Improving Crisis Standards of Care

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Disclosures

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Greenwall Foundation Award (Parker)

Objectives

Overall: Improve the performance and equity of allocation procedures for scarce ICU resources in a crisis

Part 1: Build an accurate proof-of-concept prediction model for ICU survival based on real-world local data

Part 2: Demonstrate the implications of several resource allocation protocols through Monte Carlo simulation

Patient Population

Two hospitals (one academic, one community)

Hospitalized adults (≥ 18) from 2019.01.01 to 2022.06.30

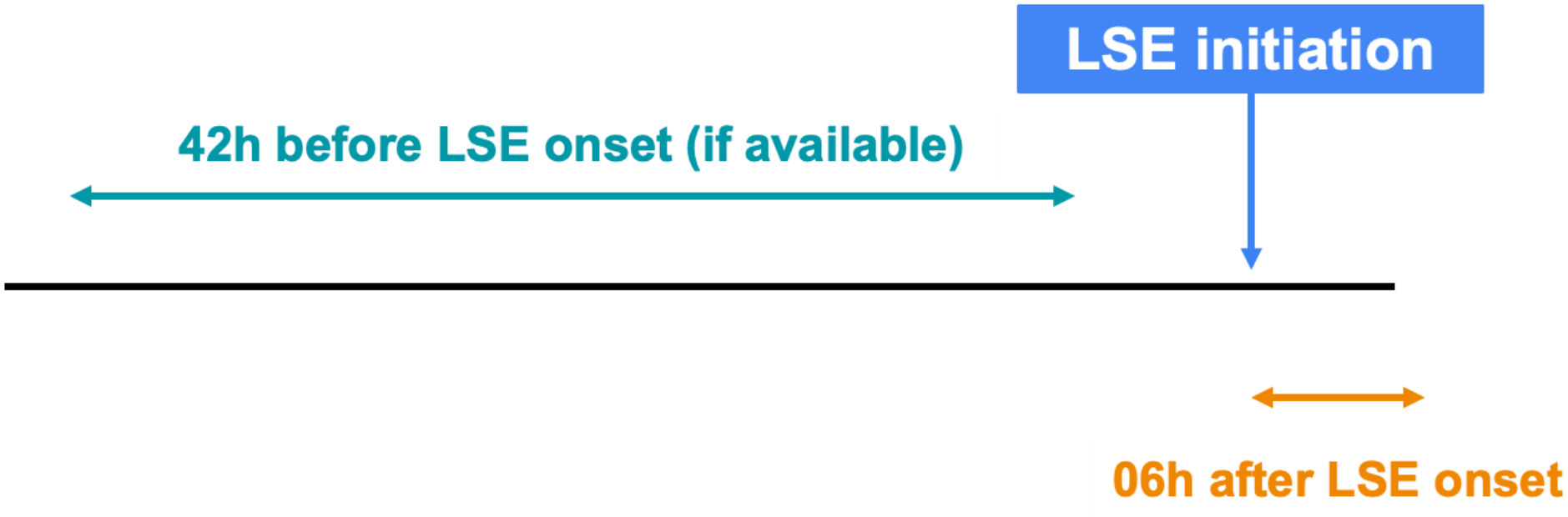
Received 6+ consecutive hours of life support

- Vasoactive medications (blood pressure support) or
- Invasive or noninvasive mechanical ventilation (breathing support) or
- High-flow O_2 + P:F ratio < 200 or S:F ratio < 179 (breathing support)

Local Data

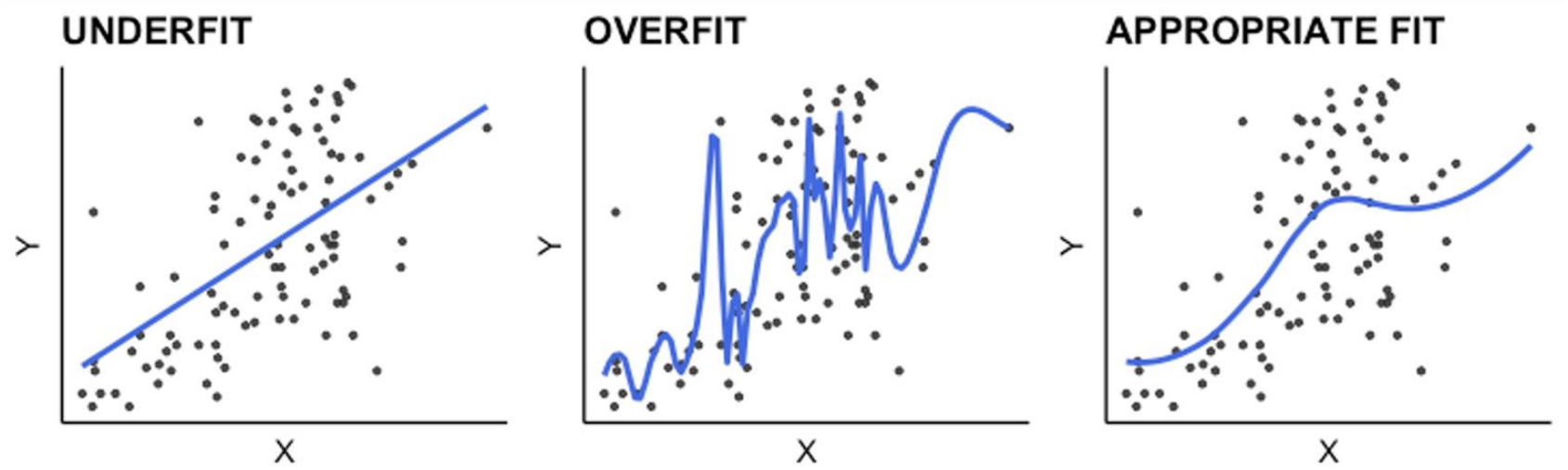
Characteristic	Survived, n = 9,512	Died, n = 2,015
Age (years), median (IQR)	62 (49-71)	65 (54-74)
Female, n (%)	4,081 (43)	782 (39)
Race, n (%)		
American Indian or Alaska Native	183 (1.9)	30 (1.5)
Asian	266 (2.8)	65 (3.2)
Black or African American	268 (2.8)	46 (2.3)
Native Hawaiian or Other Pacific Islander	91 (1.0)	22 (1.1)
White	8,080 (85)	1,534 (76)
Not Available	624 (6.6)	318 (16)
Ethnicity, n (%)		
Hispanic or Latino	810 (8.5)	136 (6.7)
Not Hispanic or Latino	7,899 (83)	1,546 (77)
Not Available	803 (8.4)	333 (17)

Data to Predict Survival



LSE = Life Support Episode

Prediction Models, Oversimplified



Learn a pattern in some data, predict in new data

Models to Predict Survival

Model	Comment
SOFA	As per common guidelines (3 tiers)
Modified SOFA	Kidney subscore limited in CKD
New Models	48h worst values in objective data

