

A Continuous Life-years Gained Priority Score for Ventilator Allocation

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1 Theory

2 Simulation using CDC data

Theory

Military triage- save as many soldiers as possible

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- 3 Rank order patients who will die without critical care by $P(ICU\text{Survival})$ (Red > Yellow)
- 4 Treat as many patients as possible in order of $P(ICU\text{Survival})$

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

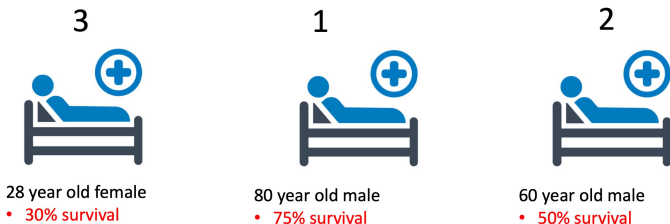
- SOFA: 50% survival

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
<p>Blue</p> <p>No ventilator provided. Use alternative forms of medical intervention and/or palliative care or discharge.</p> <p>Reassess if ventilators become available.</p>	<p>Exclusion criterion</p> <p>OR</p> <p>SOFA > 11</p>
<p>Red</p> <p>Highest</p> <p>Use ventilators as available</p>	<p>SOFA < 7</p> <p>OR</p> <p>Single organ failure²</p>
<p>Yellow</p> <p>Intermediate</p> <p>Use ventilators as available</p>	<p>SOFA 8 – 11</p>
<p>Green</p> <p>Use alternative forms of medical intervention or defer or discharge.</p> <p>Reassess as needed.</p>	<p>No significant organ failure</p> <p>AND/OR</p> <p>No requirement for lifesaving resources</p>

Priority rankings under NY triage system



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

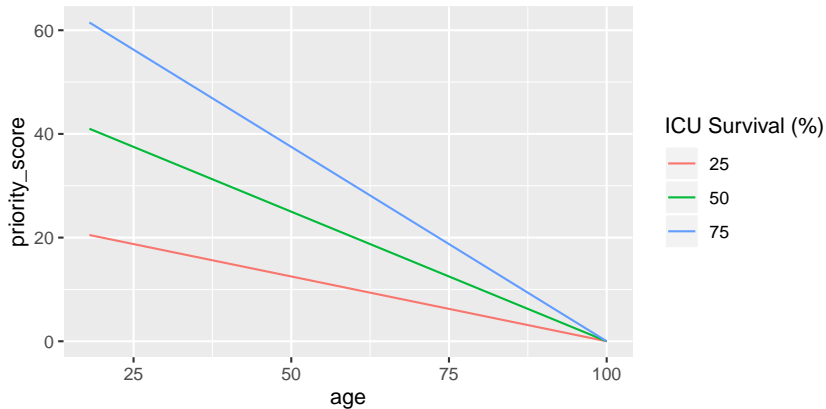
Maximizing life-years gained

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

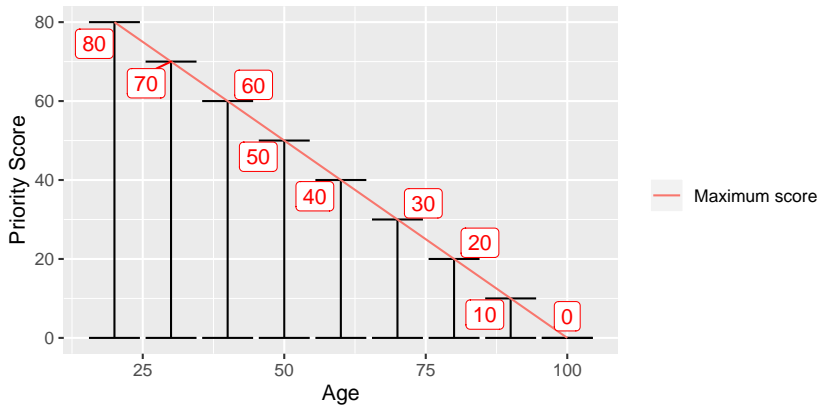
Priority Score that maximizes life-years gained

