FEASIBILITY AND UTILITY OF ROBUST ANTIBIOTIC USE RISK-ADJUSTMENT IN ANTIMICROBIAL STEWARDSHIP PROGRAM ASSESSMENTS (R-SAARS): **OVERVIEW, PART 2**

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2-Part Process for Data Feedback + Response:

Receive Hospital Data Report #1, Unadjusted Comparisons and 2017 SAAR data

- You will have 1 month's time to:
  - Review the report and discuss with your ASP regarding a consensus response
  - Submit Part 1 Survey through REDCAP

Receive Hospital Data Report #2, Robust Risk Adjusted SAARs

- You will have 1 month's time to:
  - Review the report and discuss with your ASP regarding a consensus response
  - Submit Part 2 Survey through REDCAP

Part 1:
Known Methods for AU Comparisons

HERE!

Part 2:
NEW Methods for AU Comparisons

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R-SAARs ASP Point-of-Contact (POC) Engagement

Goals:

6-8 weeks total

~4 weeks between reports

HERE!

IF site agrees to participate, Email to POC:

- Data Report #1 (attachment)
- Link to Educational/Methods documents and webinar recording
- Email REDCAP #1 link to POC

Weekly REDCAP reminder email to POC with survey #1 link

When survey #1 is completed, Email:

- Data Report #2 (attachment)
- Email REDCAP link #2 to POC

Weekly reminder email to POC with survey #2 link

When survey 2 is completed, Email to POC

- Confirmation/Thank you

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R-SAARs Resources for your team

1. R-SAARs materials: https://dason.medicine.duke.edu/research-publications

2. Site PIs:

Epicenter	Contacts
Duke-UNC DASON	Rebekah Moehring and DASON: Libby Dodds Ashley, Melissa Johnson, Angelina Davis
Utah, Intermountain	Emily Spivak and Whitney Buckel
Chicago	Carlos Santos and Bill Trick
Hopkins	Sara Cosgrove and Eli Klein

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DEVELOPMENT OF R-SAARS MODELS

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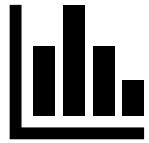
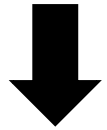
What about an R-SAAR?





R-SAAR = “Robust” SAAR models based on encounter-level electronic health record data

- 3 prior investigations of encounter-level AU risk adjustment modeling suggest **diagnosis data** can provide better model accuracy as compared with facility- or location-level data

Gap: Optimal methods to define input variables for encounter-level risk-adjustment are not established

Tradeoff between accuracy/model fit and acceptance of variables by end users (e.g. ASP teams, Hospitals)

- More factors/variables may improve model fit, but not be the “right” data to include. Who does the variable selection?

Prior Work:

Yu et al. *CID* 2018 Nov 13;67(11):1677-1685

Goodman et al. *CID* 2021 Dec 6;73(11): e4484-e4492.

Moehring et al. *JAMA Network Open* 2021 Mar 1;4(3):e213460.

Aim: Compare 4 Variable Input Strategies

Agency for Healthcare Research and Quality (AHRQ) Clinical Classification Software Refined (CCSR)

https://hcup-us.ahrq.gov/toolssoftware/ccsr/ccs_refined.jsp

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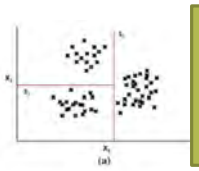

DRGs

Comorbidity category

CCSR category

CCSR category

1. Replication/Validation of Yu et al.
   - Diagnosis Related Group (DRG) Categories based on recursive partitioning method
   - 4-DRG Categories, Location Variables
   - 13 variables
2. Replication/Validation of Goodman et al.
   - Expert-adjudicated Elixhauser comorbidity categories based on assessments of clinical vignettes, Location variables
   - 34 variables
3. Agnostic Model using AHRQ CCSRs
   - Includes both diagnosis and procedure categories, Location variables
   - 967 variables
4. Adjudicated Model using AHRQ CCSRs
   - Same as 3, except Expert Panel assessed and excluded CCSRs “not appropriate” for risk-adjustment, Location variables
   - 477 variables + 4 Months of Personnel time!

Methods

CDC Prevention Epicenters Collaborators:

- Duke/UNC
- DASON community hospitals
- Johns Hopkins
- U of Utah and Intermountain
- Chicago

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50-Hospital Retrospective Analysis of electronic health record data from 2020-2021

Data: Encounter-level information on antibiotic use, diagnosis, procedures, demographics, unit locations

Inclusion: Encounters with at least 1 day present in an inpatient location

Exclusion: Neonates, Incomplete data

Outcome: NHSN's All Antibacterials Days of Therapy (DOT)

- Any Inpatient location; DOT over whole encounter

Adult (>18 years) and Pediatric (1-18 years) assessed separately

Statistical Methods

Datasets split randomly, stratified by hospital bed size to 1 Training and 2 Testing sets

Gradient-boosted machine tree-based model and 2-staged approach

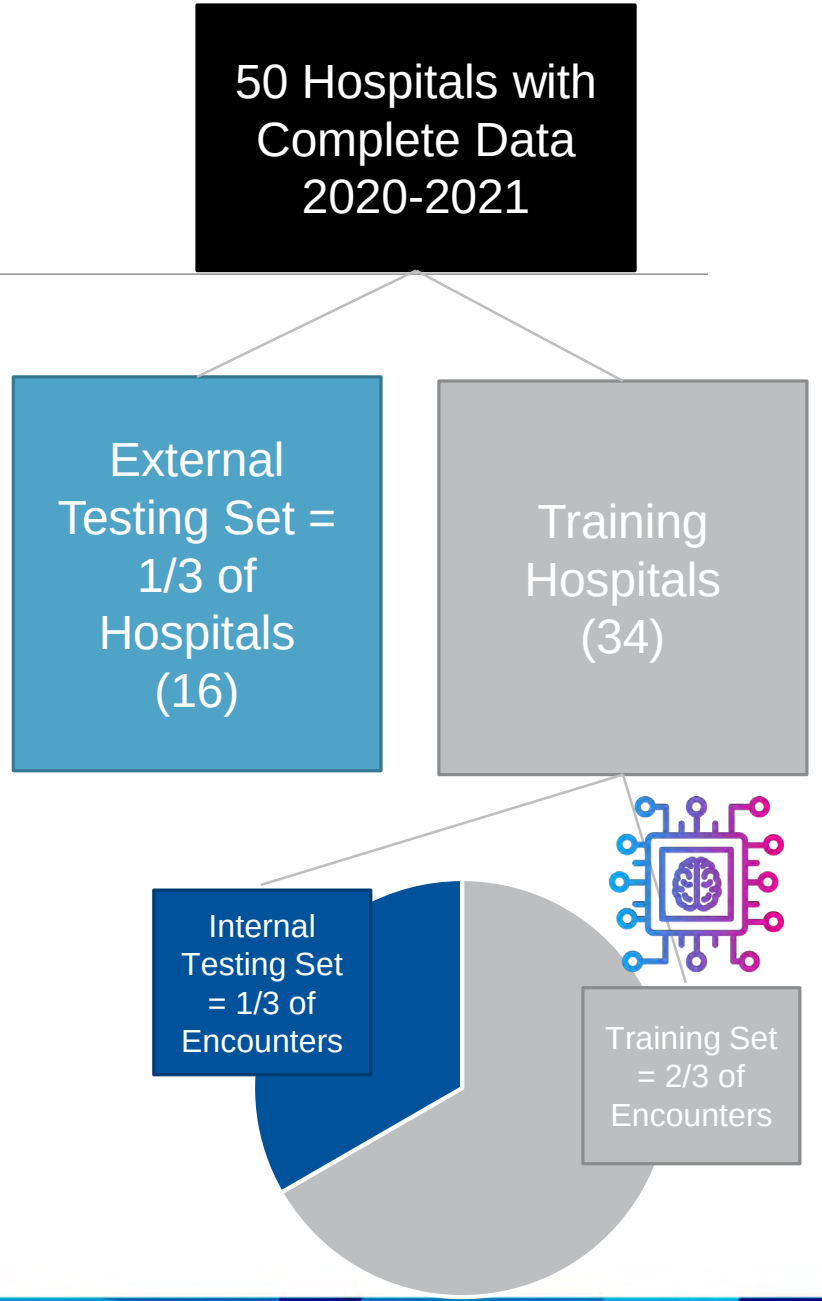
- First identify zero or “any” DOT encounters
- Then estimate DOT value among those with >0.5 probability of receiving antibiotics

