



American Recovery and Reinvestment Act  
Epidemiology and Laboratory Capacity (ELC)  
for Infectious Disease Program  
Healthcare-Associated Infections (HAIs)  
Grantee Meeting

*Jonathan R. Edwards, M.Stat*  
October 19-20, 2009



# NHSN HAI Comparison Metrics

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# Objectives

- Review HAI point estimation
- Explain standardized infection ratio (SIR)
- Describe improved SIR calculations
- Discuss options for hospital comparisons



# Point Estimation for HAI Surveillance

- A type of statistical inference often resulting in the calculation of HAI rates
- Turn surveillance “data” into decision making “information”
- Allows you to express surveillance information in numerical terms or metrics

$$\frac{\text{Numerator}}{\text{Denominator}} \times \text{Constant}$$



# Incidence Density Rate

Type of rate that accounts for differences in follow-up (exposure) time for each person included in the at-risk population.

Numerator is number of new cases of disease.  
Denominator is “person-time” units.

## Example 1:

Central line-associated BSI (CLABSI) rate

$$\frac{12 \text{ CLABSIs}}{4000 \text{ central line-days}} \times 1000 = 3.0$$



# Example CLABSI Rate Table



SAS Output - Windows Internet Explorer provided by ITSO

File Edit View Favorites Tools Help SnagIt

National Healthcare Safety Network  
Rate Table for Central Line-Associated BSI Data for ICU-Other

As of: May 12, 2008 at 10:54 AM

Date Range: All CLAB\_RATESICU

Org ID=10000 CDC Location=IN:ACUTE:CC:S

**Local CLABSI Rates**  
**Aggregate CLABSI Rate**  
**p-values for local vs. aggregate**

Location	Summary Mon/Yr	CLA BSI Count	Central Line Days	CLA BSI Rate	NHSN CLAB Pooled Mean	Incidence Density p-value	Incidence Density Percentile	Patient Days	CL Util Ratio	NHSN Line DU Pooled Mean	Proportion p-value	Proportion Percentile
SICU	2005M10	0	394	0.0	2.7	0.3385	10	436	0.90	0.62	0.0000	93
SICU	2005M11	1	314	3.2	2.7	0.5782	63	464	0.68	0.62	0.0054	72
SICU	2005M12	0	314	0.0	2.7	0.4218	10	452	0.69	0.62	0.0005	72
SICU	2006M01	1	541	1.8	2.7	0.5620	45	833	0.65	0.62	0.0337	46
SICU	2006M02	1	391	2.6	2.7	0.7082	56	476	0.82	0.62	0.0000	91
SICU	2006M04	1	218	4.6	2.7	0.4508	76	451	0.48	0.62	0.0000	31
SICU	2006M05	1	404	2.5	2.7	0.6951	55	931	0.43	0.62	0.0000	14
SICU	2006M06	3	298	10.1	2.7	0.0502	95	833	0.36	0.62	0.0000	14
SICU	2006M07	0	400	0.0	2.7	0.3329	10	844	0.47	0.62	0.0000	31
SICU	2006M08	0	200	0.0	2.7	0.5770	10	388	0.52	0.62	0.0000	31
SICU	2006M09	0	89	0.0	2.7	0.7829	10	291	0.31	0.62	0.0000	8

Source of aggregate data: NHSN Report, Am J Infect Control 2007;35:290-301

Data contained in this report were last generated on April 17, 2008 at 9:26 AM.