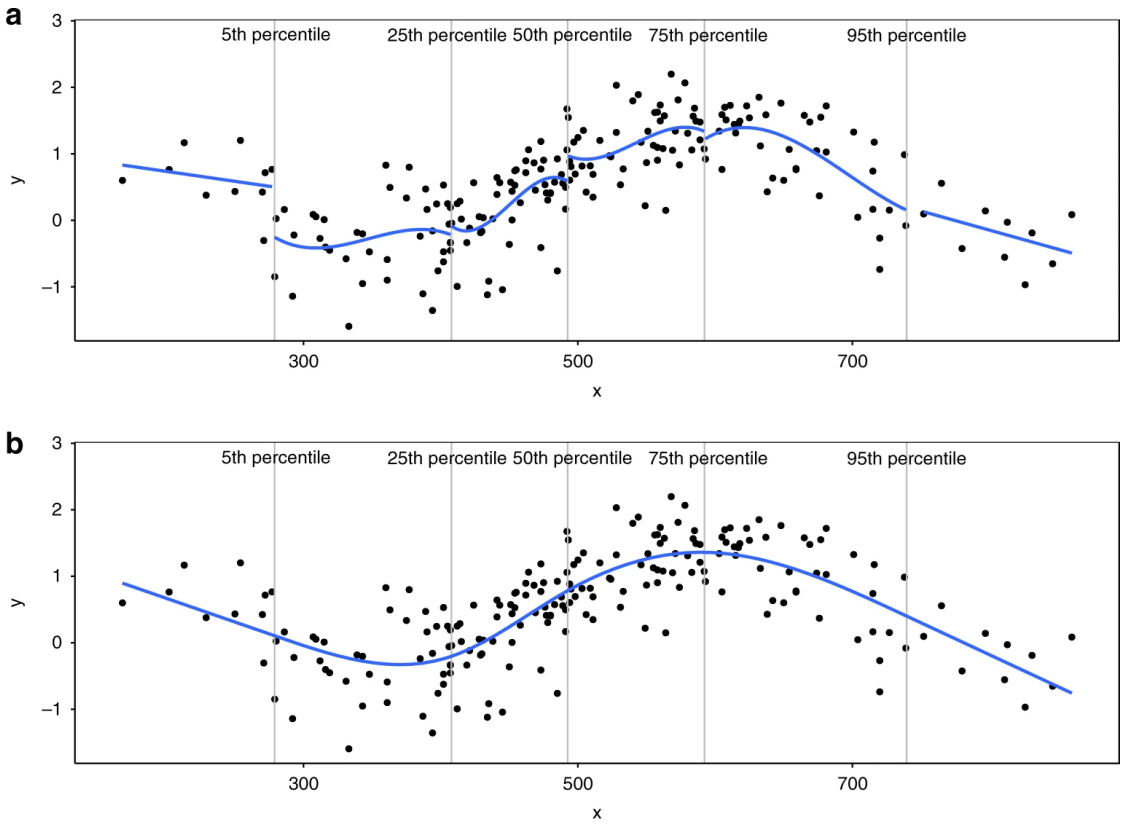
Logistic Regression Modeling

Organ System	Predictor Variables	Comment
Heart	Highest number of vasoactive medications	
	Lowest mean arterial pressure (MAP)	
	Highest shock index	heart rate / systolic BP
Lung	Lowest S:F ratio	
	Use of advanced respiratory support	IMV, NIV, HFO
Kidney	Use of new acute dialysis	sCr, chronic dialysis not considered
Brain	Lowest Glasgow Coma Scale (GCS) score	
Liver	Highest total bilirubin concentration	
Blood	Lowest platelet count	