Accuracy assessed using Mean Absolute Error

- Among Encounters in 2 Testing datasets

Correlation/Calibration Plots

Top 20 Most Influential Variables, based on modeled variable importance



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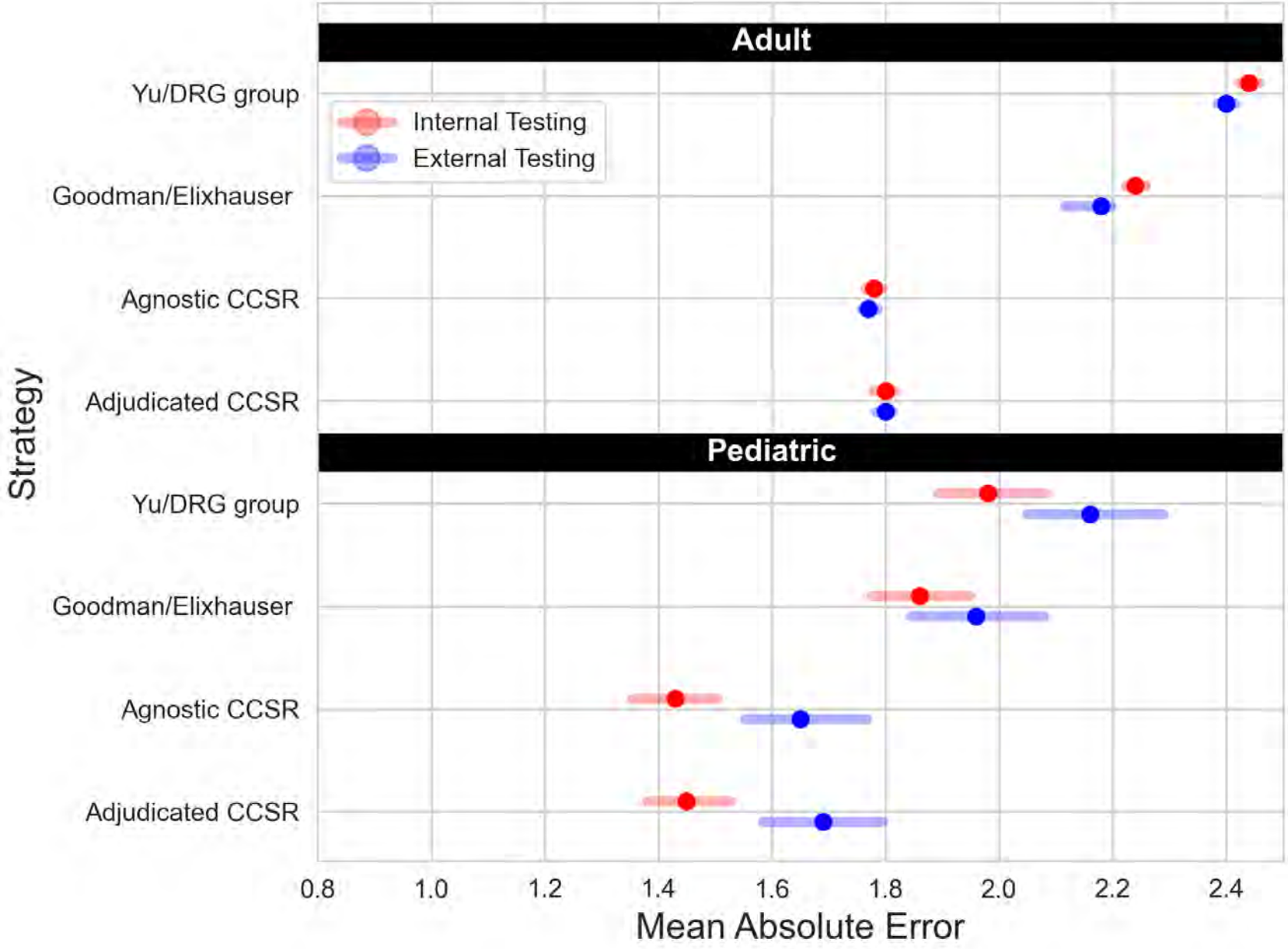
Mean Absolute Error (MAE) All antibacterial, All Locations

MAE lower in peds than adults

MAE lowest for models incorporating CCSR inputs

Similar for external/internal testing sets

Pediatric data more sparse and more zeros



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CCSR: Adult Agnostic vs Adjudicated (Top 20)

These lists are VERY similar.

