A Continuous Life-years Gained Priority Score for Ventilator Allocation

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Theory

Military triage- save as many soldiers as possible

In military triage situations, a utilitarian framework is employed to save the greatest number of wounded soliders in a mass casualty event

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3. Rank order patients who will die without critical care by $P(ICUSurvival)$ (Red $>$ Yellow)

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3. Rank order patients who will die without critical care by $P(ICUSurvival)$ (Red $>$ Yellow)
4. Treat as many patients as possible in order of $P(ICUSurvival)$

Problems with military triage approach in the COVID-19 Pandemic

Three patients with COVID-19

28 year old female
- SOFA: 30% survival

80 year old male
- SOFA: 75% survival

60 year old male
- SOFA: 50% survival

Who gets the one remaining ventilator?

New York ventilator allocation policy

Step 2 – Mortality Risk Assessment Using SOFA[1]	
Color Code and Level of Access	**Assessment of Mortality Risk/ Organ Failure**
Blue No ventilator provided. Use alternative forms of medical intervention and/or palliative care or discharge. Reassess if ventilators become available.	Exclusion criterion OR SOFA > 11
Red Highest Use ventilators as available	SOFA < 7 OR Single organ failure[2]
Yellow Intermediate Use ventilators as available	SOFA 8 – 11
Green Use alternative forms of medical intervention or defer or discharge. Reassess as needed.	No significant organ failure AND/OR No requirement for lifesaving resources

Priority rankings under NY triage system

3

28 year old female
- 30% survival

1

80 year old male
- 75% survival

2

60 year old male
- 50% survival

Goes against "youngest first" allocation principles and does not maximize life-years saved

Maximizing life-years gained

An alternative **utilitarian** approach is to maximize life-years gained

Priority Score that maximizes life-years gained

$$PriorityScore = P(ICUSurvival) * (100 - age)$$

Example: Maximizing life-years

Life-years gained allocation

28 year old female
- SOFA: 30% survival
- 100 – 28 = 72 years of life left
- **22 life-years gained** with vent

1

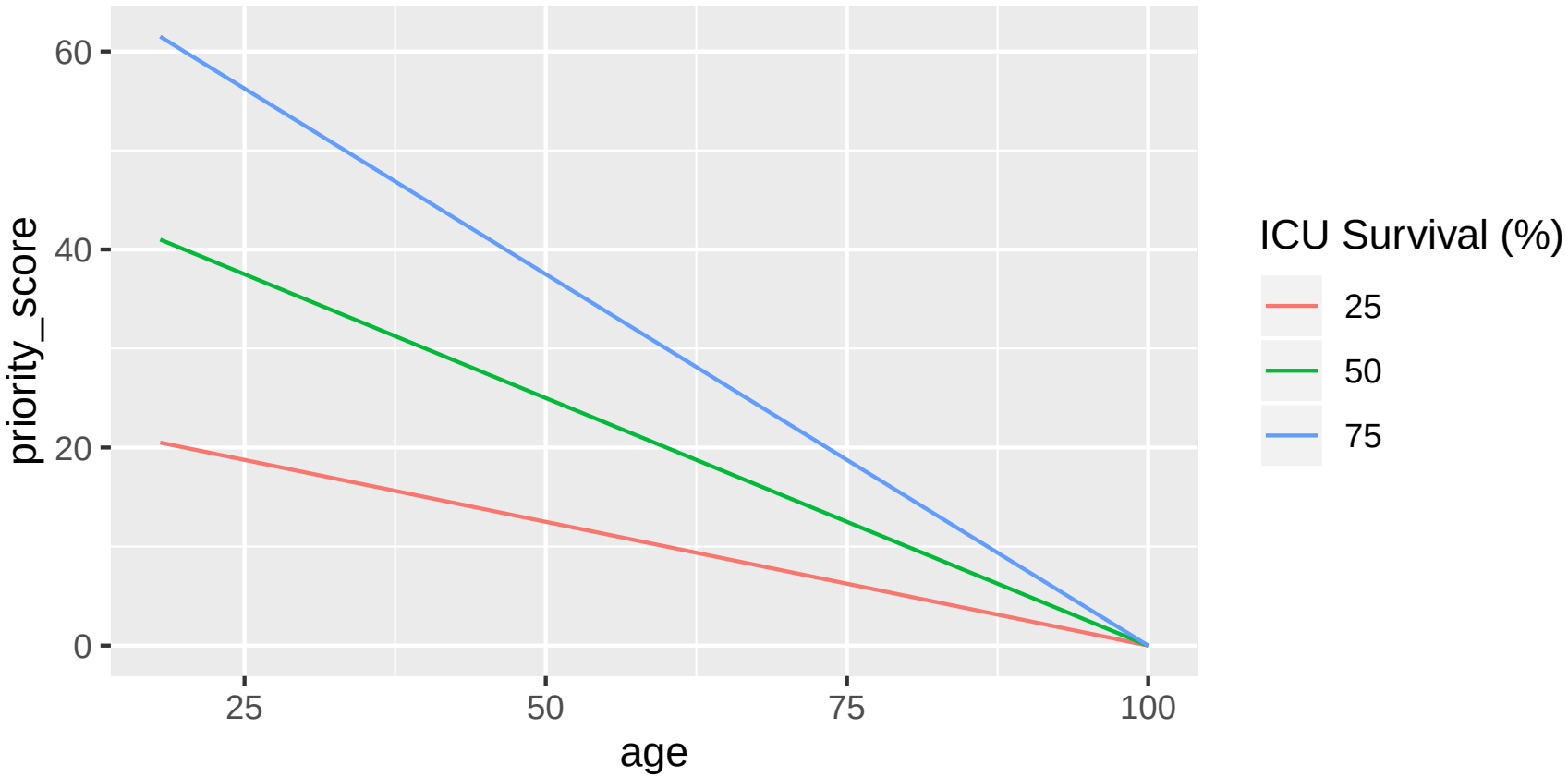
80 year old male
- SOFA: 75% survival
- 100 – 80 = 20 years of life left
- **15 life-years gained** with vent