Additional Modeling Details

Splines

Imputation



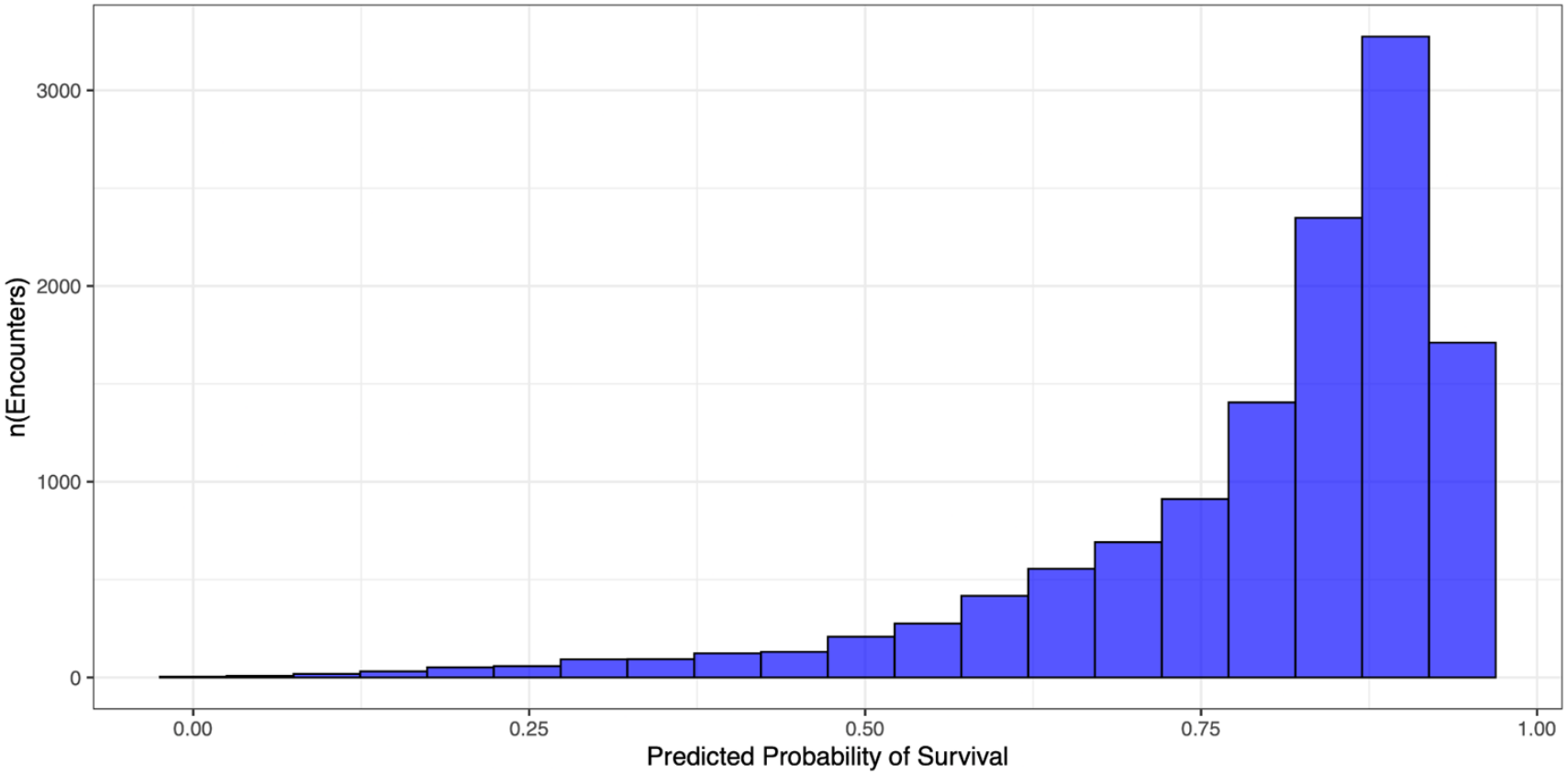
Analysis

Calibration

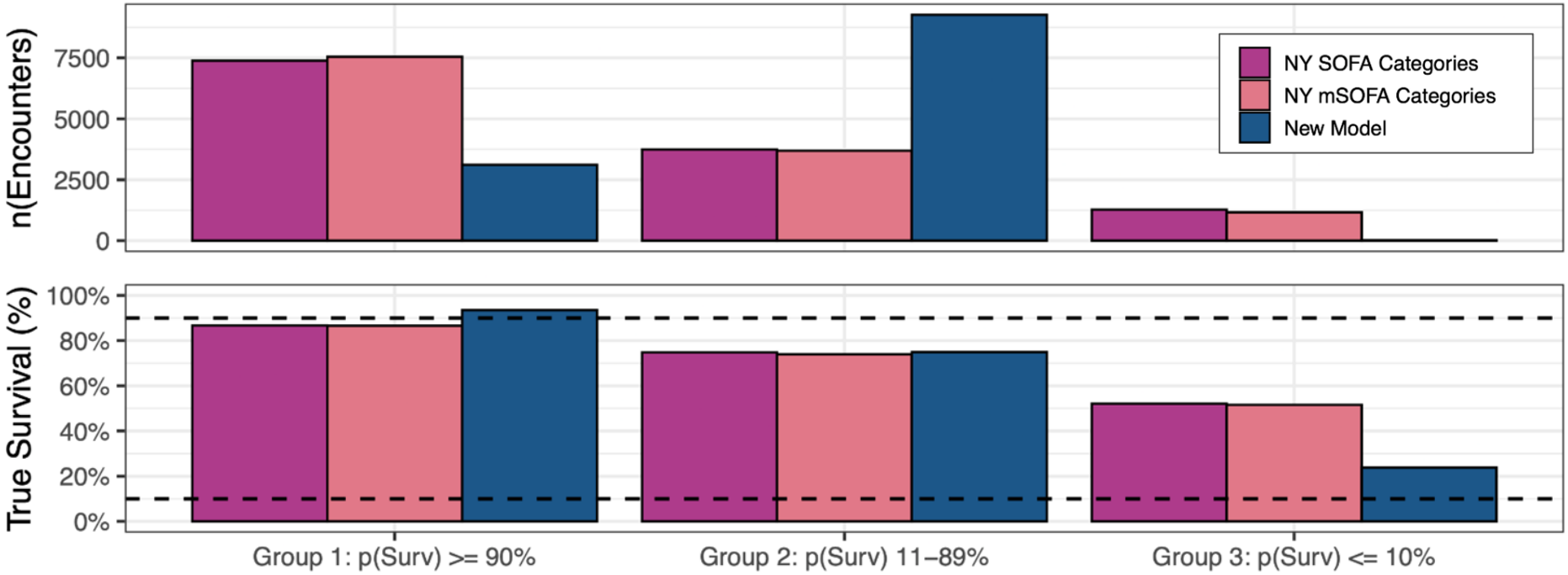
Discrimination

Equity and Fairness

Predicted Probability of Survival



Predicted Probability of Survival



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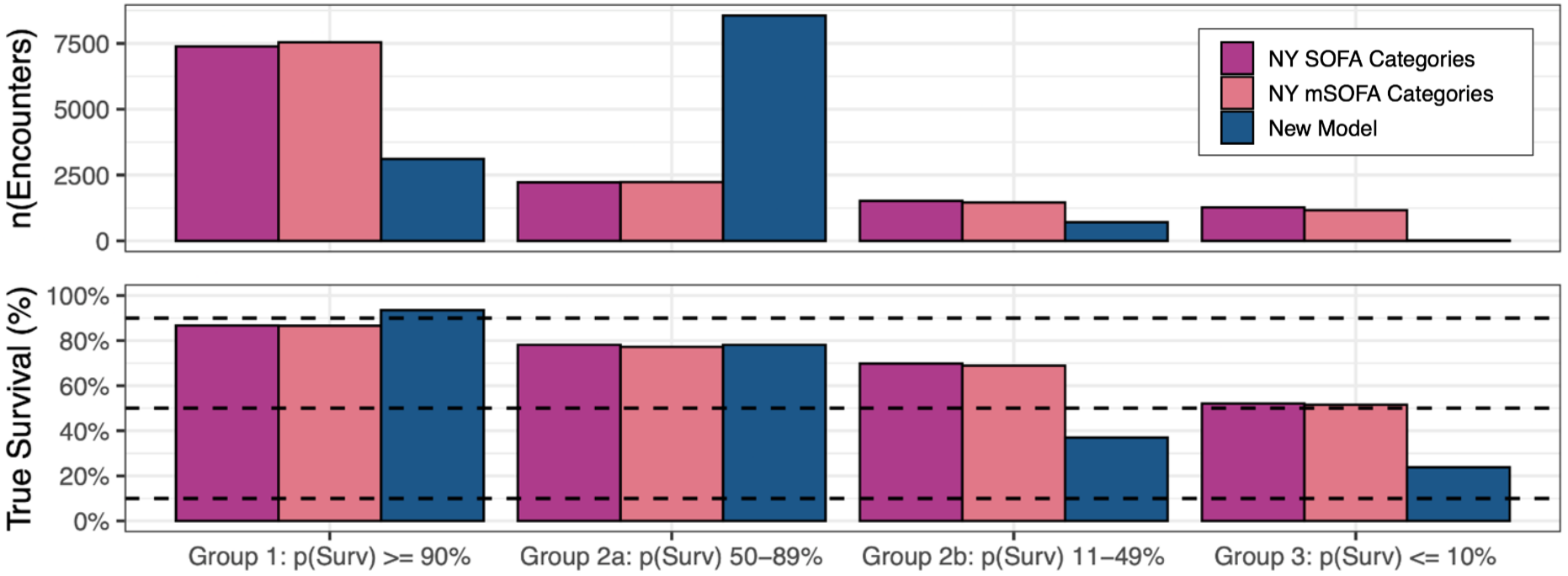
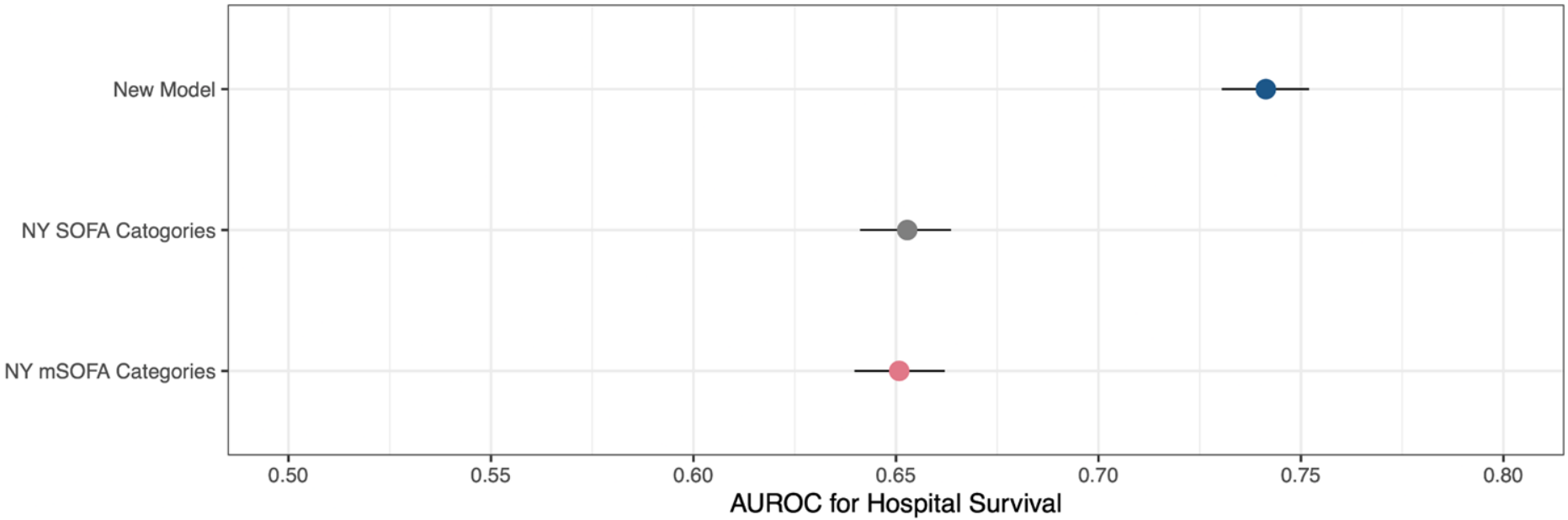