**Percentile rank among all units**





# Proportion

A fraction in which the numerator is included within the denominator

- Numerator is the magnitude of the part
- Denominator is the magnitude of the whole
- Often expressed as a percent

## Example 2:

Surgical site infection rate:

$$\frac{4 \text{ SSI in hysterectomy patients}}{280 \text{ women undergoing hysterectomy}} \times 100 = 1.4\%$$



# Example SSI Rate Table

SAS Output - Windows Internet Explorer provided by ITS0

File Edit View Favorites Tools Help SnagIt

National Healthcare Safety Network  
 Rate Table for Surgical Site Infection Data by Procedure and Risk Index  
 As of: December 1, 2008 at 3:26 PM  
 Date Range: All SSI\_RATESPROC\_RISK

orgID=10000

**Local SSI Rates**      **Aggregate SSI Rate**      **p-value for local vs. aggregate**

procCode	riskcat	outpatient	summaryYM	SSICount	ProcCount	SSIRate	SSI_Mean	P_pval	P_pctl
CBGB	1	N	2006M11	0	45	0.00	2.96	0.2324	10
CBGB	1	N	2007M07	0	12	0.00	2.96	0.6975	10
HPRO	0	N	2006M11	0	13	0.00	0.75	0.9071	25
HPRO	1	N	2005M02	0	11	0.00	1.68	0.8304	25
HPRO	1	N	2006M01	2	16	12.50	1.68	0.0290	100
HPRO	1	N	2006M04	1	12	8.33	1.68	0.1839	100
HPRO	1	N	2006M11	0	19	0.00	1.68	0.7255	25
HPRO	1	N	2007M07	0	21	0.00	1.68	0.7014	25
HPRO	1	N	2007M08	0	17	0.00	1.68	0.7504	25
HPRO	1	N	2007M11	2	17	11.76	1.68	0.0325	100
HYST	0	N	2006M11	0	50	0.00	1.12	0.5690	25
KPRO	1	N	2006M11	0	12	0.00	1.12	0.8733	25

Source of aggregate data: NHSN Report, Am J Infect Control 2008;36:609-26  
 Data contained in this report were last generated on December 1, 2008 at 2:31 PM.

**Percentile rank among all hospitals**



# Standardized Infection Ratio (SIR)



# Standardized Infection Ratio?

- Standardized Infection Ratio, SIR, is a summary measure used to compare the HAI experience among one or more groups of patients to that of a standard population's (e.g. NHSN)
- Indirect standardization method
- Accounts for differences in risk of HAI among the groups



# Calculating an SIR

$$\text{SIR} = \frac{\text{Observed (O) HAIs}}{\text{Expected (E) HAIs}}$$

- To calculate O, sum the number of HAIs among a group
- To calculate E, requires the use of the appropriate aggregate data (risk-adjusted rates)



# Central Line- associated Bloodstream Infections



# Annual NHSN Report

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Edwards et al AJIC

**Table 3.** Pooled means and key percentiles of the distribution of central line-associated BSI rates and central line utilization ratios, by type of location, DA module, 2006 through 2007

Type of location	Central line-associated BSI rate*				Percentile				
	No. of locations	No. of CLABSI	Central line-days	Pooled mean	10%	25%	50% (median)	75%	90%
Critical care units									
Burn	22	239	42,452	5.6	0.0	1.5	3.8	8.2	13.5
Coronary	121	373	181,079	2.1	0.0	0.0	1.3	2.8	5.3
Surgical cardiothoracic	97	397	275,194	1.4	0.0	0.0	1.2	1.9	3.4
Medical	144	1073	454,839	2.4	0.0	0.6	1.9	3.6	5.3
Medical/surgical, major teaching	104	692	342,214	2.0	0.0	0.5	1.5	3.0	4.2
Medical/surgical, all others	343	972	662,489	1.5	0.0	0.0	0.6	2.0	3.6

Edwards JR et al. Am J Infect Control 2008;36:609-26.





# Annual NHSN Report

612 Vol. 36 No. 9

Edwards et al *AJIC*

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Medical/surgical, all others teaching	343	972	662,489	1.5	0.0	0.0	0.6	2.0	3.6
Medical/surgical, all others		972	662,489	1.5					

Edwards JR et al. Am J Infect Control 2008;36:609-26.