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

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



Range of possible priority scores by patient age



Allocation that maximizes life-years saved

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

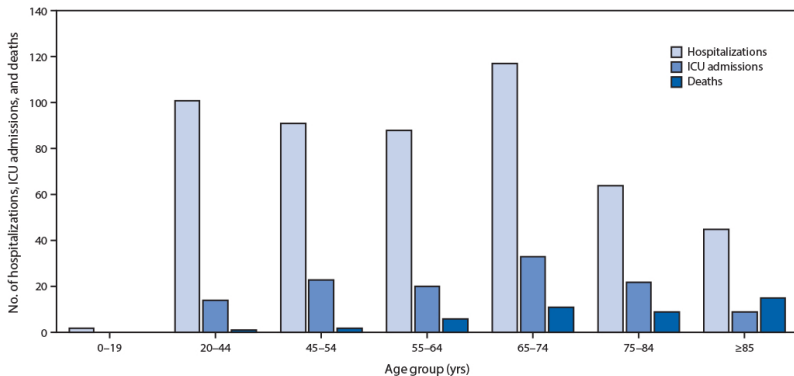
- SOFA: 50% survival
- $100 - 60 = 40$ years of life left
- **20 life-years gained** with vent

3

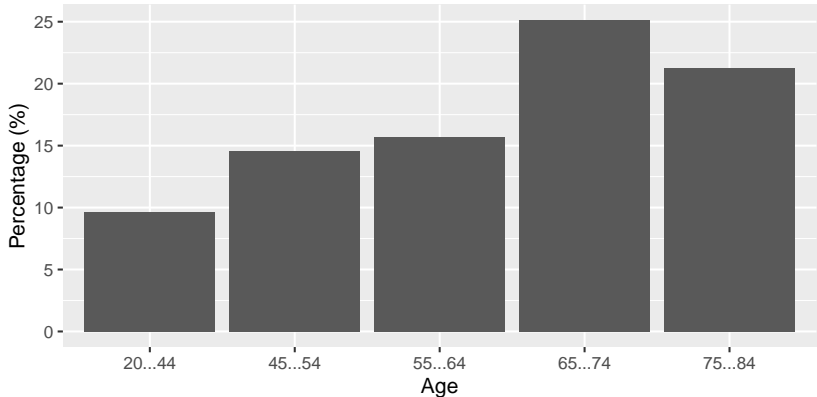
Simulation using CDC data

Data sources

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

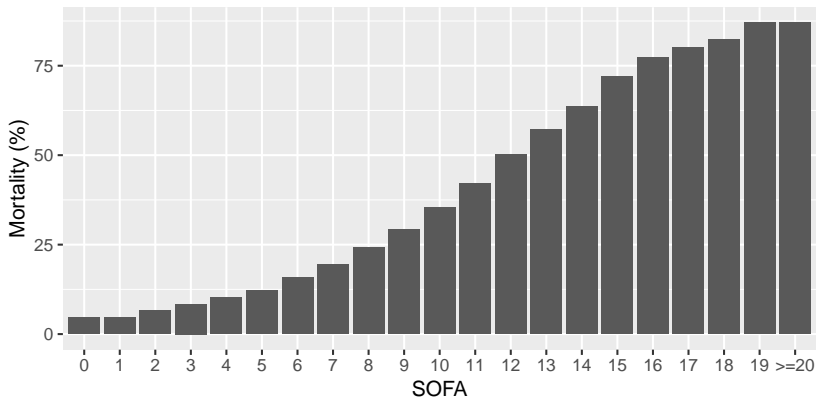


COVID-19 Age Distribution of patients requiring ICU

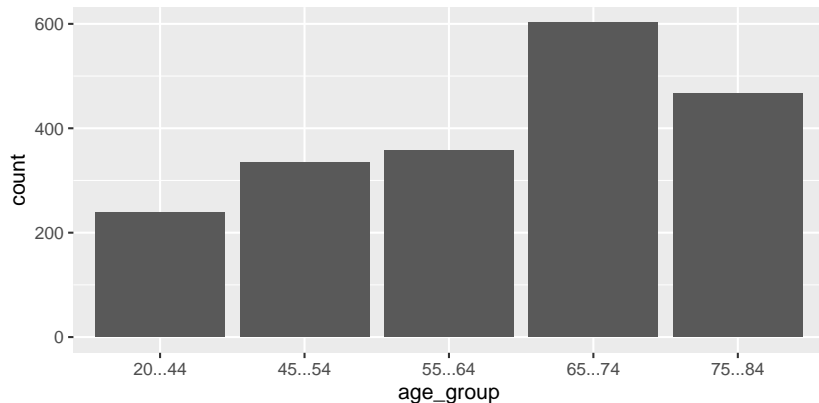