Discriminatory Performance



Conceptualizing Resource Allocation

A popular band announces a one-night-only concert in town. What are some consequences if tickets are sold ___? (Ignore resale, etc)

First-come, first-served: Favors the fans with flexible schedules, fast internet, extra resources needed to be “well-prepared”

By lottery: Equal chances for anyone who enters. Casual fans have the same chances as the biggest fans.

By some other strategy: How might you update these processes?

Simulating ICU Bed Allocation

Regardless of how prognosis is made, we must understand the implications of the triage strategy being used

Strategy	Definition
Lottery	Random Assignment
SOFA categories	NY state protocol
mSOFA categories	Renal correction
Equitable Chances	Lottery weight proportional to a measure of preexisting disadvantage (e.g., C19 AAMR)

What Are the Possible Triage Outcomes?

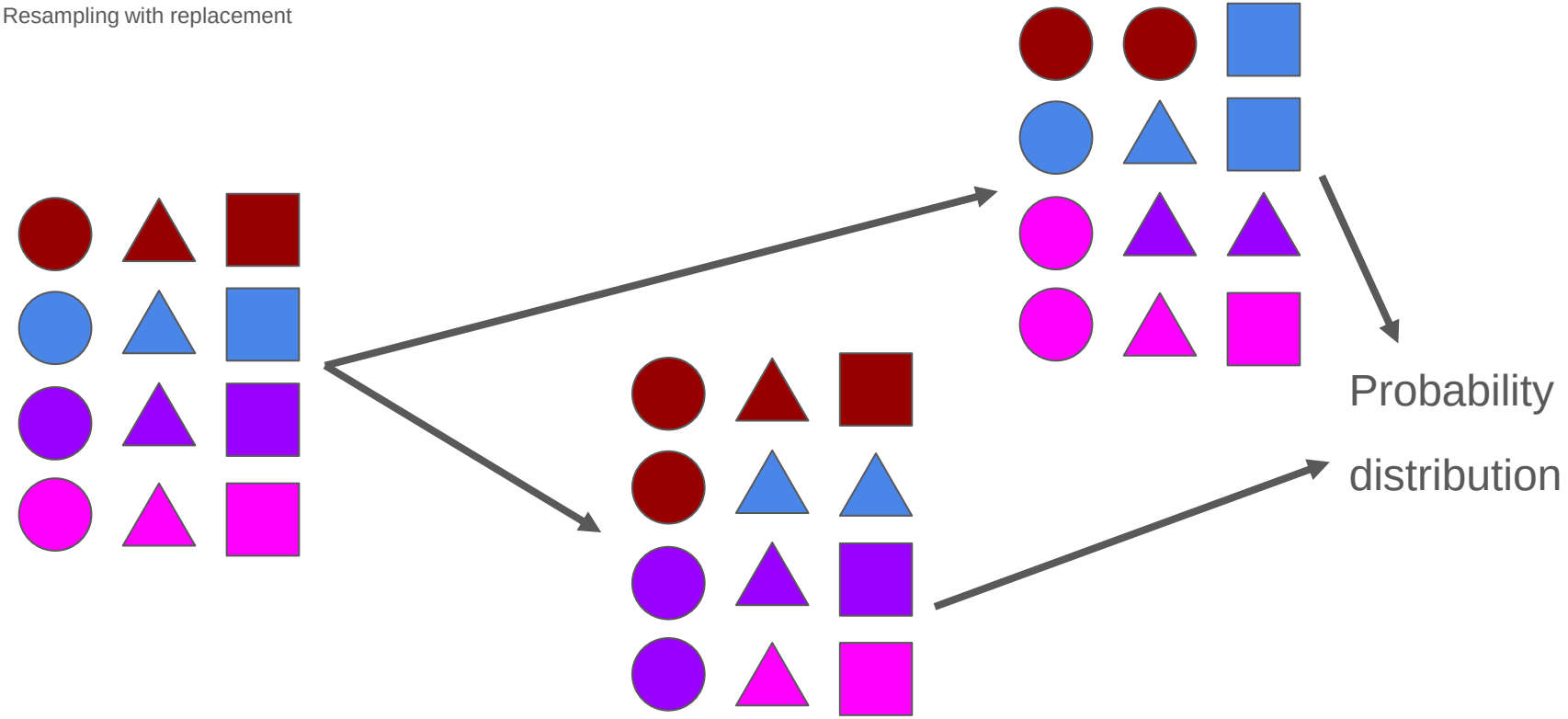
Allocated ICU bed and survives

Allocated ICU bed but does not survive

Not allocated ICU bed (expected that all patients in this group would not survive)

Monte Carlo Simulation

Resampling with replacement



How Does This Simulation Work?