# Example CLABSI Rate Table

Type of Location	# CLABSI	# Central line-days	CLABS I Rate	NHSN Rate	p-value
Coronary	2	380	5.26	2.1	0.09
Cardiothoracic	1	257	3.89	1.4	0.15
Medical	3	627	4.78	2.4	0.11
Med/Surg, major teaching	2	712	2.81	2.0	0.32
Total	8	1976	4.05	---	---



# Example CLABSI Rate Table

Type of Location	# CLABSI	# Central line-days	CLABS I Rate	NHSN Rate	p-value	Expected # of CLABSI
Coronary	2	380	5.26	2.1	0.09	0.8
Cardiothoracic	1	257	3.89	1.4	0.15	
Medical	3	627	4.78	2.4	0.11	
Med/Surg, major teaching	2	712	2.81	2.0	0.32	
Total	8	1976	4.05	---	---	

**Expected Number = 380 \* (2.1 / 1000) = 380 \* 0.0021 = 0.8**



# Example CLABSI Rate Table

Type of Location	# CLABSI	# Central line-days	CLABS I Rate	NHSN Rate	p-value	Expected # of CLABSI
Coronary	2	380	5.26	2.1	0.09	0.80
Cardiothoracic	1	257	3.89	1.4	0.15	0.36
Medical	3	627	4.78	2.4	0.11	1.15
Med/Surg, major teaching	2	712	2.81	2.0	0.32	1.42
Total	8	1976	4.05	---	---	3.73



# Example CLABSI Rate Table

Type of Location	# CLABSI	# Central line-days	CLABS I Rate	NHSN Rate	p-value	Expected # of CLABSI
Coronary	2	380	5.26	2.1	0.09	0.80
Cardiothoracic	1	257	3.89	1.4	0.15	0.36
Medical	3	627	4.78	2.4	0.11	1.15
Med/Surg, major teaching	2	712	2.81	2.0	0.32	1.42
Total	8	1976	4.05	---	---	3.73

$$\text{Standardized Infection Ratio (SIR)} = \frac{\text{Observed}}{\text{Expected}} \frac{\quad}{3.73} = 2.14$$



# External Comparison of an SIR to its Nominal Value of 1.0

$$\text{SIR} = 1.0 \longleftrightarrow \begin{aligned} &\text{Observed Number of SSI} \\ &= \text{Expected Number of SSI} \end{aligned}$$

Is the SIR of Hosp A (2.14) **significantly greater** than 1.0?

Answer: p-value = 0.07 (Poisson test)

Conclusion: **NO**, the observed number of CLABSI is not "significantly greater" than expected



# Surgical Site Infections



# Annual NHSN Report



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**Table 22.** SSI rates\* by operative procedure and risk index category, PA module, 2006 through 2007

SSI rate-inpatient procedures						
Procedure code	Operative procedure description	Duration cut point (min)	Risk index category	No. of procedures	No. of SSI	Pooled mean
AAA	Abdominal aortic aneurysm repair	225	0,1	881	16	1.82
AAA	Abdominal aortic aneurysm repair	225	2,3	288	15	5.21
APPY	Appendix surgery	81	0,1	2691	40	1.49
APPY	Appendix surgery	81	2,3	372	13	3.49
AVSD	Arteriovenostomy for renal dialysis	111	0,1,2,3	606	6	0.99
BILI	Bile duct, liver or pancreatic surgery	330	0,1	422	37	8.77
BILI	Bile duct, liver or pancreatic surgery	330	2,3	202	33	16.34
BRST	Breast surgery	202	0	997	8	0.80
BRST	Breast surgery	202	1	914	25	2.74
CARD	Cardiac surgery	300	0,1	10,382	121	1.17
CARD	Cardiac surgery	300	2,3	3396	58	1.71
CBGB	Coronary bypass w/chest and donor incision	300	0	1003	3	0.30
CBGB	Coronary bypass w/chest and donor incision	300	1	47,296	1399	2.96
CBGB	Coronary bypass w/chest and donor incision	300	2,3	15,706	767	4.88
CBGC	Coronary bypass graft with chest incision	285	0,1	3495	57	1.63
CBGC	Coronary bypass graft with chest incision	285	2,3	1147	33	2.88
CEA	Carotid endarterectomy	133	0,1,2,3	2615	11	0.42
CHOL	Gallbladder surgery	121	0,1,2,3	3337	23	0.69
COLO	Colon surgery	188	0	9539	399	4.18
COLO	Colon surgery	188	1	16,537	1004	6.07
COLO	Colon surgery	188	2	7270	582	8.01
COLO	Colon surgery	188	3	810	88	10.86
CRAN	Craniotomy	219	0,1	4596	99	2.15
CRAN	Craniotomy	219	2,3	1048	49	4.68
CSEC	Cesarean section	57	0	12,351	185	1.50
CSEC	Cesarean section	57	1,2,3	5951	157	2.64
FUSN	Spinal fusion	240	0	11,780	85	0.72
FUSN	Spinal fusion	240	1	9559	186	1.95
FUSN	Spinal fusion	240	2,3	2543	105	4.13