2

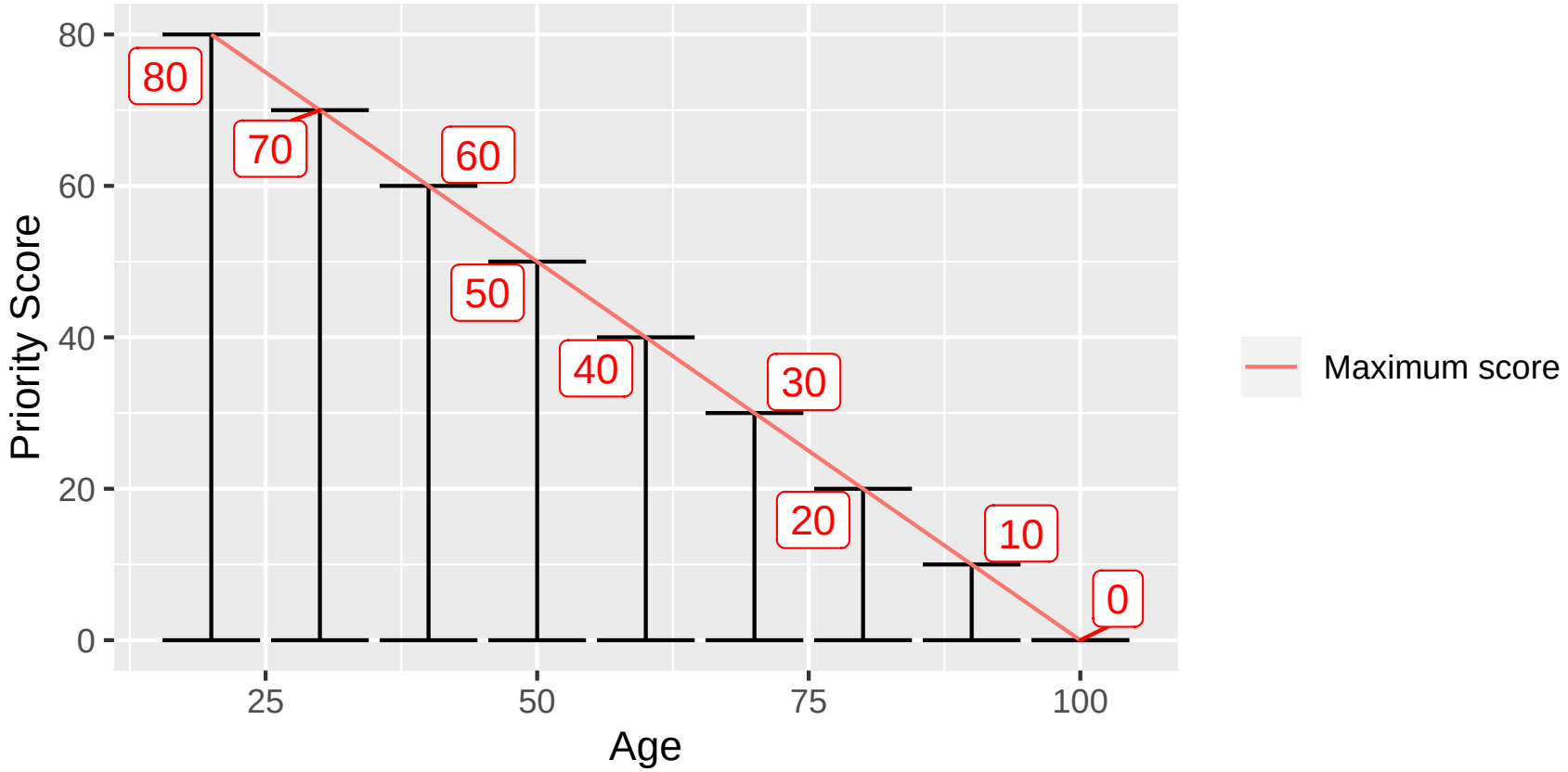
60 year old male
- SOFA: 50% survival
- 100 – 60 = 40 years of life left
- **20 life-years gained** with vent

3

Priority Score vs. Patient Age, by Probability of ICU Survival



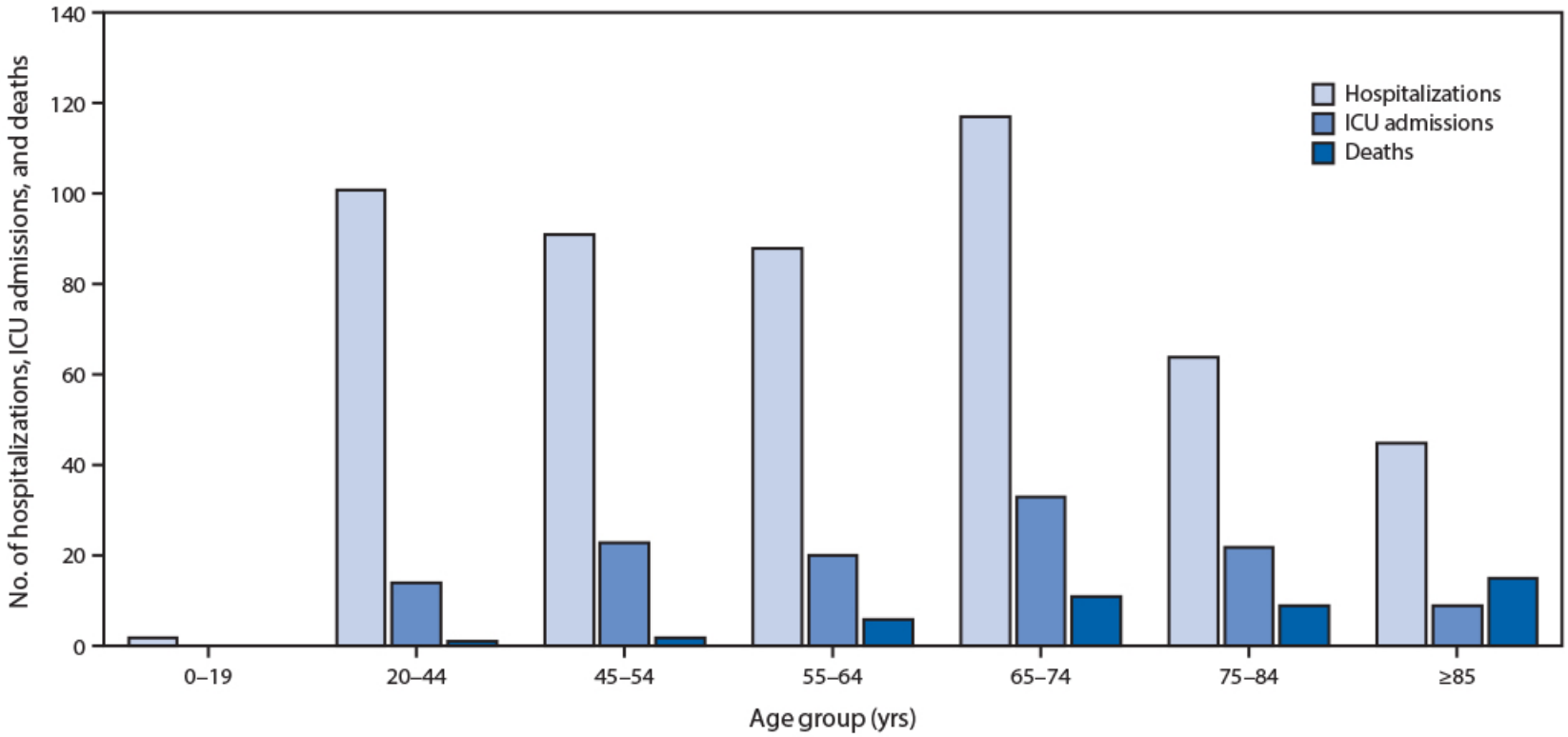
Range of possible priority scores by patient age