Patients arrive in groups of 4

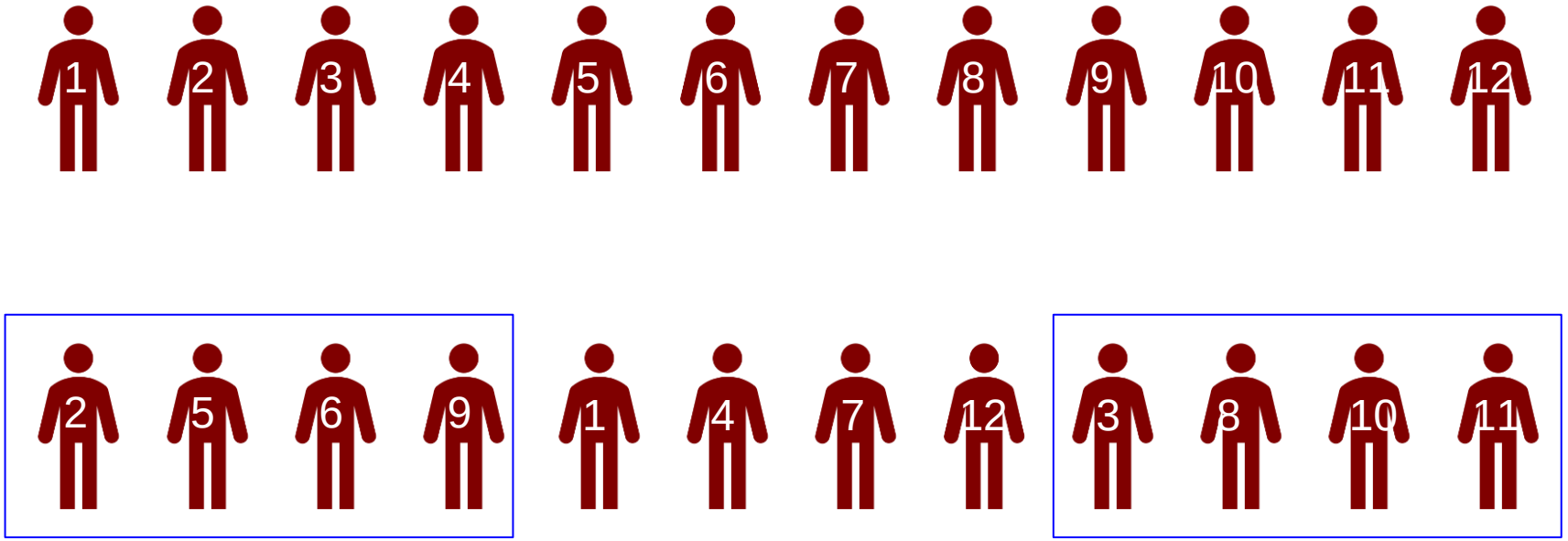
25% scarcity: 3 patients allocated ICU

50% scarcity: 2 patients allocated ICU

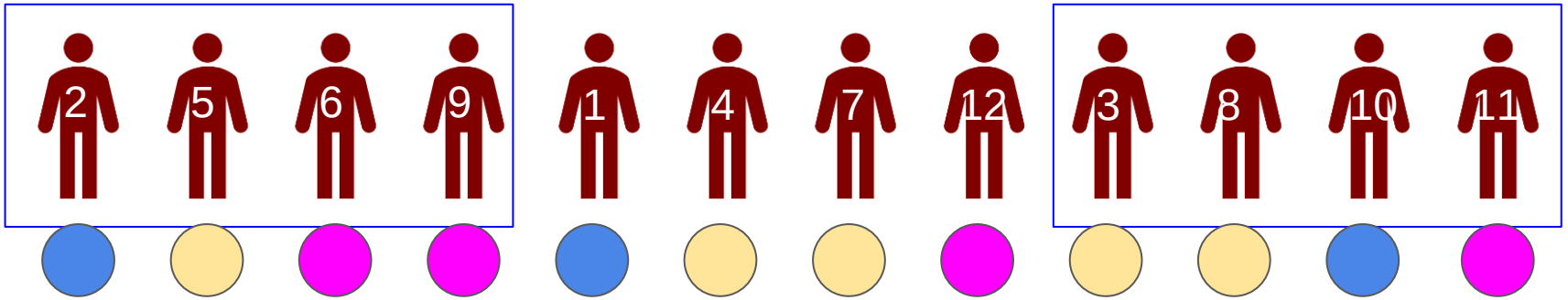
75% scarcity: 1 patient allocated ICU

Based on allocation strategy
Priority #1
Priority #2
etc…

Simulation Example (SOFA categories) [slide 1 of 4]



Simulation Example (SOFA categories) [slide 2 of 4]