Edwards JR et al. Am J Infect Control 2008;36:609-26.





# Annual NHSN Report



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Table 22. SSI rates\* by operative procedure and risk index category, PA module, 2006 thro

SSI rate-inpatient procedures				
Procedure code	Operative procedure description	Duration cut point (min)	Risk index category	N pro
AAA	Abdominal aortic aneurysm repair	225	0,1	
AAA	Abdominal aortic aneurysm repair	225	2,3	
APPY	Appendix surgery	81	0,1	
APPY	Appendix surgery	81	2,3	
AVSD	Arteriovenostomy for renal dialysis	111	0,1,2,3	
BILI	Bile duct, liver or pancreatic surgery	330	0,1	
BILI	Bile duct, liver or pancreatic surgery	330	2,3	
BRST	Breast surgery	202	0	
BRST	Breast surgery	202	1	
CARD	Cardiac surgery	300	0,1	
CARD	Cardiac surgery	300	2,3	
CBGB	Coronary bypass w/chest and donor incision	300	0	
CBGB	Coronary bypass w/chest and donor incision	300	1	
CBGB	Coronary bypass w/chest and donor incision	300	2,3	
CBGC	Coronary bypass graft with chest incision	285	0,1	
CBGC	Coronary bypass graft with chest incision	285	2,3	
CEA	Carotid endarterectomy	133	0,1,2,3	
CHOL	Gallbladder surgery	121	0,1,2,3	
COLO	Colon surgery	188	0	
COLO	Colon surgery	188	1	
COLO	Colon surgery	188	2	
COLO	Colon surgery	188	3	
CRAN	Craniotomy	219	0,1	
CRAN	Craniotomy	219	2,3	
CSEC	Cesarean section	57	0	
CSEC	Cesarean section	57	1,2,3	
FUSN	Spinal fusion	240	0	
FUSN	Spinal fusion	240	1	
FUSN	Spinal fusion	240	2,3	
				2543 105 4.13

## Risk index category

0,1

2,3

0,1

2,3

0,1,2,3

0,1

2,3

Edwards JR et al. Am J Infect Control 2008;36:609-26.



# Example SSI Rate Table

Procedure	Index	# SSI	# procedures	SSI Rate	NHSN Rate	p-value
Cardiac surgery	0,1	3	80	3.75	2.02	0.25
	2,3	3	20	15.0	5.29	0.08
CBGB	0	1	10	10.0	1.59	0.16
	1	10	230	4.35	3.15	0.20
	2,3	5	60	8.33	5.76	0.28
Total		22	400	5.50	---	---