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Variable	Description	Agnostic	Adjudicated
DaysPresent	N Days in an inpatient location	Y	Y
InfectionOnAdmission, NoPOA	ICD-10 in the AHRQ Appx F “Infectious Diagnosis” List	Y	Y
CCS_CM_INF003	Bacterial Infections	Y	Y
CCS_PCS_CAR024	Venous and arterial catheter placement	Y	Y
CCS_CM_SKN001	Skin and subcutaneous tissue infection	Y	Y
CCS_PCS_RES013	Lung Transplant	Y	Y
CCS_PCS_RES001	Bronchoscopy (diagnostic)	Y	N
ICD10_Sepsis	ICD-10 for Sepsis	N	Y
CCS_CM_MUS002	Osteomyelitis	Y	Y
CCS_CM_INF002	Septicemia	Y	N
CCS_CM_RSP002	Pneumonia (except that caused by tuberculosis)	Y	Y
ICD10_Neutropenia	ICD-10 for Neutropenia	N	Y
CCS_CM_GEN004	Urinary Tract Infections	Y	Y
CCS_CM_DIG016	Peritonitis and Intra-abdominal abscess	Y	Y
CCS_CM_PRG030	Maternal outcome of delivery	Y	N
CCS_CM_PRG002	Gestational weeks	N	Y
CCS_CM_INF004	Fungal infections	Y	Y
CCS_CM_SYM002	Fever	Y	N
CCS_CM_INF012	COVID-19	N	Y
CCS_PCS_MST020	Subcutaneous tissue and fascia excision	Y	Y
CCS_CM_BLD008	Immunity disorders	Y	Y
CCS_CM_DIG001	Intestinal Infection	Y	Y
PulWardDaysPercent	Percent of inpatient days on pulmonary ward	Y	Y
CCS_CM_END011	Fluid and Electrolyte disorders	Y	Y

Summary of Findings

or

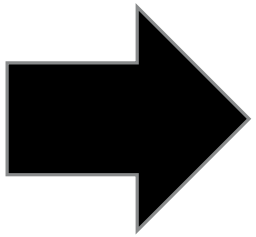
Large numbers of CCSR diagnosis and procedure inputs improved model accuracy as compared with prior variable input strategies.

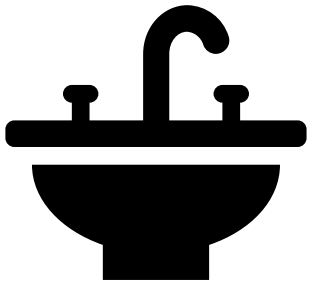
Length of stay was highly influential in encounter-level model performance

Agnostic vs. Adjudicated CCSR had similar accuracy and influential variables

Expert review: Significant personnel time investment, would require revision/maintenance. Potential for personal bias?

Evaluated all 4 Variable Strategies…





Ranks	Yu	Goodman	Agnostic CCSR	Adjudicated CCSR
Accuracy	2	3	1	1
Feasibility	3	2	1	2
Interp/Transparency	3	4	1	2
Equity	UNABLE TO ASSESS, NO DIFFERENCE BETWEEN STRATEGIES			

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R-SAARs models are not perfect.

Some Agent/Age Models have better performance than others.

Correlation to Testing Data was at best 0.73

MAE still around 1.8 per Encounter for All Antibacterials.

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METHODS: R-SAARS MODELS → HOSPITAL-SPECIFIC REPORTS

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Step 1: Calculate Expected DOT for each 2022 Encounter

2022

0	6	1	0.6
1	5	0	0.2
0	11	0	0.0
0	9	0	1.0
0	0	1	0.3

R-SAARs Model Estimator (Built on 2020-2021 Training data)

Expected 2022

Probability of Abx = 0.6

Expected DOT = 2.2

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Facility-wide R-SAARs: Indirect Standardization – Why?

1. Helps with case mix adjustment

Compare encounters at similar Expected DOT or “Common Risk” Level

Accounts for different risk distributions between hospitals in 2022

- e.g., comparing a hospital with many high Expected DOT risk patients to one with primarily low Expected DOT risk patients

2. Gets rid of the “old data” issue (2022 compared to 2022)

Use the risk distribution for the whole All Hospitals population of encounters from 2022

Step 2: Create the Common Risk Strata

Common Risk Strata, in Expected Encounter DOT
0
(0,1.6)
[1.6,2.04)
[2.04,2.76)
[2.76,3.57)
[3.57,4.42)
[4.42,5.41)
[5.41,6.78)
[6.78,8.82)
[8.82,12.8)
[12.8,928]
Total

Start with 2022 Encounters from All Hospitals

Sorted by Expected DOT

Split population of 2022 Encounters into Categories or Deciles that include approximately equal population sizes. Output their Expected DOT ranges for each stratum.

Kept a 0 category (about half of encounters).

= 11 Common Risk Strata

Step 3: Calculate the Mean Observed DOT for each Stratum

Common Risk Strata, in Expected Encounter DOT	Mean Observed DOT, among All Hospitals' 2022 Encounters
0	0.64
(0,1.6)	1.17
[1.6,2.04)	1.39
[2.04,2.76)	1.67
[2.76,3.57)	2.34
[3.57,4.42)	3.12
[4.42,5.41)	4.13
[5.41,6.78)	5.46
[6.78,8.82)	7.26
[8.82,12.8)	10.47
[12.8,928]	23.75
Total	

Step 4: Calculate the standardized Expected DOT based on the N of Hospital Encounters in each stratum

Common Risk Strata, in Expected Encounter DOT	Mean Observed DOT, among All Hospitals' 2022 Encounters	N of Encounters in Example Hospital	Hospital-Specific, Standardized Expected DOT
0	0.64	18,404	11,811.84
(0,1.6)	1.17	4,084	4,759.35
[1.6,2.04)	1.39	2,256	3,138.15
[2.04,2.76)	1.67	2,165	3,625.52
[2.76,3.57)	2.34	1,810	4,243.58
[3.57,4.42)	3.12	1,683	5,255.16
[4.42,5.41)	4.13	1,454	6,000.21
[5.41,6.78)	5.46	1,419	7,744.58
[6.78,8.82)	7.26	1,551	11,254.40
[8.82,12.8)	10.47	1,539	16,118.39
[12.8,928]	23.75	1,515	35,978.79
Total		37,880	109,930

Standardized Expected DOT

= Mean x N
For each stratum

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Step 5: Calculate Totals and Ratio

Observed/Expected

104,458 / 109,930

O:E = 0.95

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Common Risk Strata, in Expected Encounter DOT	Mean Observed DOT, among All Hospitals' 2022 Encounters	N Encounters in Example Hospital	Hospital-Specific, Standardized Expected DOT	Hospital-specific Observed DOT
0	0.64	18,404	11,811.84	10,119
(0,1.6)	1.17	4,084	4,759.35	4,174
[1.6,2.04)	1.39	2,256	3,138.15	2,221
[2.04,2.76)	1.67	2,165	3,625.52	3,123
[2.76,3.57)	2.34	1,810	4,243.58	4,560
[3.57,4.42)	3.12	1,683	5,255.16	5,541
[4.42,5.41)	4.13	1,454	6,000.21	6,523
[5.41,6.78)	5.46	1,419	7,744.58	8,381
[6.78,8.82)	7.26	1,551	11,254.40	12,138
[8.82,12.8)	10.47	1,539	16,118.39	16,514
[12.8,928]	23.75	1,515	35,978.79	31,164
Total		37,880	109,930	104,458