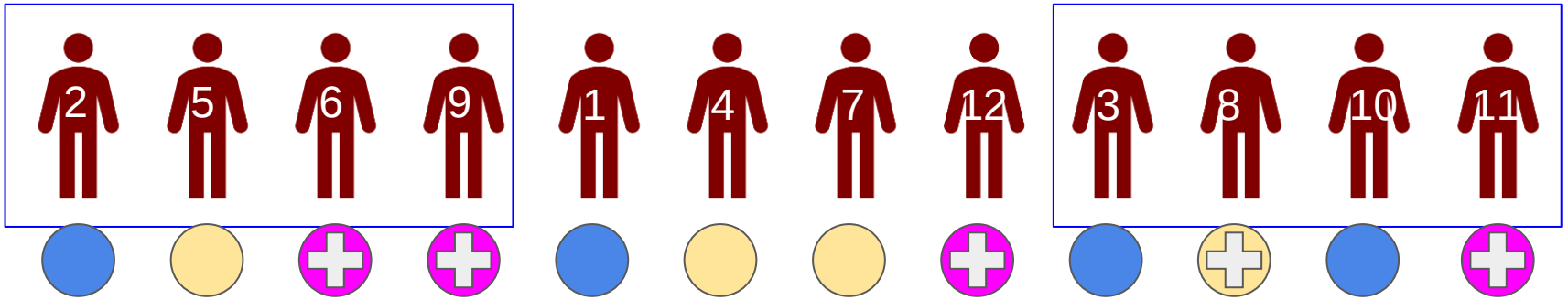


SOFA < 8

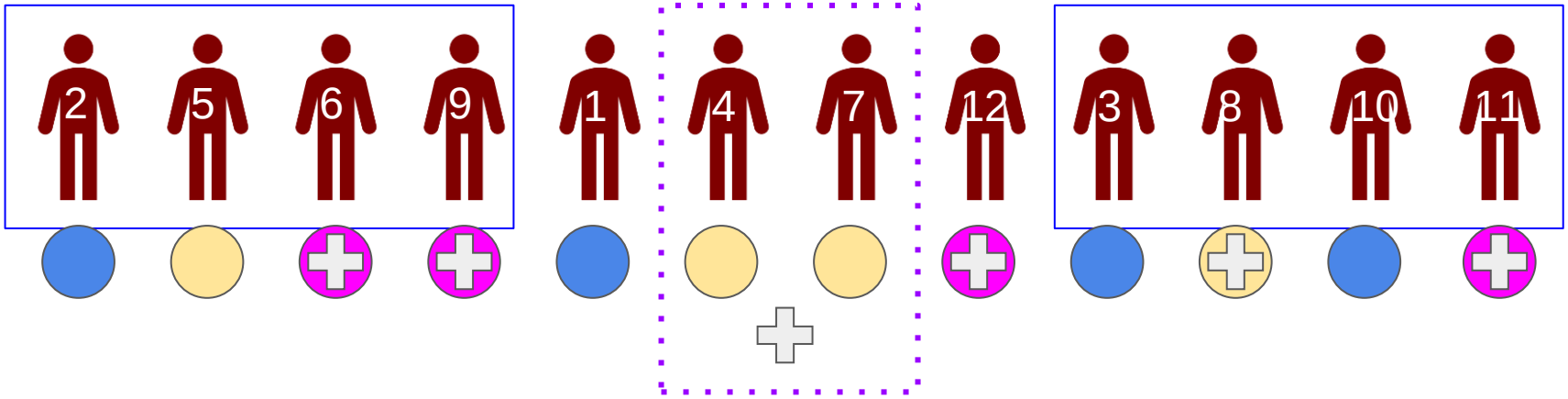
SOFA 8-11

SOFA > 11

Simulation Example (SOFA categories) [Slide 3 of 4]



Simulation Example (SOFA categories) [Slide 4 of 4]



Lottery within SOFA group

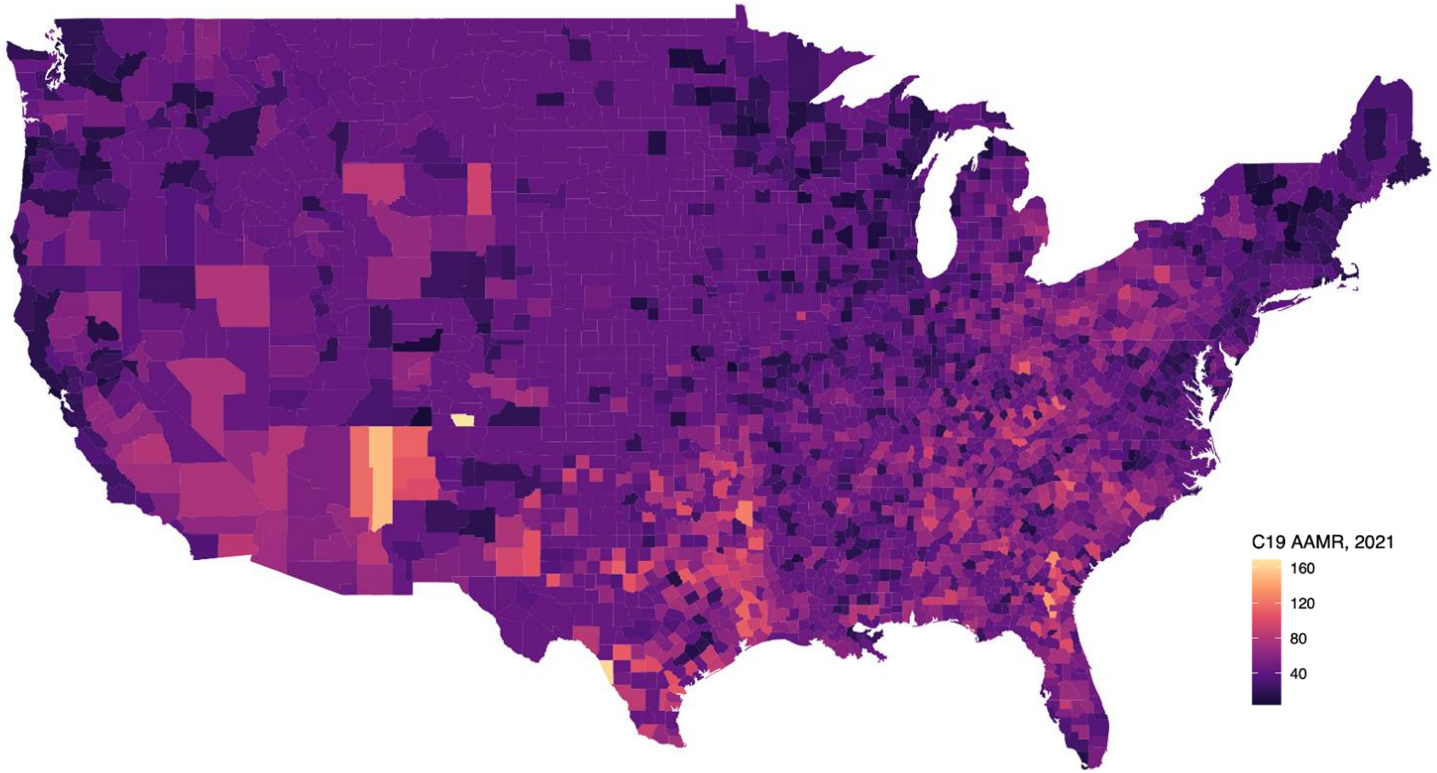
Equitable Chances

Assign patient to group based on new model

If a pair of patients are in the same group, run a **weighted** lottery

Step 1: Clinician Prognosis: assess patient's chance to survive hospitalization. Group 1 gets highest priority for the resource, and Group 3 gets lowest priority for the resource:
Group 1: lowest risk of death (≥ 90% chance of hospital survival)
Group 2: moderate risk of death (89-11 % chance of hospital survival)
Group 3: high risk of death (≤ 10% chance of hospital survival)
Step 2: Equitable Chances Criterion: In the event there are not enough resources for patients in the same prognosis group, apply equitable chances criterion.
Determine the disadvantage score for each patient based on the disadvantage index for their geographic residence. Assign additional equitable chances weighting for patients based on level of disadvantage, proportionate to impact (as measured by disadvantage index). Complete the automated, weighted randomization process (a drawing) using available software to determine who receives the resource. See detailed example below.