# Example SSI Rate Table

Procedure	Index	# SSI	# procedures	SSI Rate	NHSN Rate	p-value	Expected # of SSI
Cardiac surgery	0,1	3	80	3.75	2.02	0.25	1.6
	2,3	3	20	15.0	5.29	0.08	
CBGB	0	1	10	10.0	1.59	0.16	
	1	10	230	4.35	3.15	0.20	
	2,3	5	60	8.33	5.76	0.28	
Total		22	400	5.50	---	---	

**Expected Number = 80 \* (2.02 / 100) = 80 \* 0.0202 = 1.6**



# Example SSI Rate Table

Procedure	Index	# SSI	# procedures	SSI Rate	NHSN Rate	p-value	Expected # of SSI
Cardiac surgery	0,1	3	80	3.75	2.02	0.25	1.6
	2,3	3	20	15.0	5.29	0.08	1.1
CBGB	0	1	10	10.0	1.59	0.16	0.2
	1	10	230	4.35	3.15	0.20	7.2
	2,3	5	60	8.33	5.76	0.28	3.5
Total		22	400	5.50	---	---	13.6



# Example SSI Rate Table

Procedure	Index	# SSI	# procedures	SSI Rate	NHSN Rate	p-value	Expected # of SSI
Cardiac surgery	0,1	3	80	3.75	2.02	0.25	1.6
	2,3	3	20	15.0	5.29	0.08	1.1
CBGB	0	1	10	10.0	1.59	0.16	0.2
	1	10	230	4.35	3.15	0.20	7.2
	2,3	5	60	8.33	5.76	0.28	3.5
Total		22	400	5.50	---	---	13.6

$$\text{Standardized Infection Ratio (SIR)} = \frac{\text{Observed}}{\text{Expected}} \frac{13.6}{13.6} = 1.62$$



# Standardized Infection Ratio (SIR)

- Ratio of **Observed** to **Expected** infections
- Risk-adjusted summary measure
- Used to compare overall HAI rates of any two patient cohorts, groups, or hospitals



# External Comparison of an SIR to its Nominal Value of 1.0

$SIR = 1.0$   $\longleftrightarrow$  Observed Number of SSI  
= Expected Number of SSI

Is the SIR of Team A (1.62) **significantly greater** than 1.0?

Answer: p-value = 0.01 (Poisson test)

Conclusion: **YES**, the observed number of SSI is "significantly greater" than expected



# Confidence Interval for SIR

- A  $(1 - \alpha)100\%$  confidence interval for  $p$

$$SIR_L = \frac{O}{E} \left( 1 - \frac{1}{9O} - \frac{Z_{\alpha/2}}{\sqrt{9O}} \right)^3$$

$$SIR_U = \frac{(O+1)}{E} \left( 1 - \frac{1}{9(O+1)} + \frac{Z_{\alpha/2}}{\sqrt{9(O+1)}} \right)^3$$

- Example normal curve values  
90% confidence  $\rightarrow z_{.05} = 1.645$   
95% confidence  $\rightarrow z_{.025} = 1.96$   
99% confidence  $\rightarrow z_{.005} = 2.58$

Liddell FDK. JECH 1984;38:85-89.



# Advances in Risk-Adjustment: Comparing Surgical Site Infections using a Standardized Infection Ratio

Skip



# Logistic Regression Analysis

## Incisional SSI after CSEC



Factor	Parameter Estimate	OR	p-value
<i>Intercept</i>	-6.300	-	-
Body Mass	0.046	1.047	<0.0001
Duration of labor $\geq$ 9 hr	0.506	1.659	<0.0001
ASA $\geq$ 3	0.598	1.818	<0.0001
Reciprocal age (years)	14.961	999.0	0.0018

\* Horan T. et al. Risk Factors for Incisional Surgical Site Infection after Cesarean Section: Results of a 5-year Multicenter Study, ICHE 2000; S-T4-05



# Logistic Regression Model

- General formula

$$\text{logit}(p) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots$$

Where:

$p \Rightarrow$  probability of SSI after operation

$\alpha \Rightarrow$  intercept

$\beta_1, \beta_2, \beta_3 \dots \Rightarrow$  parameter estimate

$X_1, X_2, X_3 \dots \Rightarrow$  risk factors



# Logistic Model for CSEC:

<u>Factor</u>	<u>Parameter Estimate</u>
<i>Intercept</i>	<b>-6.300</b>
Body Mass	<b>0.046</b>
Duration of labor $\geq$	<b>0.506</b>
ASA $\geq$ 3	<b>0.598</b>
Reciprocal age (years)	<b>14.961</b>

$$\begin{aligned}
 \text{logit}(p) &= \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 \\
 &= -6.300 + 0.046 (\text{Body Mass}) + \\
 &\quad 0.506 (\text{Duration of labor} \geq 9 \text{ hr}^*) \\
 &+ \\
 &\quad 0.598 (\text{ASA} \geq 3^*) + \\
 &\quad 14.961 (1 / \text{Age})
 \end{aligned}$$

**\*For these risk factors, if present = 1; if not = 0**



# Example Patient #1

## Risk Factors



- Body mass = 28
- Duration of labor = 12 hours
- ASA score = 1
- Age = 22



# Logistic Model

## Calculation for Example Patient #1

$$\text{logit}(p) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4$$

$$\text{logit}(\hat{p}) = -6.300 + 0.046 (28) + 0.506 (1) + 0.598 (0) + 14.961 (1/22) = \underline{-3.825}$$

Solve for  $\hat{p}$  :  $\hat{p} = e^{\text{logit}(\hat{p})} / (1 + e^{\text{logit}(\hat{p})})$

$$\hat{p} = e^{-3.825} / (1 + e^{-3.825}) = \mathbf{0.022} \text{ or } 2.2\% \text{ risk}$$



# Example Patient #2

## Risk Factors



- Body mass - 36
- Duration of labor = 9 hours
- ASA score = 3
- Age = 18



# Logistic Model

## Calculation for Example Patient #2

$$\text{logit}(p) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4$$

$$\text{logit}(\hat{p}) = -6.300 + 0.046(36) + 0.506(1) + 0.598(1) + 14.961(1/18) = \underline{-2.708}$$

$$\text{Solve for } \hat{p}: \quad \hat{p} = e^{\text{logit}(\hat{p})} / (1 + e^{\text{logit}(\hat{p})})$$

$$\hat{p} = e^{-2.708} / (1 + e^{-2.708}) = \mathbf{0.063} \text{ or } 6.3\% \text{ risk}$$



# List of Patient Risk Factors

## Incisional SSI after CSEC

Patient	Body Mass	Duration of labor	ASA	Age	SSI	$\hat{p}$
1	28	12	1	22	0	0.022
2	36	9	3	18	1	0.063
3	30	7	2	28	0	0.012
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
100	31	8	4	38	0	0.020
Total					0 - 3	E - 2.3

$$SIR = O/E = 3 / 2.3 = 1.3$$



# Interpreting an SIR

- If  $SIR = 1$ , or  $O = E$ , observed SSIs equals the expected SSIs based on NHSN
- If SIR is significantly  $>1$ , this suggests the institution may need further investigation for the contributing procedures



# Conclusions

- Appropriate multivariate models are useful to better estimate SSI risk
- Calculation of a risk-adjusted Standardized Infection Ratio (SIR) will improve comparisons for hospitals