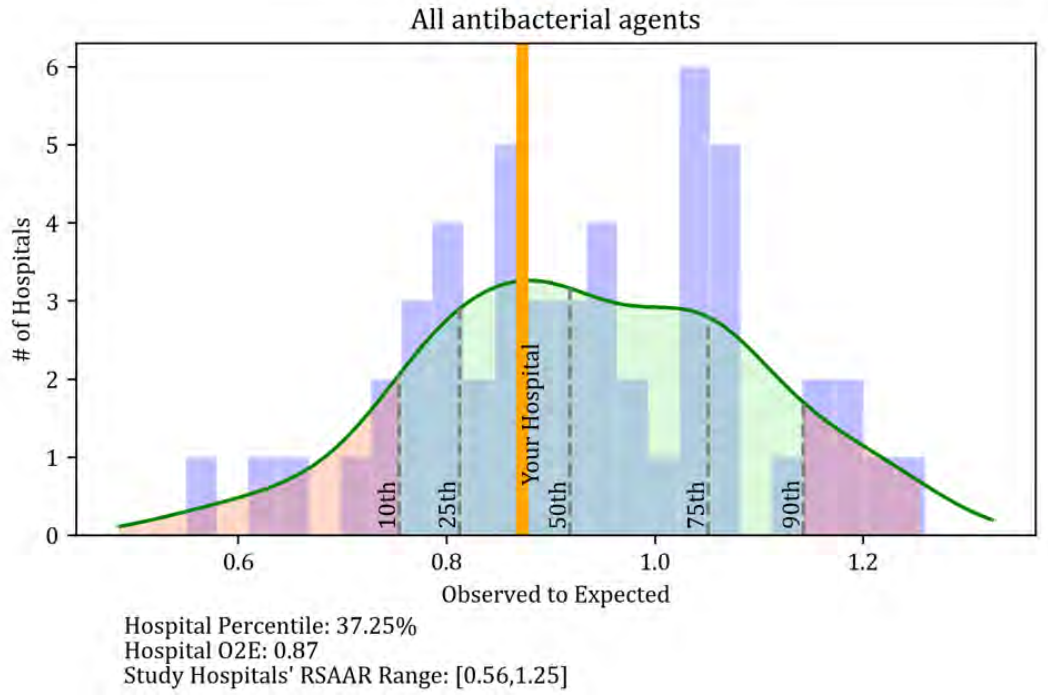
Evaluate Facility-wide R-SAARs: Graphically and with Percentiles

Similar Figures as in Part 1 Except Now Risk-adjusted

- X axis is the R-SAAR or O:E Value; Y axis is the N hospitals at that value

Repeated the process for all Age/Agent Groups

Pediatrics now have Facility-wide graphs!



Unit-Level R-SAARs are Different: ***No*** Indirect Standardization

We ran out of time to do Indirect Standardization on the Unit Level

Instead, we followed an approach similar to current methods (and Part 1) with the O:E + percentiles based on the modeled Expected DOT.

2022 O:E Percentiles presented among units of that same Type (if >10 in the study)

Differences from Part 1: R-SAARs models (based on 2020-2021 Training Data); More Unit Types with O:E Ratios

Unit-Level R-SAARs: Sum and Divide

Sum Expected DOT and Observed DOT across Encounters with at least 1 day present in that unit. Then divide to get the O:E Ratio.

Notes:

- Whole Encounter Expected and Observed DOTs counted; Does NOT split encounters to just their time on unit
- A single Encounter's DOT might be double counted in the plots if seen on >1 unit
- "Observed" DOT estimate will likely be larger on the unit level (than Part 1) if your unit has transfers from other units

She stays Whole.
She appears in >1 Unit if she spent time in >1

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Caveats and Exclusions: Unit-Level R-SAARs Methods

1. Lacks the advantages of indirect standardization:

- Old data issue in the O:E Ratios (partially addressed by percentiles)
- Lacks some adjustment of differing risks of Expected DOT by hospital/unit

2. Some rare-use Unit Types have Expected DOT = 0

- E.g. OB Units often have 0s or near-0s from the R-SAARs model estimator.
- Cannot divide by 0. No O:E calculated.

3. Small population effects.

- R-SAARs can get quite extreme and be affected by a few outliers.
- Exclusions: Did not report Unit-level R-SAARs for units with <6 months of reported data, <20 days present, or <50 encounters with exposure to “All Antibacterials” in 2022.
- N encounters exposed to that unit and antimicrobial group added into figures
- Red Text when N<50 encounters in that unit/agent group

Treat Unit-Level SAARs like you do MIC Reports…

Don’t Compare the Quantitative Value between Units (like antibiotic MICs listed on a micro susceptibility report).

Evaluate each unit (and unit-type) individually.

Use the percentile, when available.

- Some unit types don’t have “interpretive criteria” yet.

If comparing to estimates from Part 1, Look at percentiles instead of O:Es

Red Text is like that *footnote on your antibiogram for <30 isolates

ANTIBIOTICS	P.aeruginosa MIC	INTRP
Amikacin	<=8	S
Aztreonam	8	S
Cefepime	4	S
Ceftazidime	4	S
Ciprofloxacin	<=0.25	S
Gentamicin	<=2	S
Levofloxacin	<=0.5	S
Meropenem	<=0.5	S
Piperacillin/Tazobactam	16/4	S
Tobramycin	<=2	S

S=SUSCEPTIBLE I=INTERMEDIATE R=RESISTANT
N/S=NON-SUSCEPTIBLE

RESULTS REVIEW

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Example Hospital: Section 1

BIG TABLES

1. Encounter Level Demographics

2A. Influential Variables (Adult)

2B. Influential Variables (Pediatric)

Tables include your hospital's data and a summary of the All Hospitals 2022 Data.

What is unique about your hospital?

Do the R-SAARs Model Variables include these qualities?

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Section 2: Facility-Wide R-SAARs