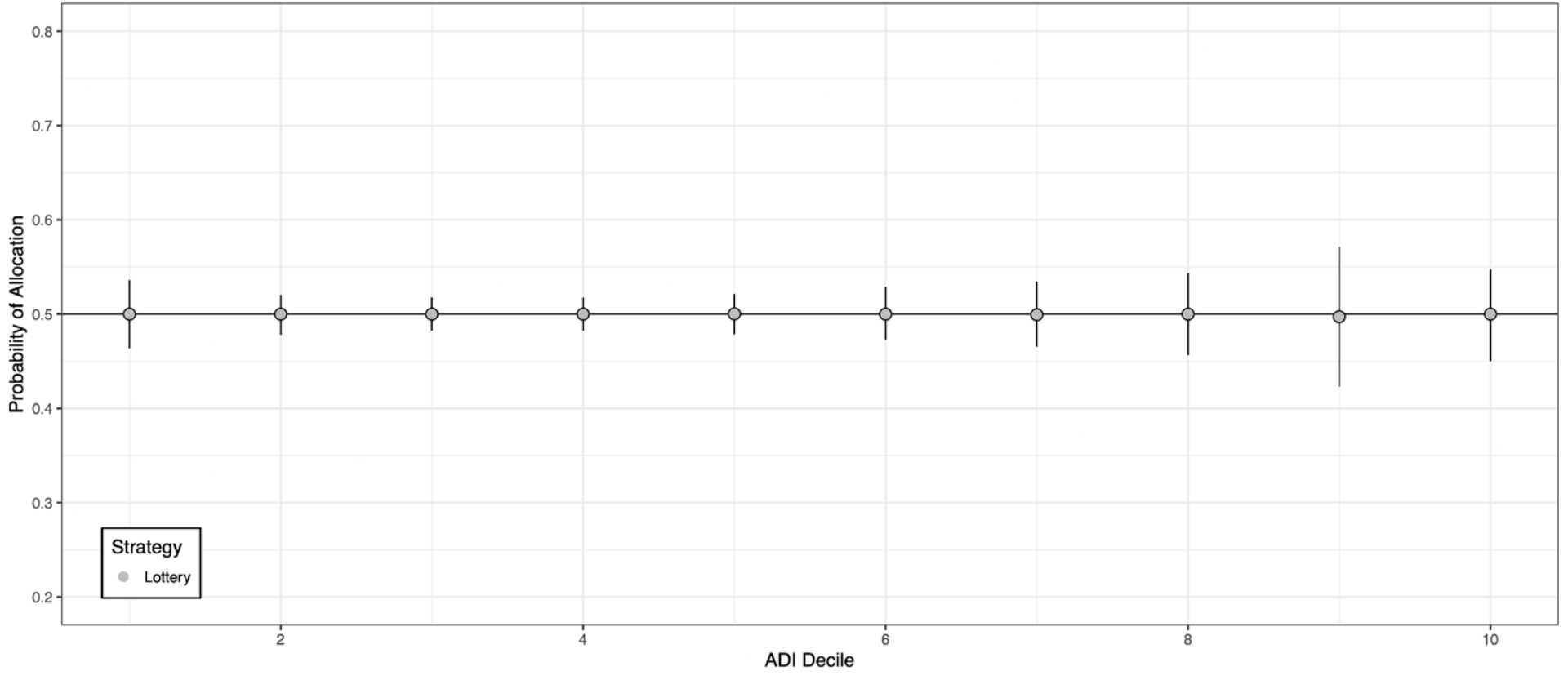
Local Age-Adjusted COVID-19 Mortality



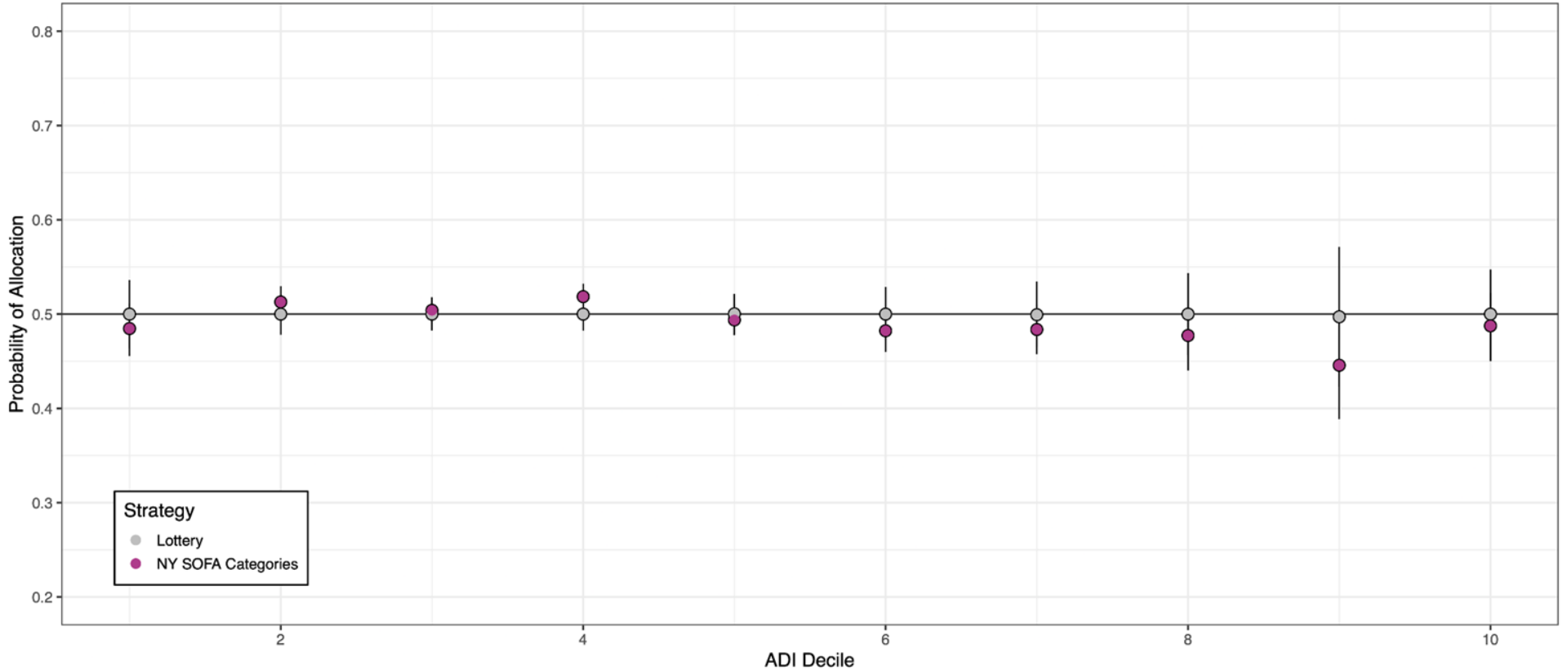
How Do Simulations Assess Performance?