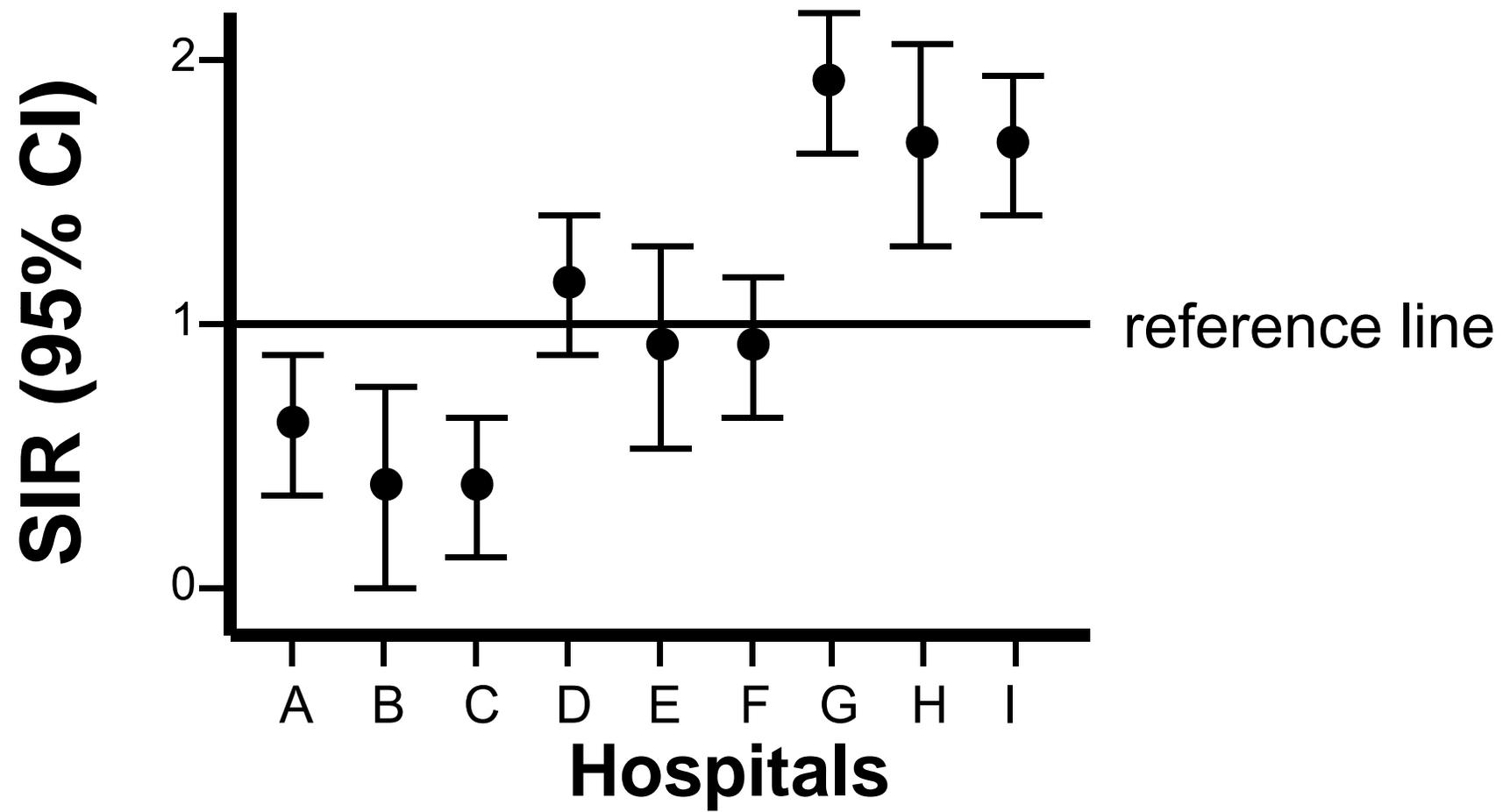


# Hospital SIRs Compared to 1

Hospital	SIR		p-value	Status group
A	1.2		0.12	Same
B	0.9		0.23	Same
C	2.7		0.001	High
D	0.7		0.002	Low
E	1.5		0.001	High