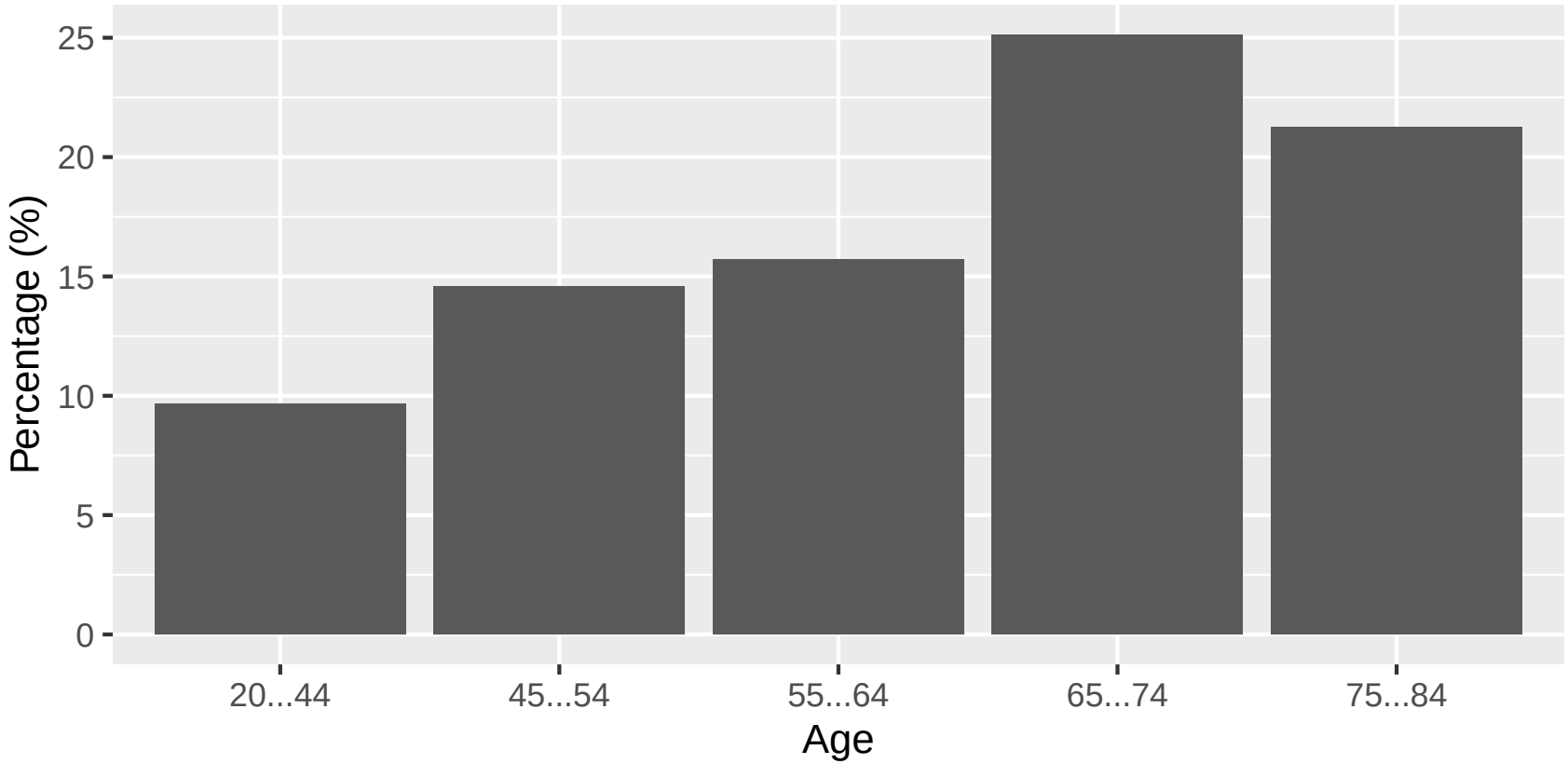
Simulation using CDC data

Data sources

We took data from the CDC report Severe Outcomes Among Patients with Coronavirus Disease 2019 — United States, February 12–March 16, 2020