Measurement	Definition
p(bed)	Probability of being assigned an ICU bed (1 - degree_scarcity)
p(survive|bed)	Probability of survival conditional on receiving an ICU bed (% of pts allocated to ICU that survive?)
p(survive overall)	Probability of survival overall (assuming that all patients not allocated ICU beds would die)
n(lives saved)	Each patient allocated to ICU who survives = 1
n(lives saved over lottery)	Compared to a random lottery, how many additional patients will survive with this strategy

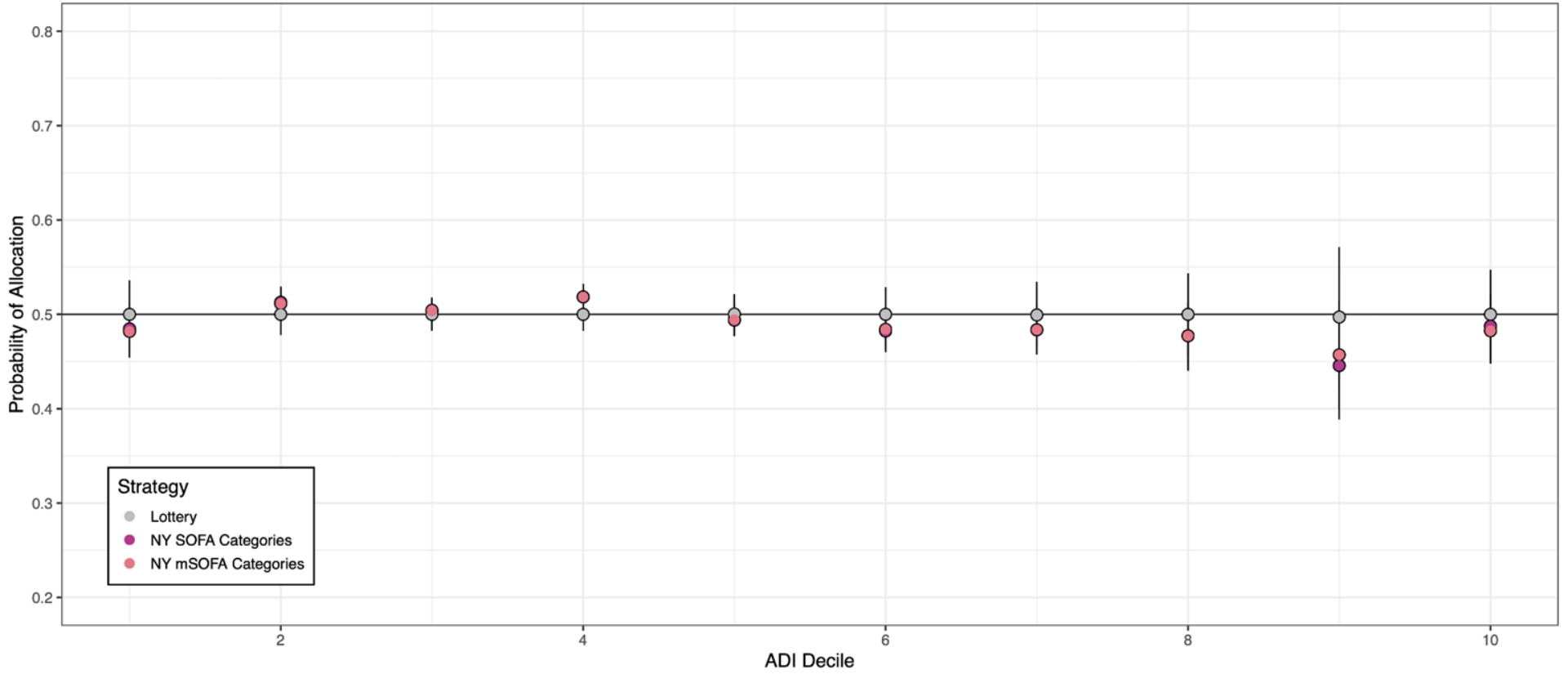
Lottery Allocates Resources Evenly Across ADI Deciles



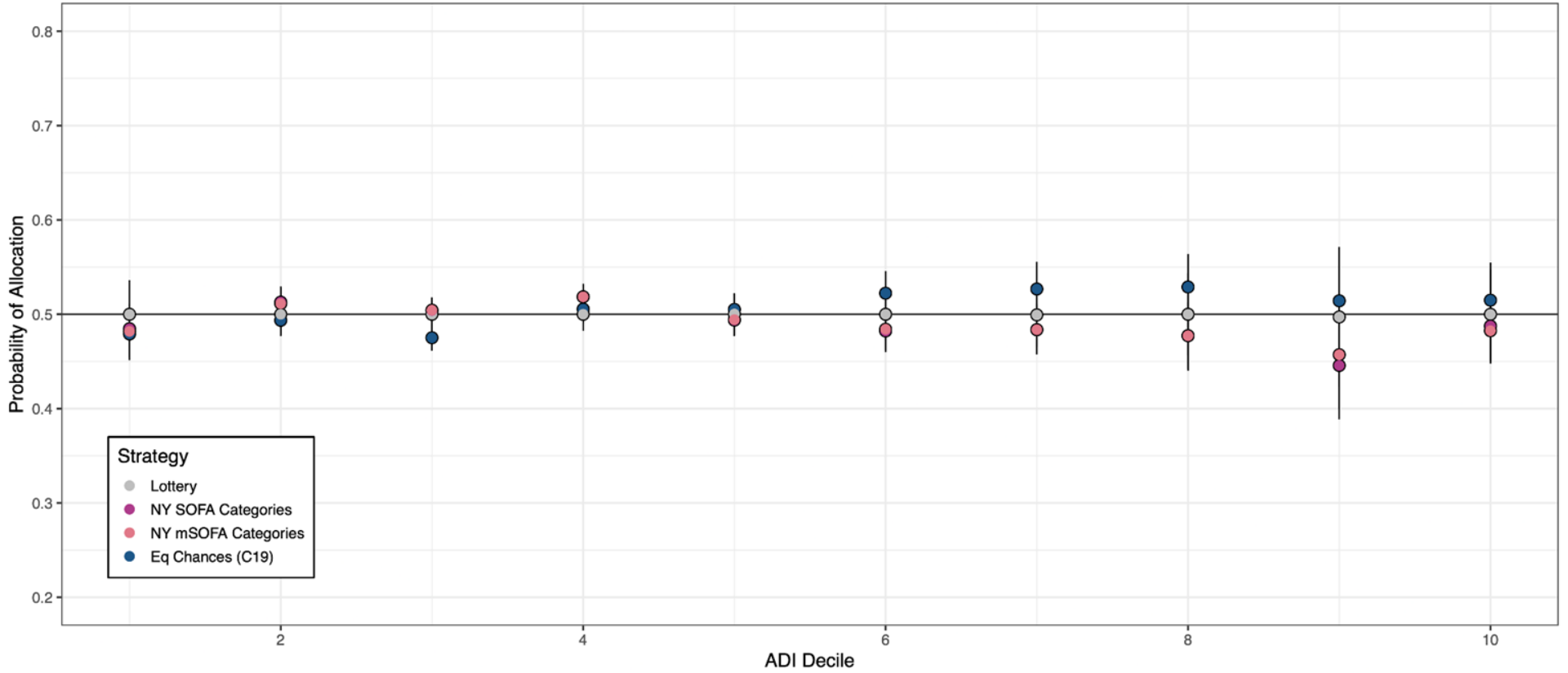
SOFA-based Protocols Deprioritize the Disadvantaged



Renal SOFA Modifications Are Not Much Help



Equitable Chances Can Counteract Biases



Lives Saved Under This Version of Eq. Chances