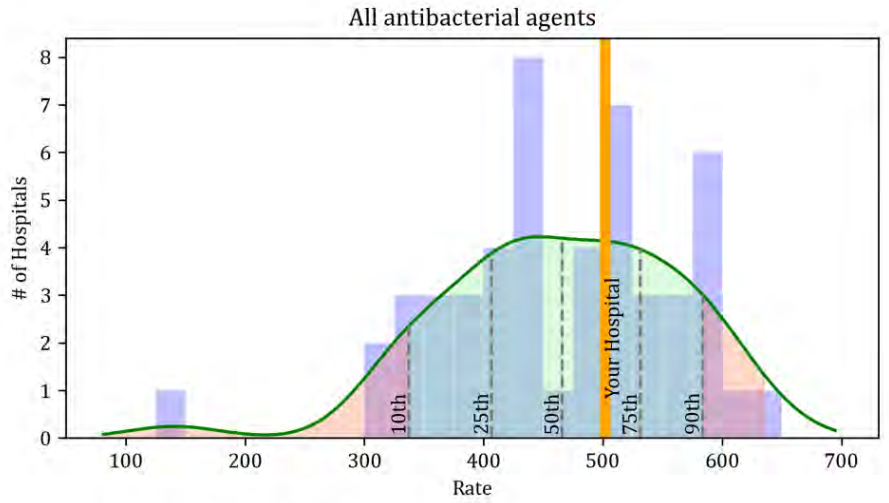
Part 1

Part 2

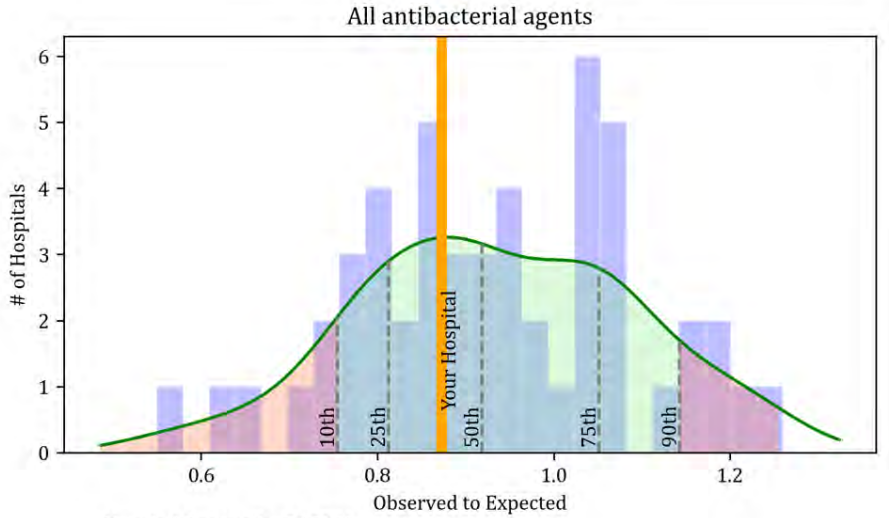
Very Similar in Structure to Part 1, BUT

X- axis = R-SAAR

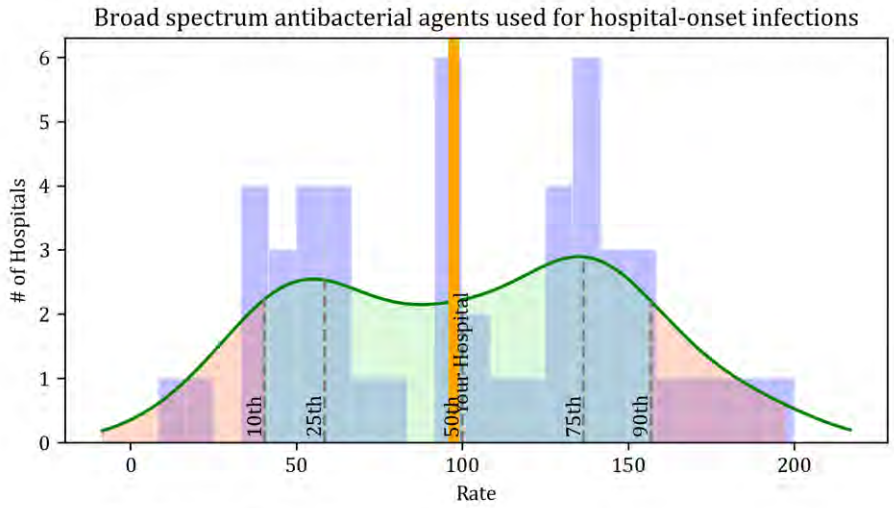
*Now with Adjustment for Encounter Level factors and indirect standardization.



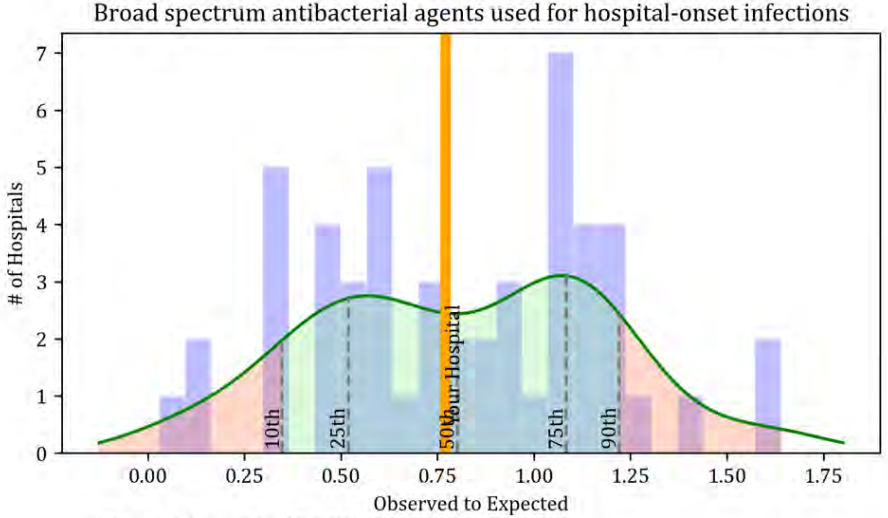
Hospital Percentile: 59%
Hospital Rate: 501.50 DOT per 1000 days present
Study Hospitals' Range: [140.82, 634.87]



Hospital Percentile: 37.25%
Hospital O2E: 0.87
Study Hospitals' RSAAR Range: [0.56,1.25]



Hospital Percentile: 47%
Hospital Rate: 97.34 DOT per 1000 days present
Study Hospitals' Range: [11.52, 196.79]



Hospital Percentile: 49.02%
Hospital O2E: 0.77
Study Hospitals' RSAAR Range: [0.03,1.64]

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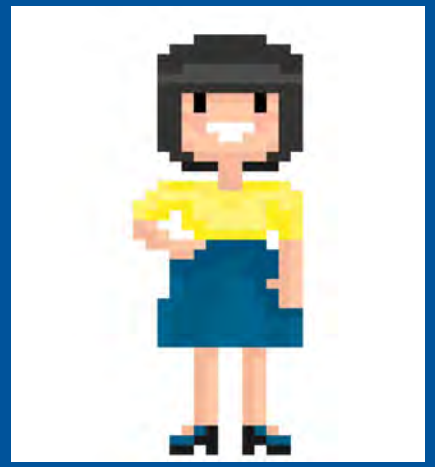
Section 2: Descriptive AU on the Encounter Level



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Stats focused on Encounter-level data!