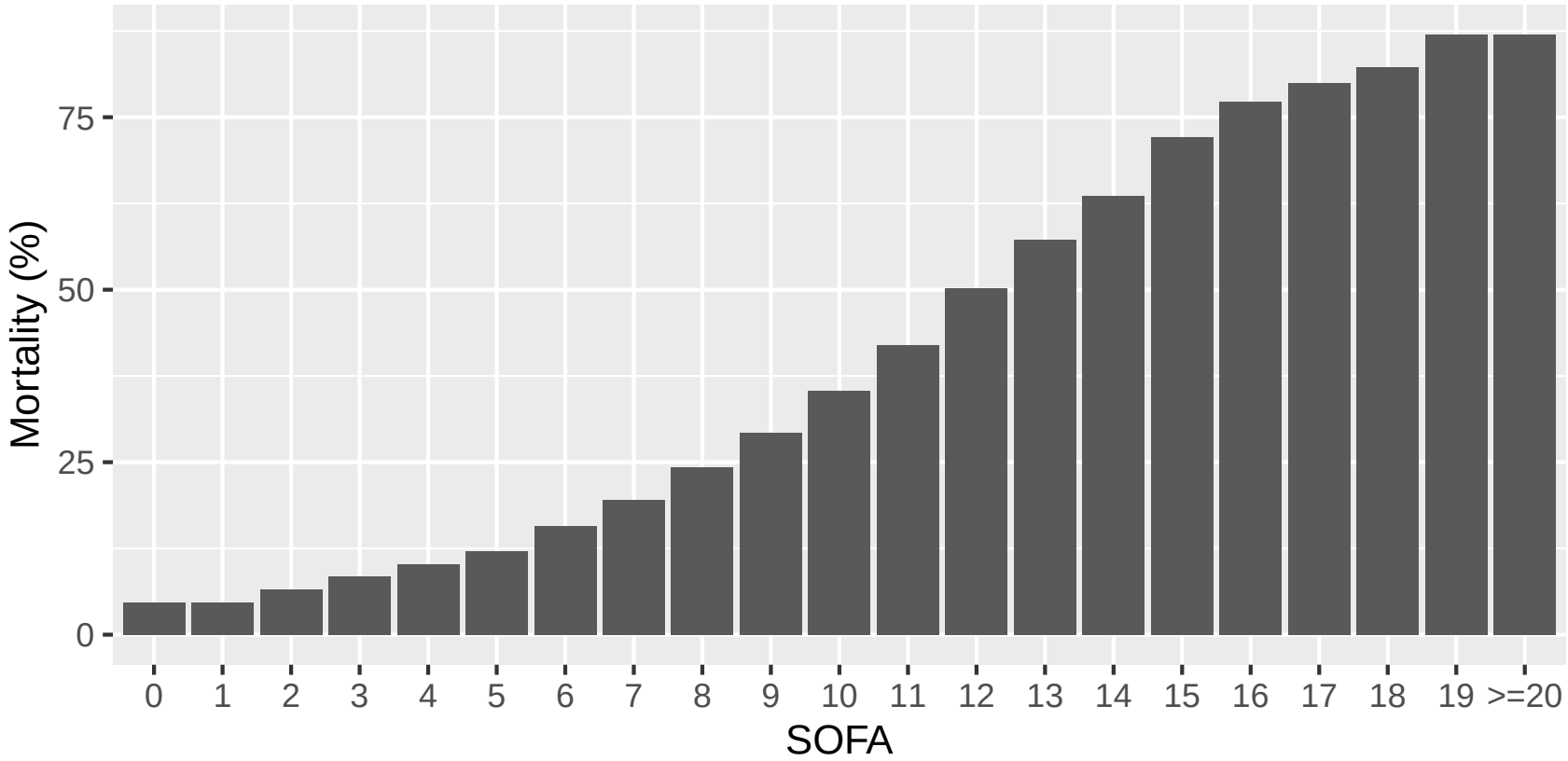


COVID-19 Age Distribution of patients requiring ICU

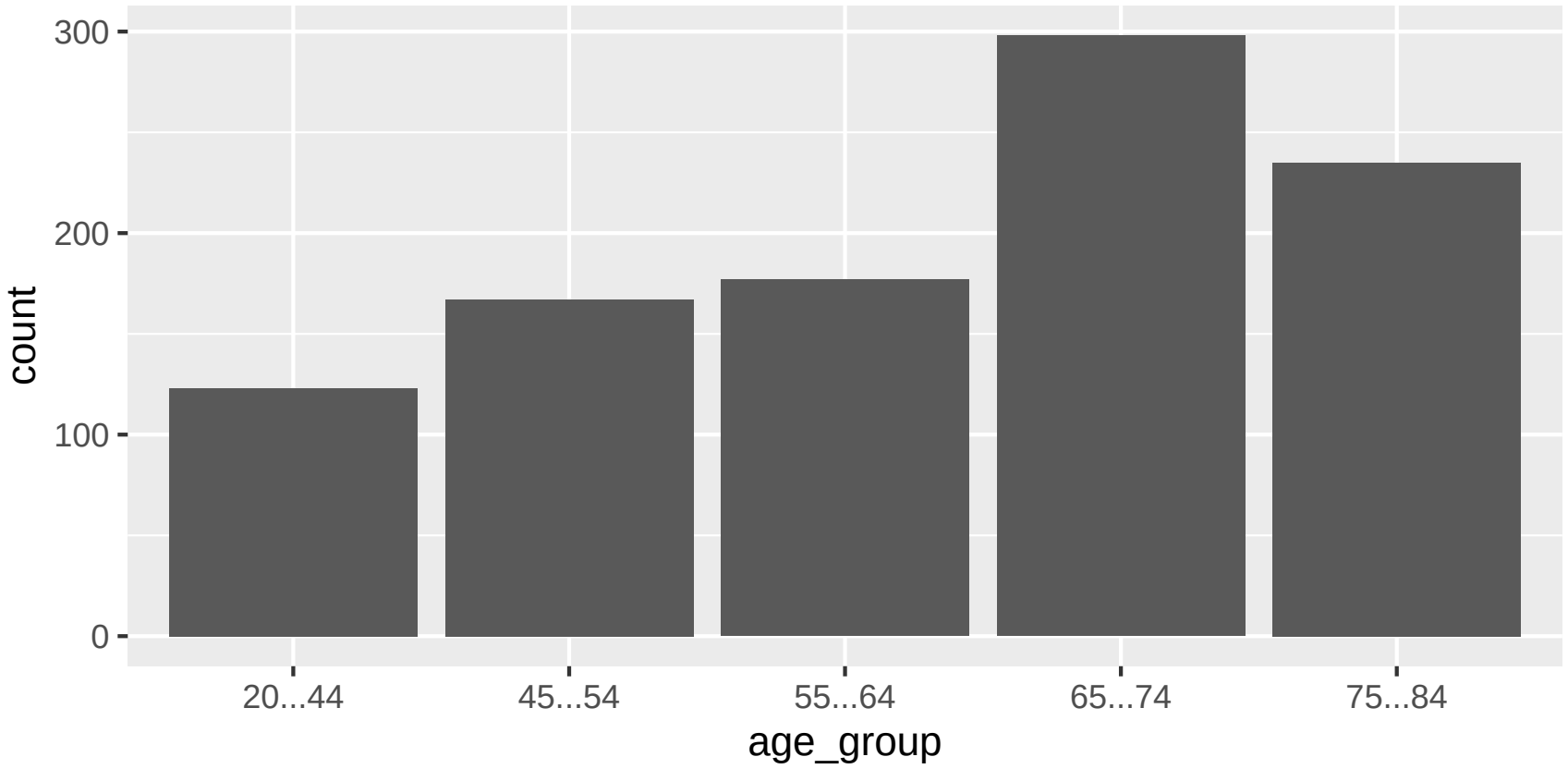


Calibration of the SOFA score

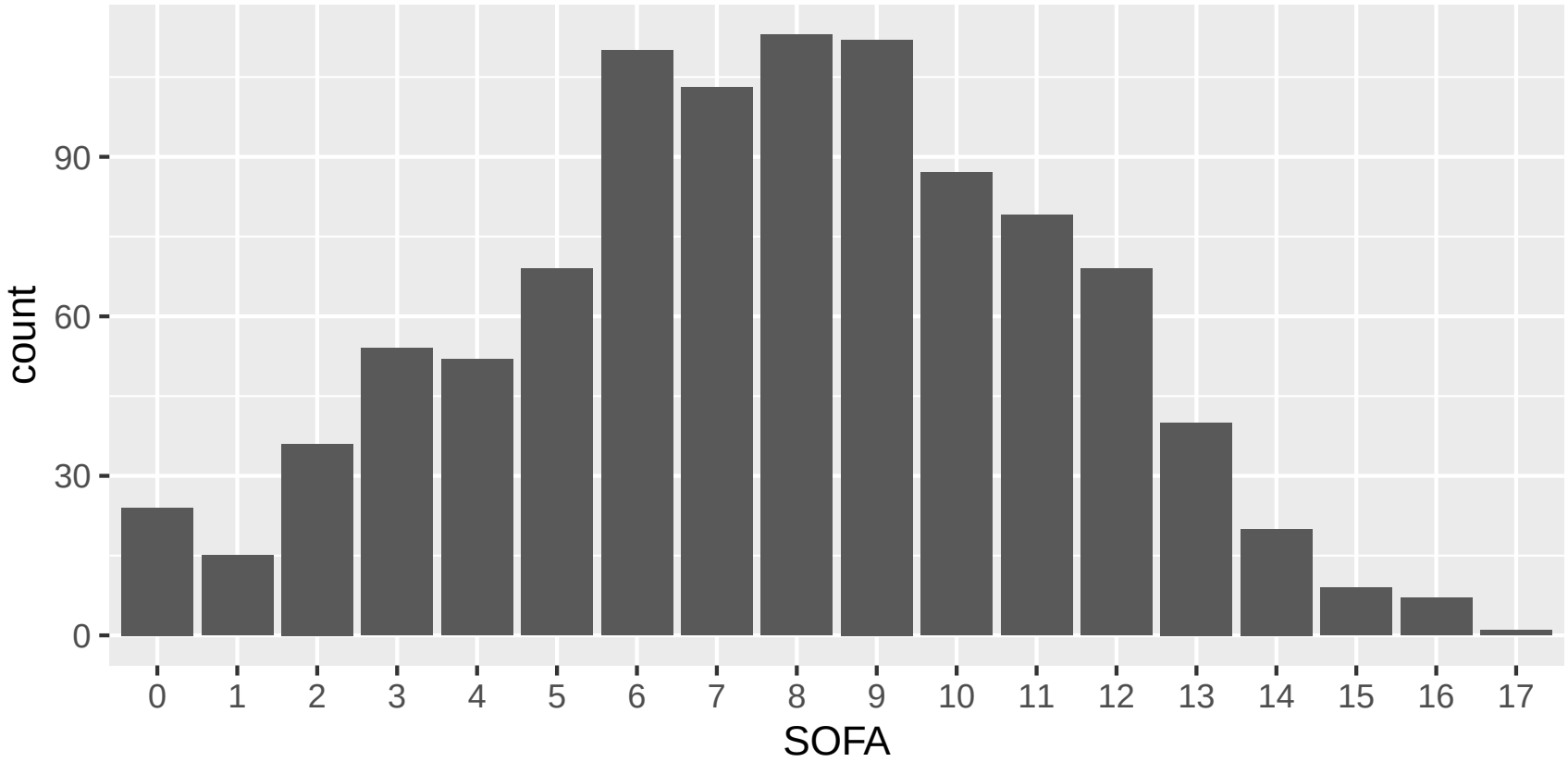
The Sequential Organ Failure Assesment (SOFA) score is a validated bedside predictor of ICU mortality. The calibration of SOFA scores is drawn from *Raith et al. JAMA, 2017*