Calibration of the SOFA score

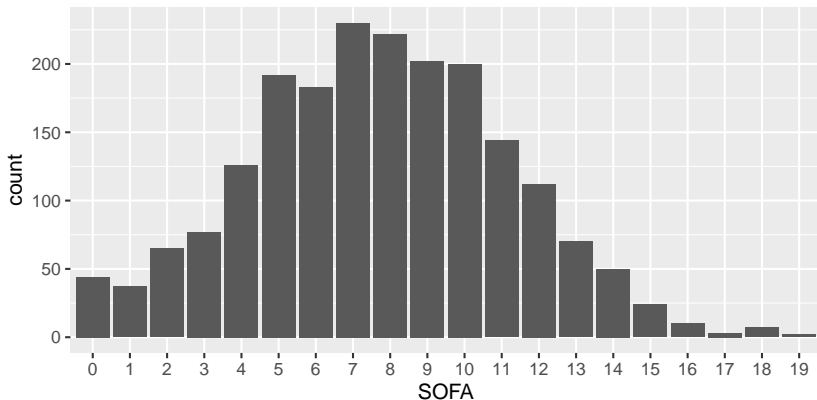
The Sequential Organ Failure Assessment (SOFA) score is a validated bedside predictor of ICU mortality. The calibration of SOFA scores is drawn from *Raith et al. JAMA, 2017*



Simulated ICU population from CDC Data



Simulated SOFA score distribution

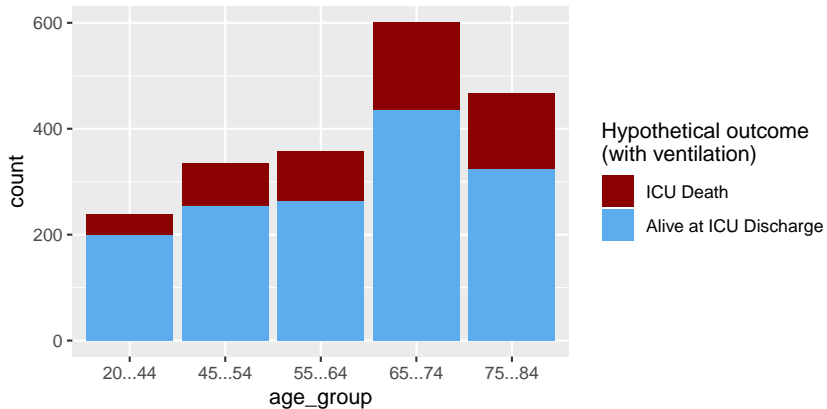


Currently drawn from $f(SOFA|age) = N(8 + \frac{age-65}{30}, 3.5)$, need to replace with a distribution estimated from real data.

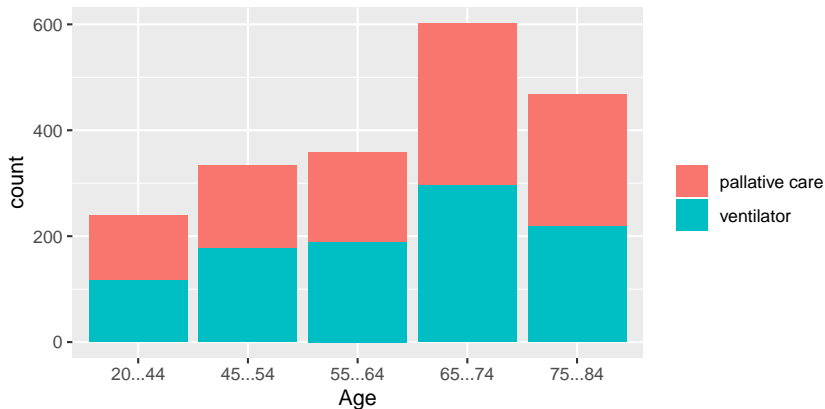
SOFA Score by Age

Age	Mean SOFA	Survival with Ventilator
20–44	6.6	79%
45–54	7.3	75%
55–64	7.5	74%
65–74	7.9	73%
75–84	8.5	70%