N (%) Encounters with Agent Exposure

Median (IQR) DOT

Table 3: Top 10 Agents

Table 4: Agent Groups

Both for Your Hospital and All Hospitals

Example: Top Agents, Adult

Top Antimicrobial	N	Your Hospital N (%) of Encounters	Your Hospital DOT Per Encounter with AU, Median (IQR)	All Hospitals N (%) of Encounters	All Hospitals DOT Per Encounter with AU, Median (IQR)
Ceftriaxone	1	3781 (19.3)	2.0 (1.0, 4.0)	99101 (14.9)	2.0 (1.0, 4.0)
Cefazolin	2	3036 (15.5)	1.0 (1.0, 2.0)	124013 (18.7)	1.0 (1.0, 2.0)
Vancomycin	3	2504 (12.8)	2.0 (1.0, 4.0)	88451 (13.3)	2.0 (1.0, 4.0)
Metronidazole	4	2013 (10.3)	2.0 (1.0, 4.0)	43969 (6.6)	2.0 (1.0, 4.0)
Ampicillin with Sulbactam	5	1299 (6.6)	3.0 (2.0, 5.0)	13135 (2.0)	3.0 (2.0, 5.0)
Cefepime	6	1190 (6.1)	3.0 (1.0, 5.0)	47530 (7.2)	3.0 (2.0, 5.0)
Azithromycin	7	1121 (5.7)	2.0 (1.0, 3.0)	42024 (6.3)	2.0 (1.0, 3.0)
Piperacillin with Tazobactam	8	884 (4.5)	3.0 (2.0, 5.0)	60084 (9.0)	3.0 (2.0, 5.0)
Levofloxacin	9	796 (4.1)	2.0 (1.0, 4.0)	20510 (3.1)	2.0 (1.0, 4.0)
Amoxicillin with Clavulanate	10	723 (3.7)	2.0 (1.0, 4.0)	14147 (2.1)	2.0 (1.0, 4.0)

Example: Agent Groups, Adult

Top Antimicrobial Group	N	Your Hospital N (%) of Encounters	Your Hospital DOT Per Encounter with AU, Median (IQR)	All Hospitals N (%) of Encounters	All Hospitals DOT Per Encounter with AU, Median (IQR)
All antibacterials	1	10100 (51.5)	4.0 (2.0, 8.0)	352935 (53.1)	3.0 (2.0, 7.0)
C Difficile	2	5453 (27.8)	2.0 (1.0, 5.0)	164677 (24.8)	3.0 (2.0, 5.0)
Narrow Beta-lactams	3	4983 (25.4)	2.0 (1.0, 4.0)	171870 (25.9)	2.0 (1.0, 2.0)
Broad, Comm-Onset	4	4571 (23.3)	2.0 (1.0, 4.0)	132208 (19.9)	3.0 (1.0, 4.0)
Resistant Gram-Pos	5	2432 (12.4)	2.0 (1.0, 4.0)	88291 (13.3)	2.0 (1.0, 4.0)
Broad, Hosp-Onset	6	2347 (12.0)	3.0 (2.0, 6.0)	107442 (16.2)	3.0 (2.0, 6.0)
Antifungals	7	420 (2.1)	4.0 (1.0, 7.0)	16313 (2.5)	4.0 (1.0, 7.0)

Section 3: Unit-Level O:E (R-SAARs)

By Unit and Agent Group

Now includes more Units

Observed and Expected AU Rate

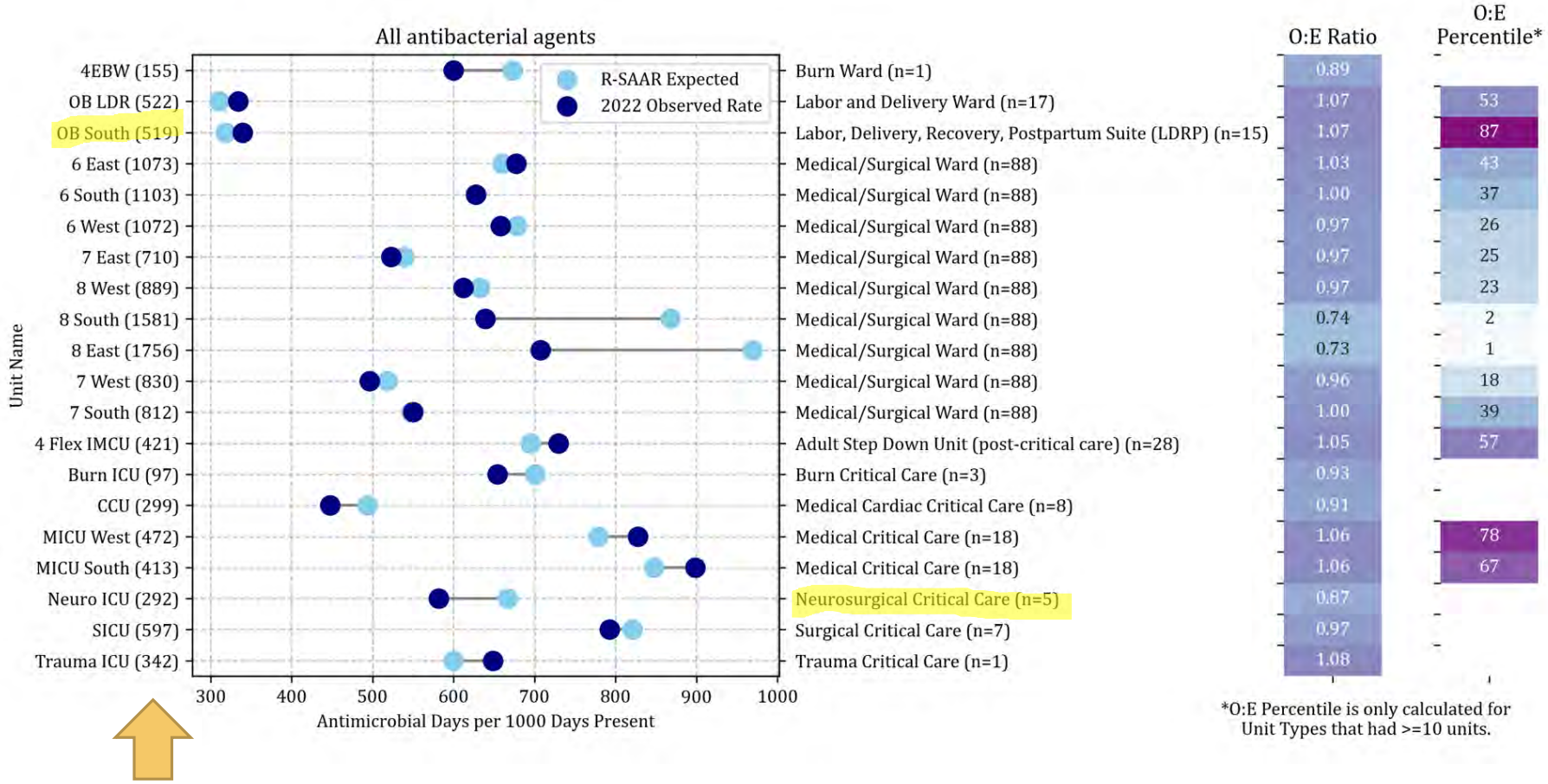
- Now using WHOLE encounter DOT

O:E Ratio (20-21 R-SAAR on 2022 data)

Percentile: 2022 O:Es among all units of that type in the study

- Not calculated if <10 units of that type in the study

Is my UNIT's R-SAAR an outlier?