Simulated ICU population from CDC Data



Simulated SOFA score distribution

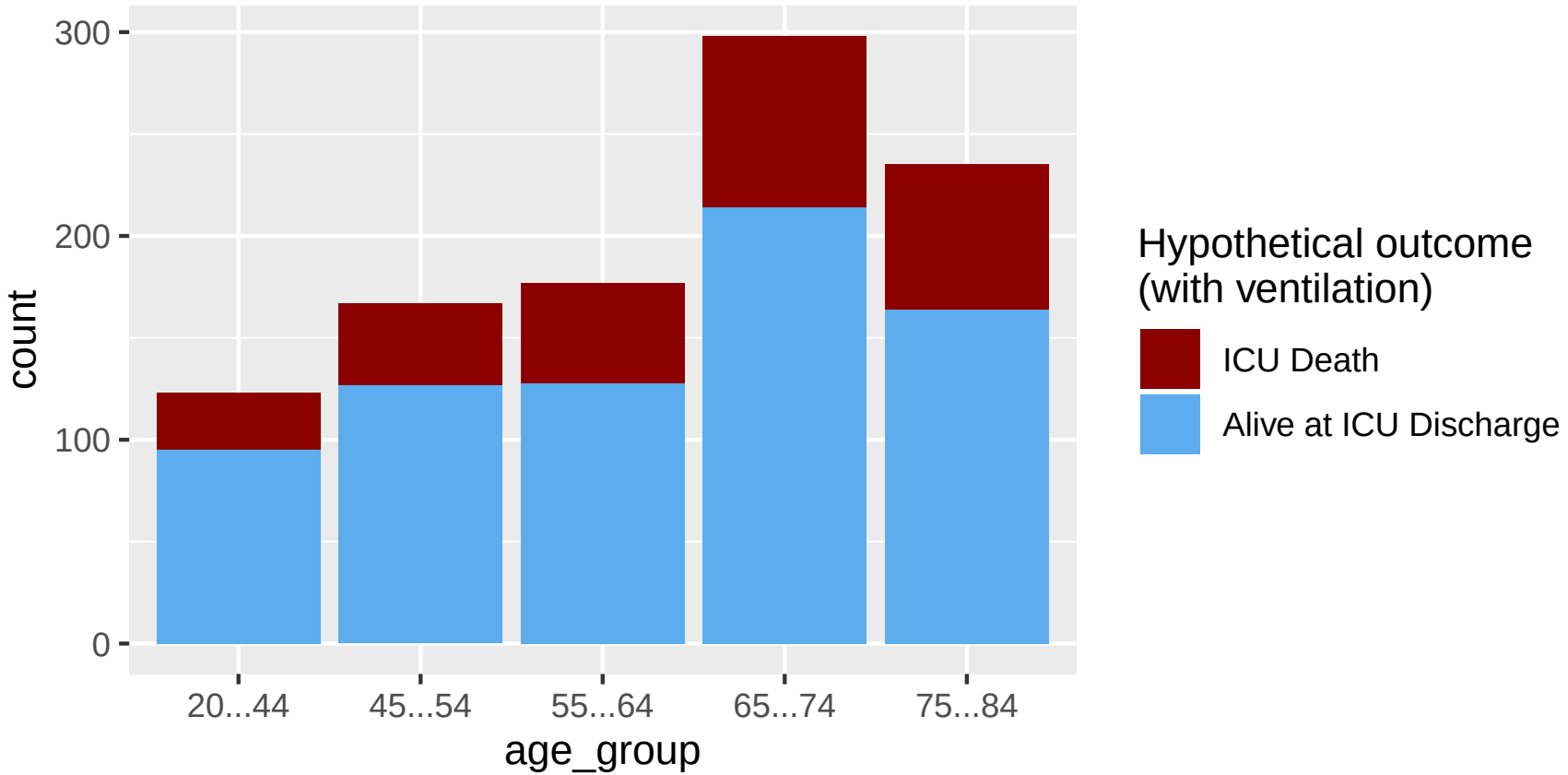


Currently drawn from $f(SOFA|age) = N(8 + \frac{age-65}{30}, 3.5)$, need to replace with a distribution estimated from real data.

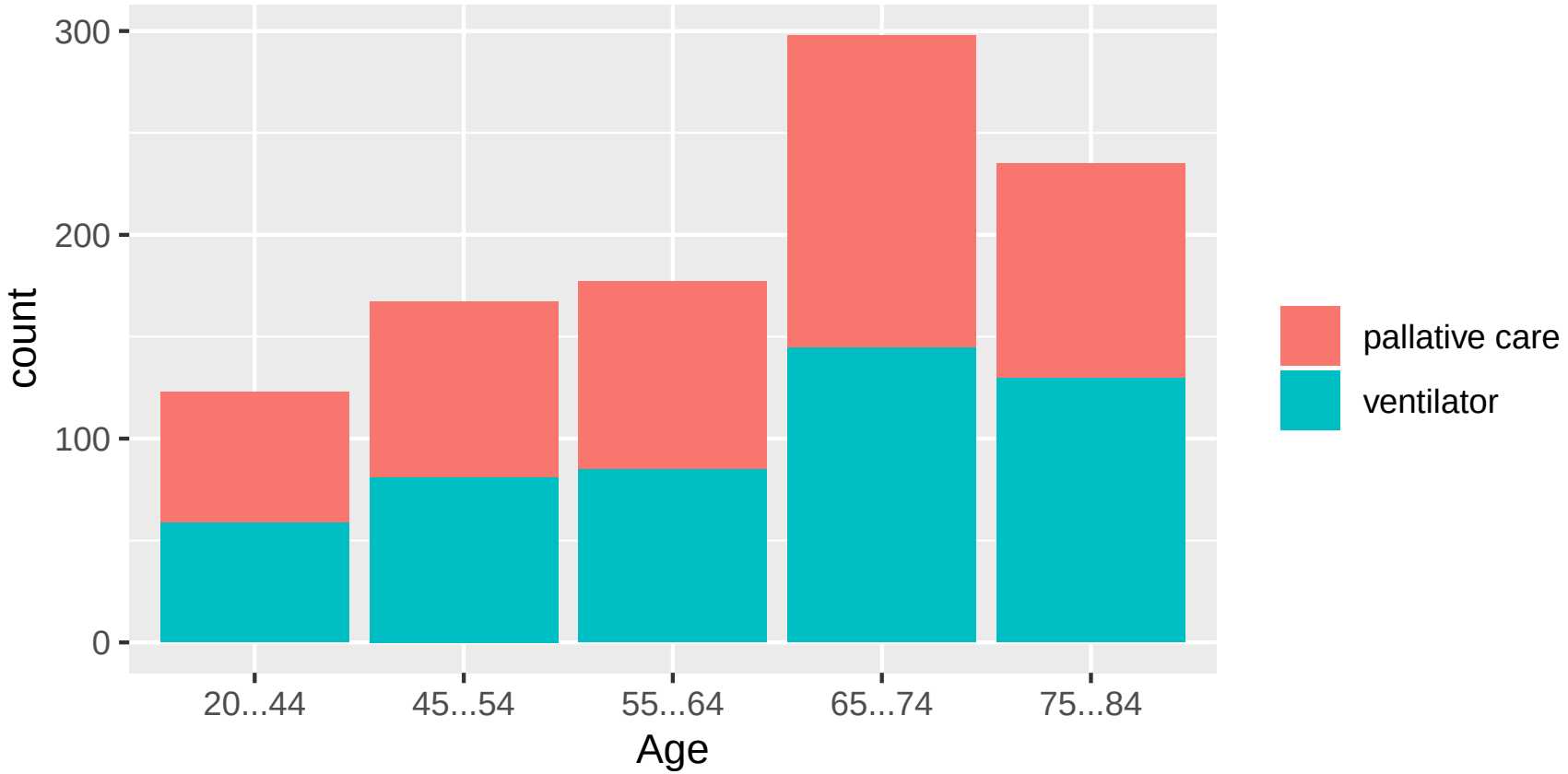
SOFA Score by Age

Age	Mean SOFA	Survival with Ventilator
20–44	7.1	77%
45–54	7.0	77%
55–64	8.2	71%
65–74	7.9	72%
75–84	7.9	72%