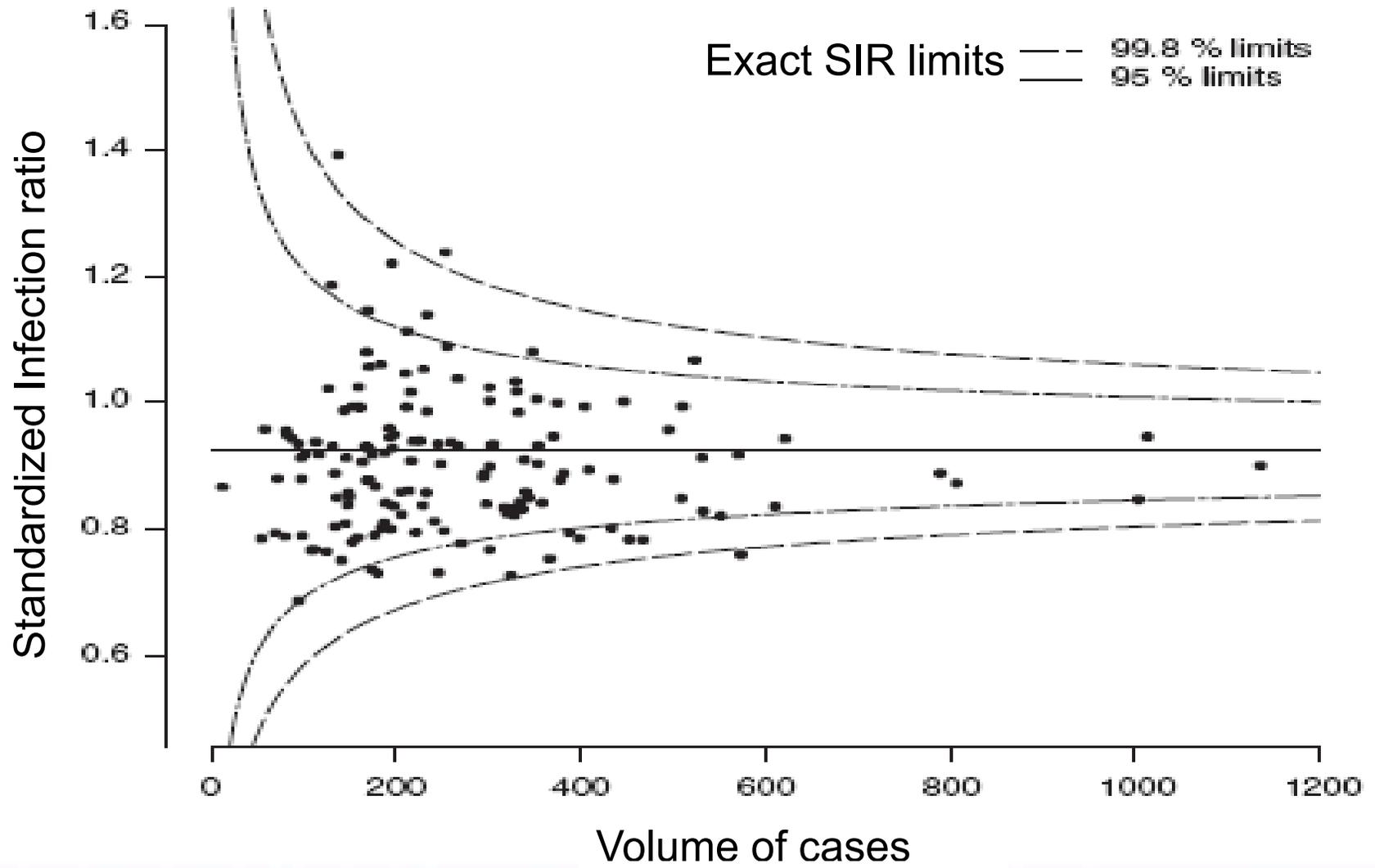


# Hospital SIR Groups





# SIR Funnel Plots





# Past/Present Hospital SIRs

Hospital	Past SIR	Present SIR	Status group
A	1.2	1.6	Same
B	0.9	0.8	Same
C	2.7	1.9	Lower
D	0.7	1.1	Higher
E	1.5	1.2	Lower



Thank You