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Part 1 vs. Part 2: All antibacterial

New! Specialized units now have an O:E ratio. Some have a percentile.

Light blue dot moved – R-SAAR estimate based on more variables than unit-type.

Dark blue dot moved – Encounters kept WHOLE

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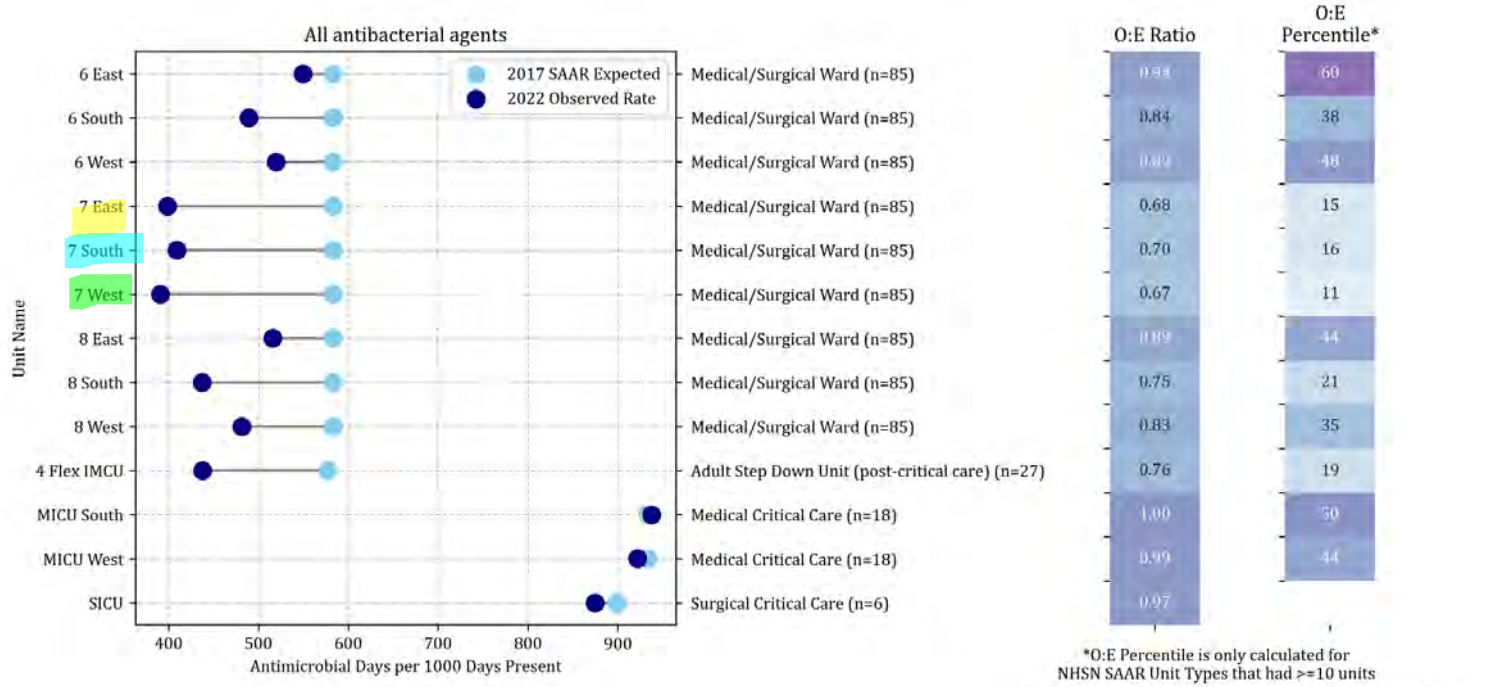
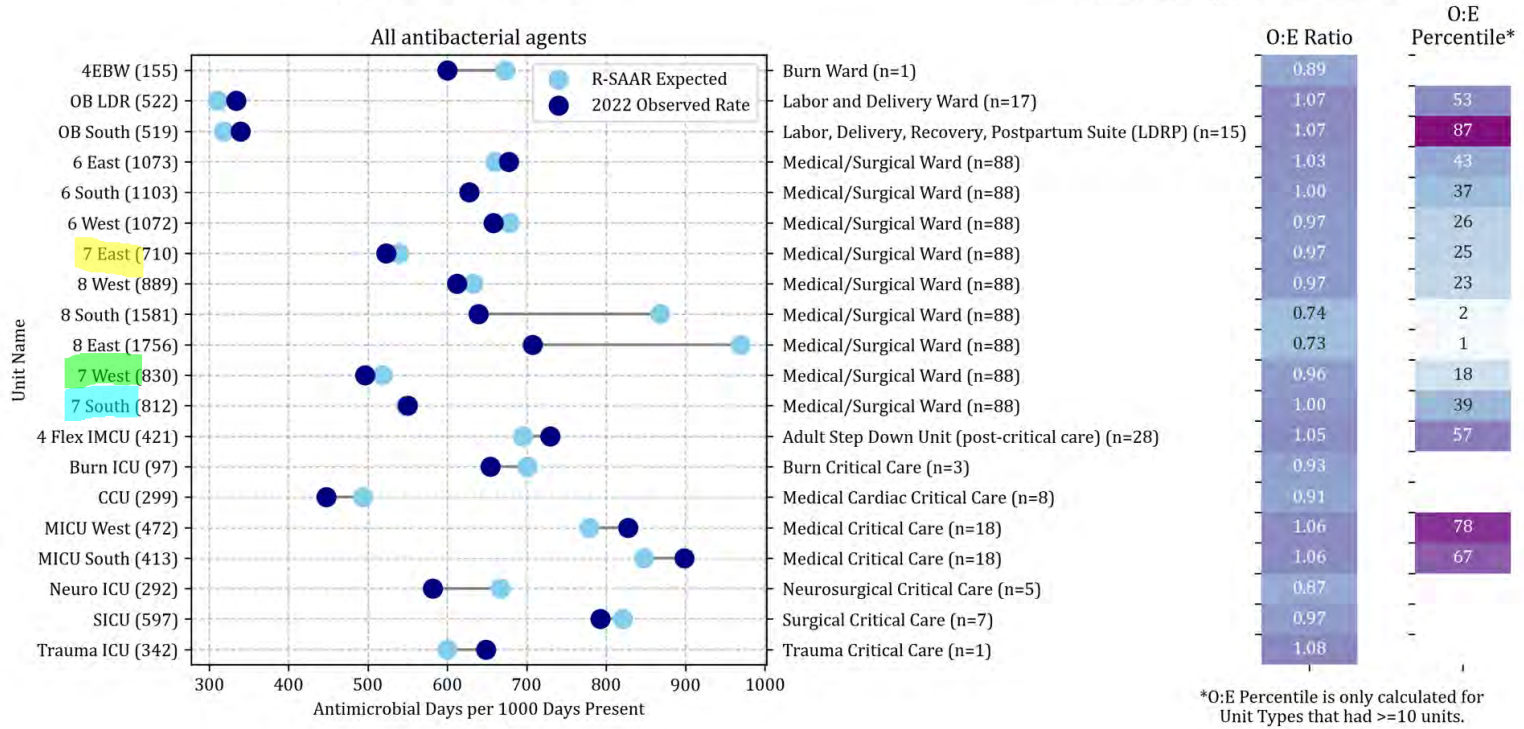