Simulated Outcomes by Age

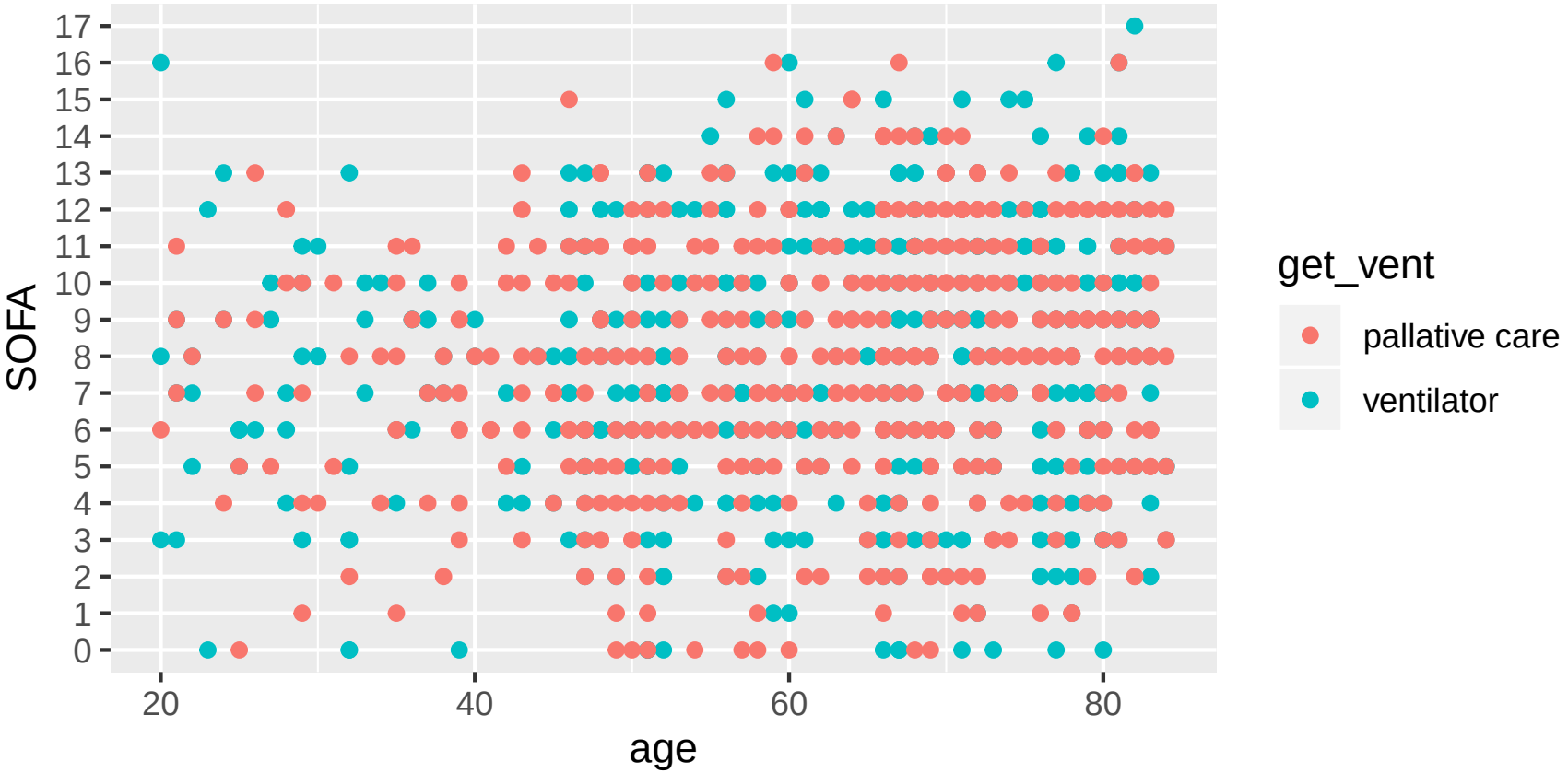


Lottery allocation

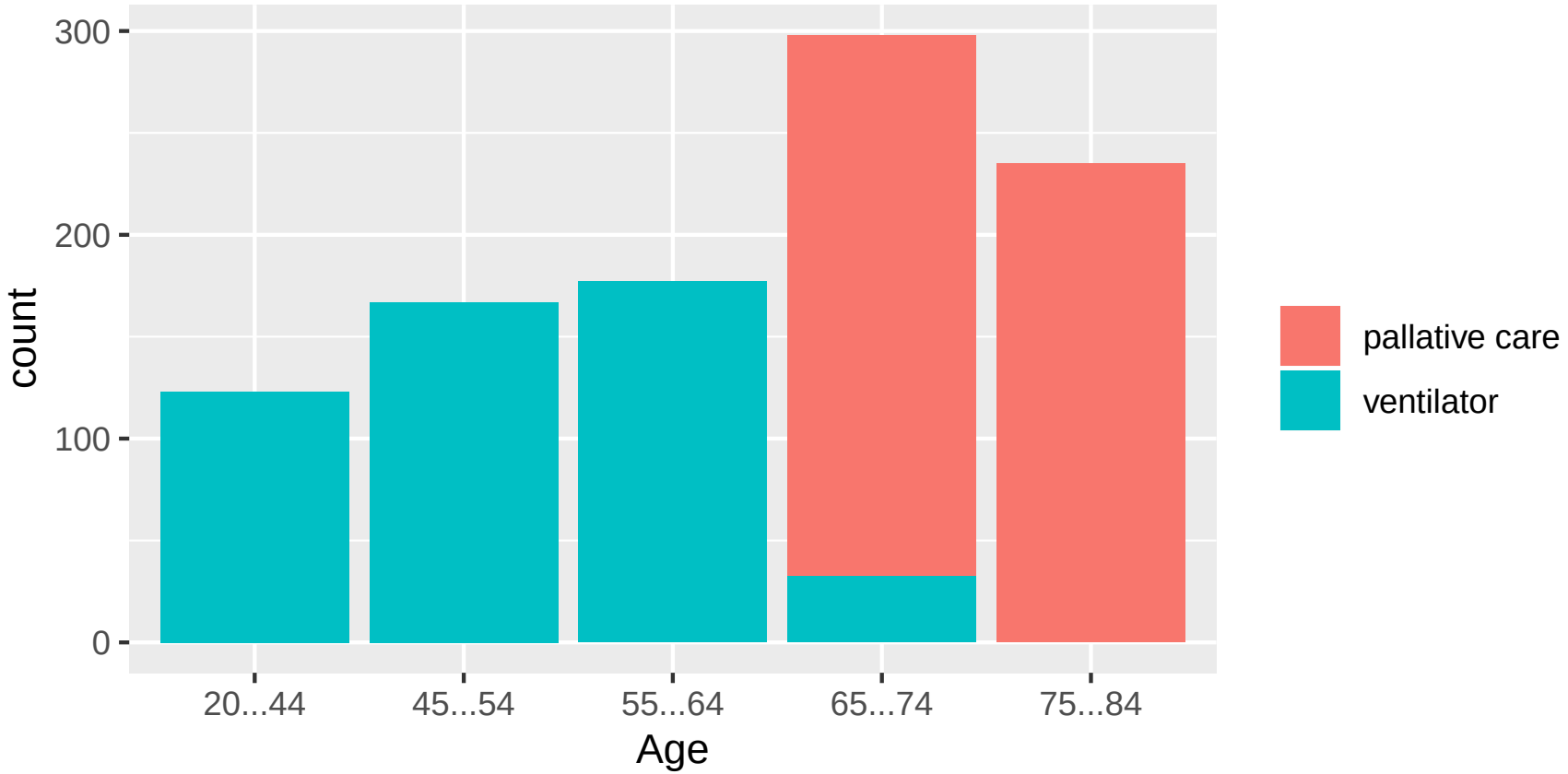


A random allocation of 500 ventilators would save 368 out of 1000 patients admitted to the ICU. A lottery saves 13,994 (37%) out of a total of possible 37,826 life years.