Simulated Outcomes by Age

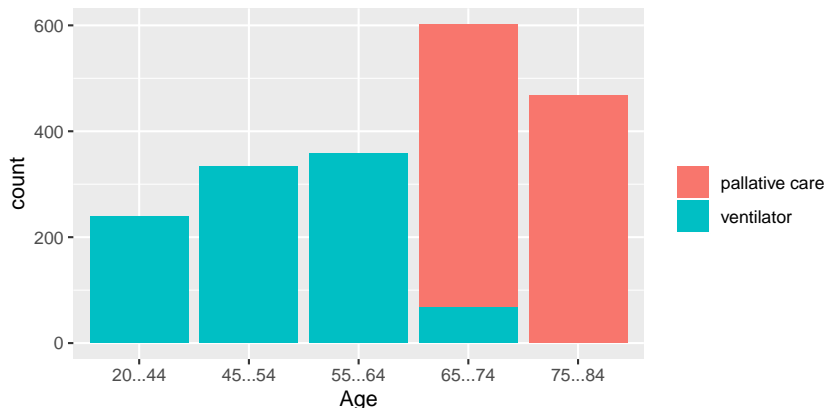


Lottery allocation



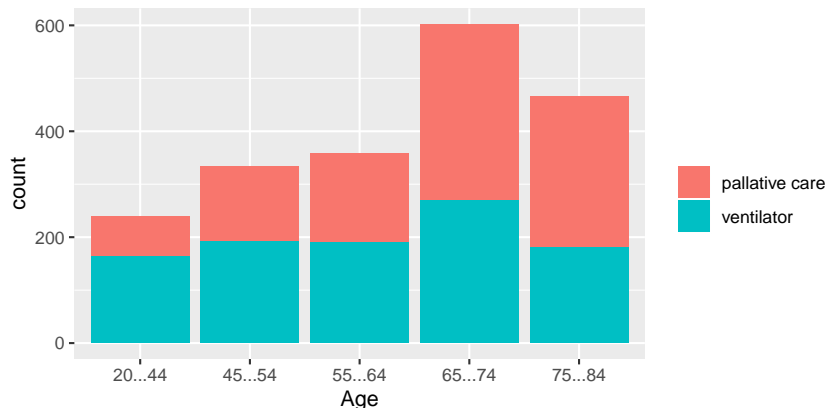
A random allocation of 1000 ventilators would save 736 out of 2000 patients admitted to the ICU. A lottery saves 28,508 (38%) out of a total of possible 75,313 life years.

Youngest first allocation



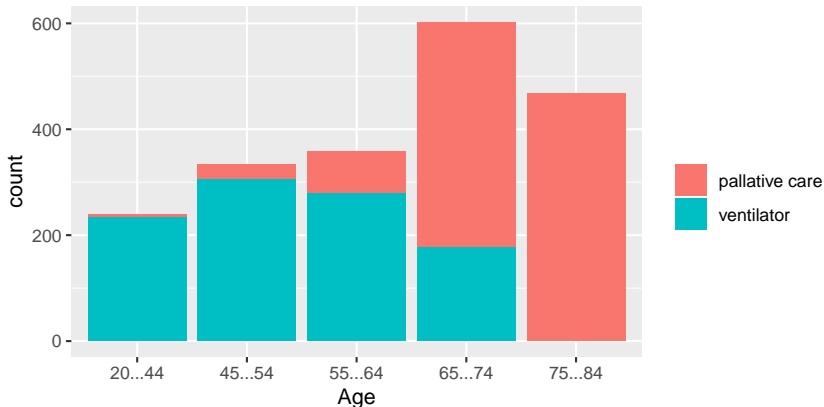
Youngest first allocation 1000 ventilators would save 774 out of 2000 patients admitted to the ICU. Youngest first saves 38,832 (52%) out of a total of possible 75,313 life years.

Maximizing ICU survival



A $P(ICU\ survival)$ triage system of 1000 ventilators would save 869 out of 2000 patients admitted to the ICU. Maximizing ICU survival saves 35,401 out of a total of possible 75,313 (47%)

Maximizing Life-years gained



Prioritizing life-years for 1000 ventilators would save 823 out of 2000 patients admitted to the ICU. Maximizing life-years gained saves 39,729 out of a total of possible 75,313 (53%) life-years.

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 4,328 life-years for this 2000 patient sample, at a cost of 46 more deaths in the ICU.