLM, gamma distribution, log link
- Dependent variable = cost in 365 days post-discharge
- Key independent variable = MRSA HAI

	Full cohort (N=369,743)			Propensity score matched subgroup (N=7,184)		
	Effect	95% CI		Effect	95% CI	
<b>Outpatient</b>	-\$465	-\$972	\$42	-\$395	-\$1,191	\$401
<b>Pharmacy</b>	\$563	\$24	\$1,102	\$710	\$407	\$1,013
<b>Total inpatient</b>	\$7,179	\$5,533	\$8,825	\$11,044	\$8,298	\$13,790
<b>Variable inpatient</b>	\$3,735	\$2,882	\$4,588	\$5,826	\$4,380	\$7,273

*Note:* Regression controlled for the following variables: demographic characteristics, comorbid conditions, LOS during index hospitalization, primary ICD-9 code for index hospitalization

# Limitations

- MRSA positive cultures
  - Could be colonization rather than infection
- We don't see post-discharge healthcare resource utilization that occurred outside the VA

# Conclusions

- Conventional methods lead to different estimates of economic burden of MRSA HAIs

	Conventional methods	Improved methods
Pre-discharge		
Total	\$33,885	\$23,733
Variable	\$18,003	\$12,272
Post-discharge		
Pharmacy	-	\$710
Total inpatient	-	\$11,044
Variable inpatient	-	\$5,826
<b>Total total costs</b>	<b>\$33,885</b>	<b>\$35,487</b>
<b>Total variable costs</b>	<b>\$18,003</b>	<b>\$18,808</b>



# Thank you

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