Lottery- age vs. SOFA

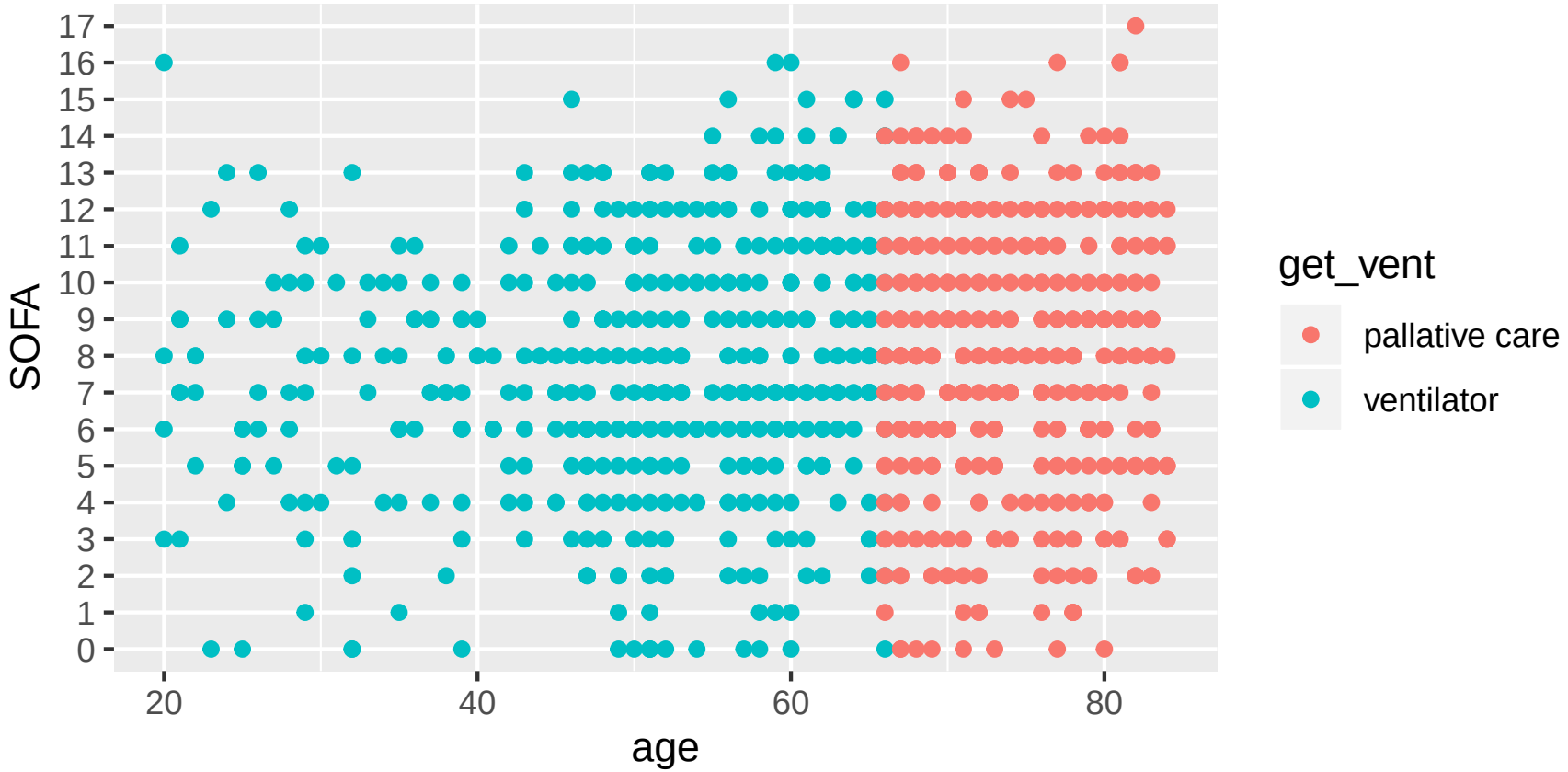


Youngest first allocation

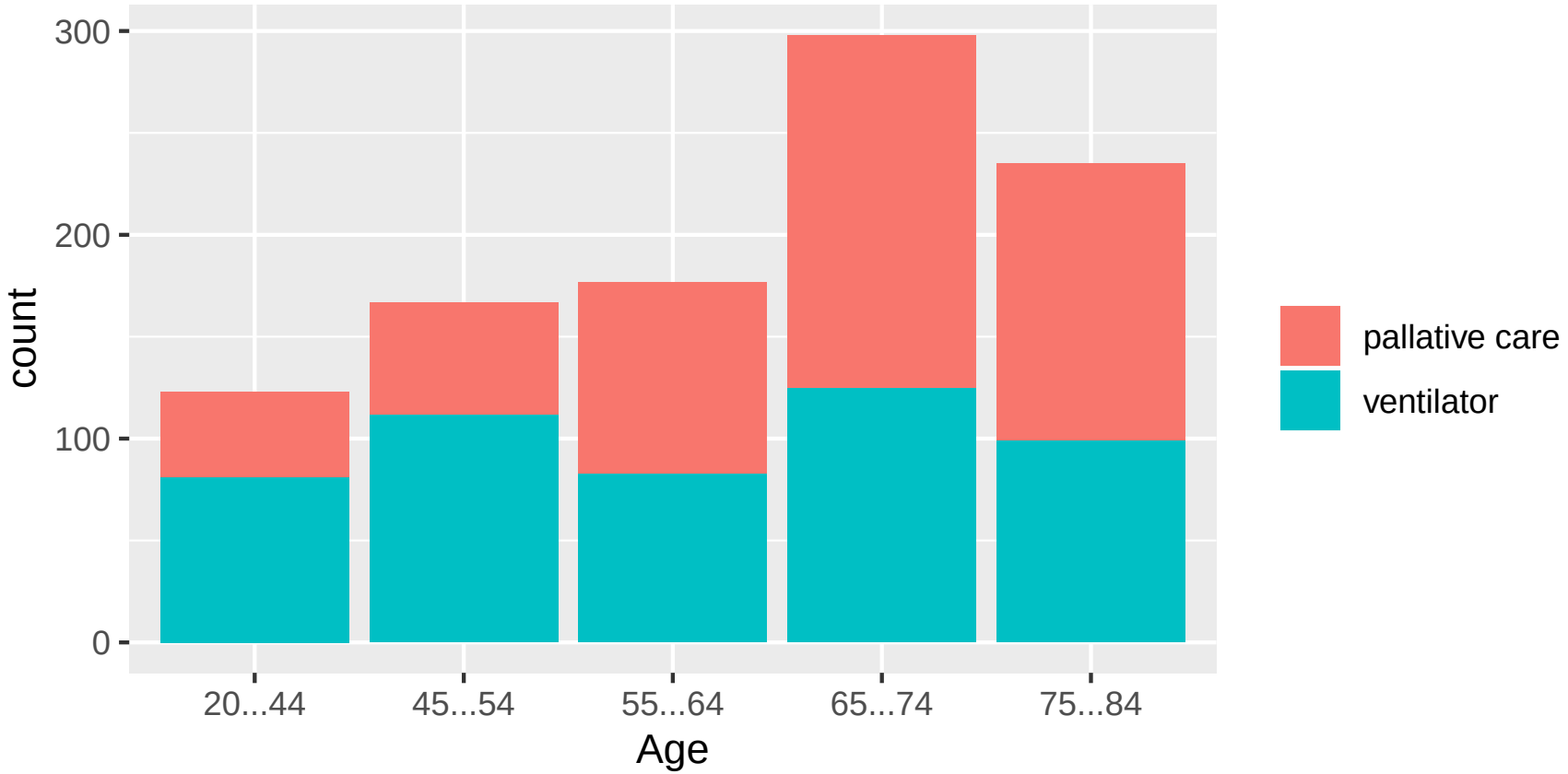


Youngest first allocation 500 ventilators would save 373 out of 1000 patients admitted to the ICU. Youngest first saves 18,713 (49%) out of a total of possible 37,826 life years.