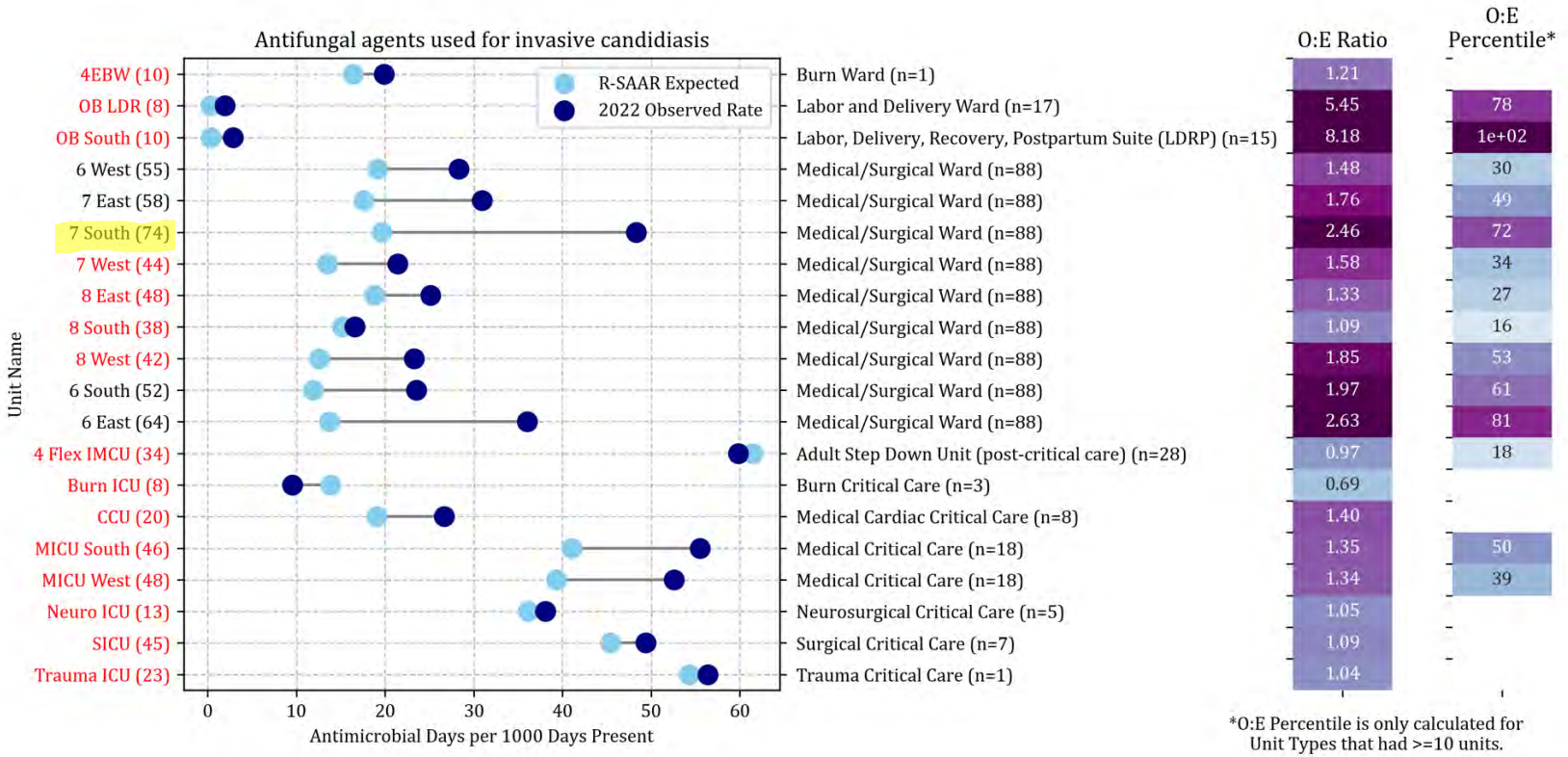
Unit-level R-SAARs: Infrequently used Agents

Example:

7 South

Part 1: O:E 1.81, 92%ile

Part 2: O:E 2.46, 72%ile



Red Text indicates <50 encounters with exposure to Agent Group + Unit.

Extremes of O:E may be due to small Ns + outlier effects.

Unit-type percentile might help.

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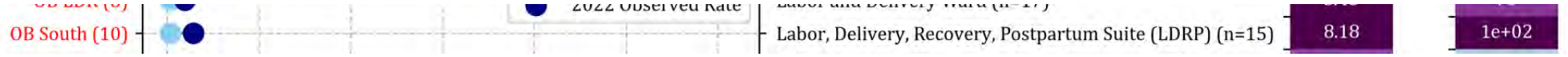
Appendix

Similar fields as Part 1, but using RSAARs instead of SAARs.

Can dig into specific unit DOTs if needed.

Example:



OB South Antifungal – RSAAR O:E was really high >8, but N encounters was small (10)

- RSAAR model estimate was 1.46 DOT and observed DOT was 12.

AntibioticGroupName	UnitName	NHSNUnitName	PooledActualAntimicrobialDays	PooledDaysPresent	PooledRate	NUnitsComparator	RSAARAllLocPredictedAntimicrobialDays	PredRate	OEAllLoc	MinRateComparator	MedianRateComparator	MaxRateComparator	RSAAR_Percentile
Antifungal agents used for invasive candidiasis	OB South	Labor, Delivery, Recovery, Postpartum Suite (LDRP)	12	4209	2.85103	14	1.467307	0.348612	8.17823	0	1.03947	5.07766	100

Next Steps: Review Data with your Team

POC: Part 2 Survey – There is only 1 submit button this time.

Repeated Question: 3 Targeted Areas/Possible ASP Response

Additional Questions at the end re: Your Teams Preferences

?Interview

- 30min or less
- Web/Zoom based
- Can review your hospital report
- Voluntary

Possible ASP Responses
Known problem area/Action Needed
Possible opportunity/Investigate Further
Doing well/ Provide positive feedback + Highlight performance

FEASIBILITY AND UTILITY OF ROBUST ANTIBIOTIC USE RISK-ADJUSTMENT IN ANTIMICROBIAL STEWARDSHIP PROGRAM ASSESSMENTS (R-SAARS): **OVERVIEW, PART 2**

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