Youngest first allocation- age vs. SOFA

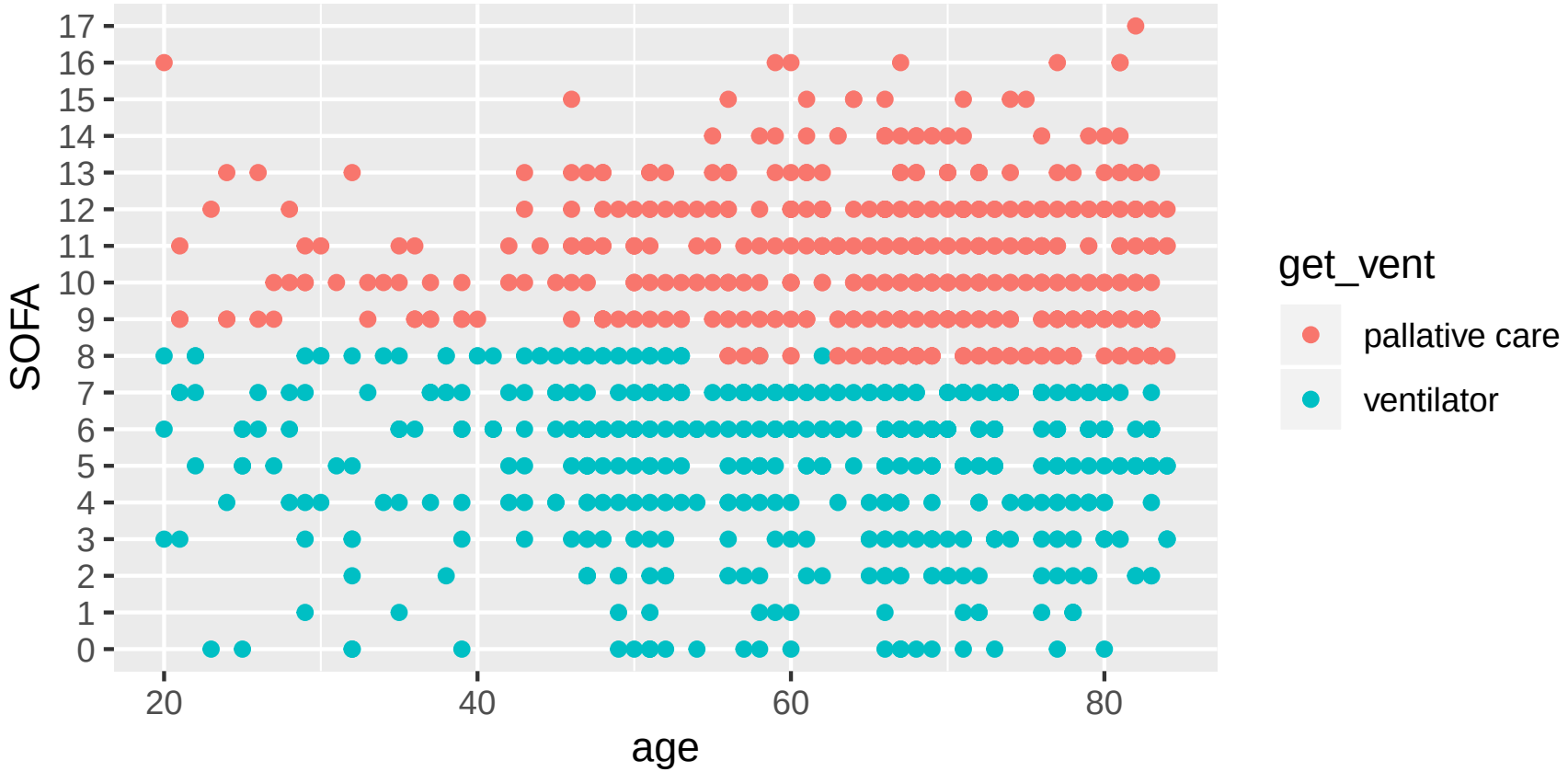


Maximizing ICU survival

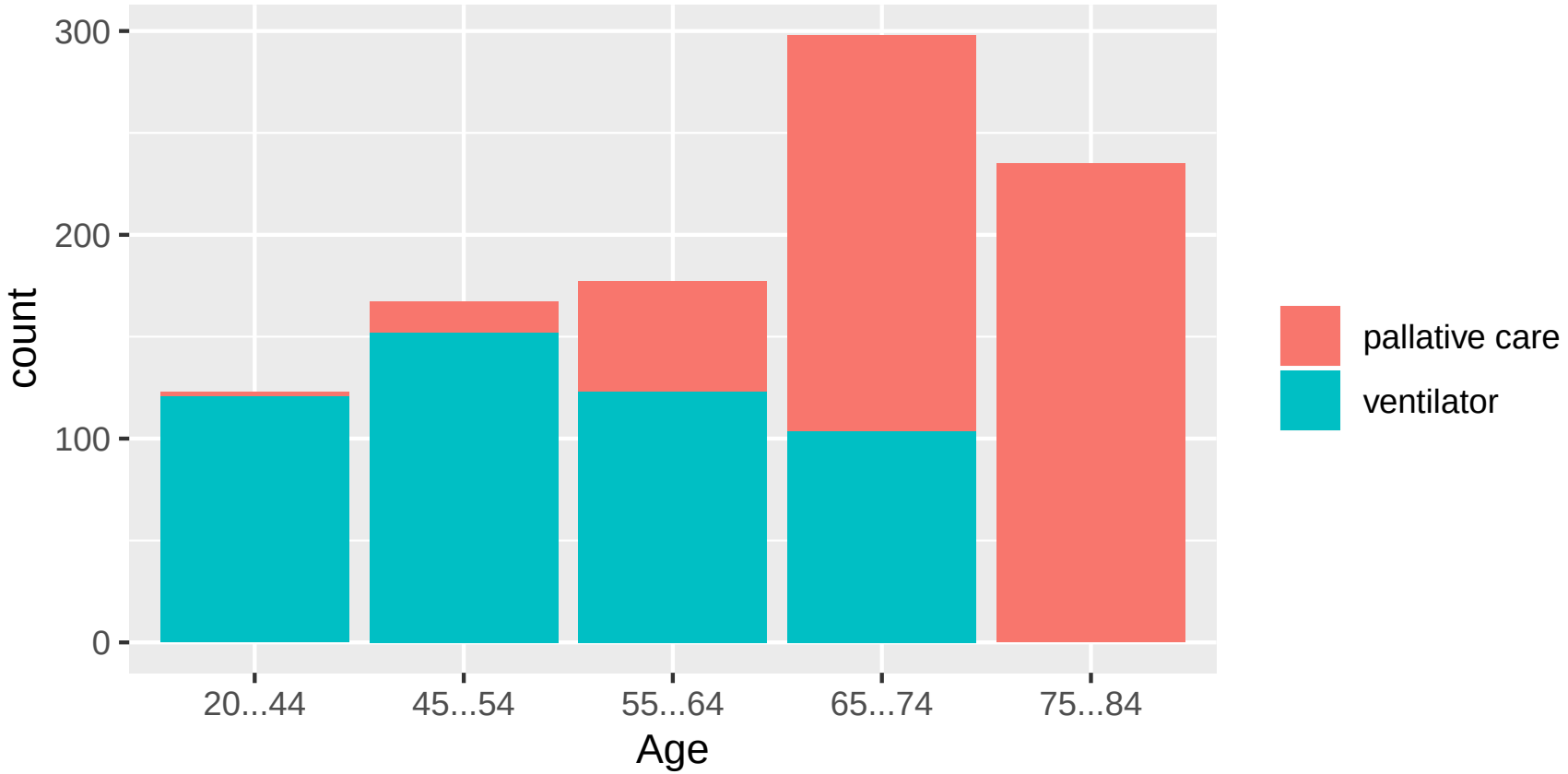


A $P(ICU survival)$ triage system of 500 ventilators would save 420 out of 1000 patients admitted to the ICU. Maximizing ICU survival saves 17,101 out of a total of possible 37,826 (45%)

Max ICU survival- age vs. SOFA



Maximizing Life-years gained



Prioritizing life-years for 500 ventilators would save 405 out of 1000 patients admitted to the ICU. Maximizing life-years gained saves 19,411 out of a total of possible 37,826 (51%) life-years.

Max life years- age vs. SOFA

Maximizing life-years vs. ICU survival

Prioritizing young sick patients over old healthy patients leads to more ICU deaths in exchange for more life-years gained.

The Tradeoff

Prioritizing life-years gained over ICU survival saves an additional 2,310 life-years for this 1000 patient sample, at a cost of 15 more deaths in the ICU.