

Ventilator Sharing during an Acute Shortage from the Covid-19 Epicenter in New York

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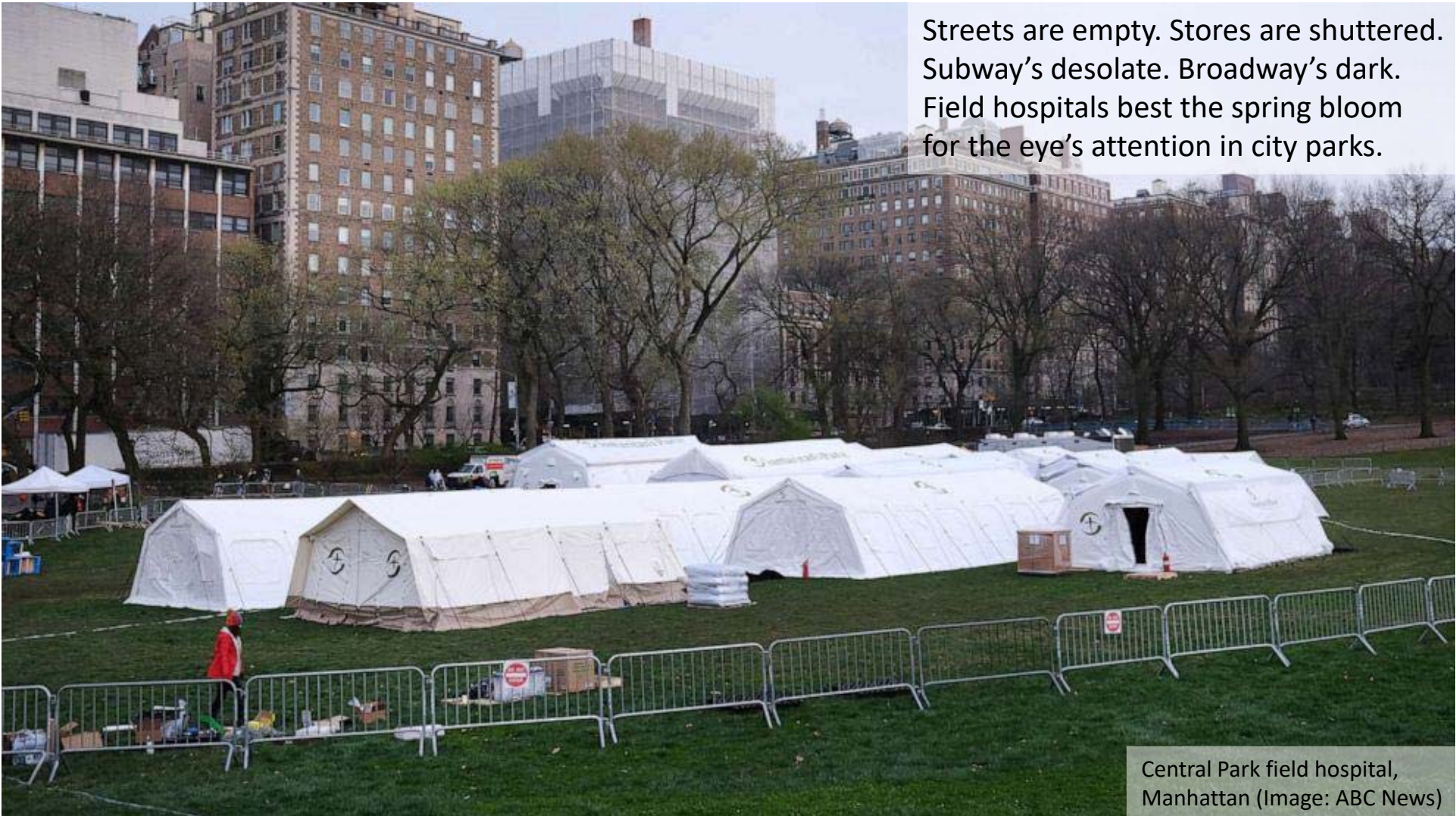
Overview

- Context: the experience on the frontlines
- Acute ventilator shortages
- Avoiding a replay of New York

Spring in New York

I have never seen war,
but I imagine it much like New York today:
a perpetual plunge
into panic, hyperarousal, and dismay.

-----r-----y-----




Streets are empty. Stores are shuttered. Subway's desolate. Broadway's dark. Field hospitals best the spring bloom for the eye's attention in city parks.

Central Park field hospital, Manhattan (Image: ABC News)

We care for critical colleagues unconscious and near death, who may forebode our shared fate in their last agonal breaths.



Washington Heights, Manhattan
(Image: Personal photo)



Face the fragility of our flesh
not together, but alone,
for families we'll never meet,
stories never told.

CU Soccer Stadium conversion to hospital, Manhattan
Image: Turner Construction



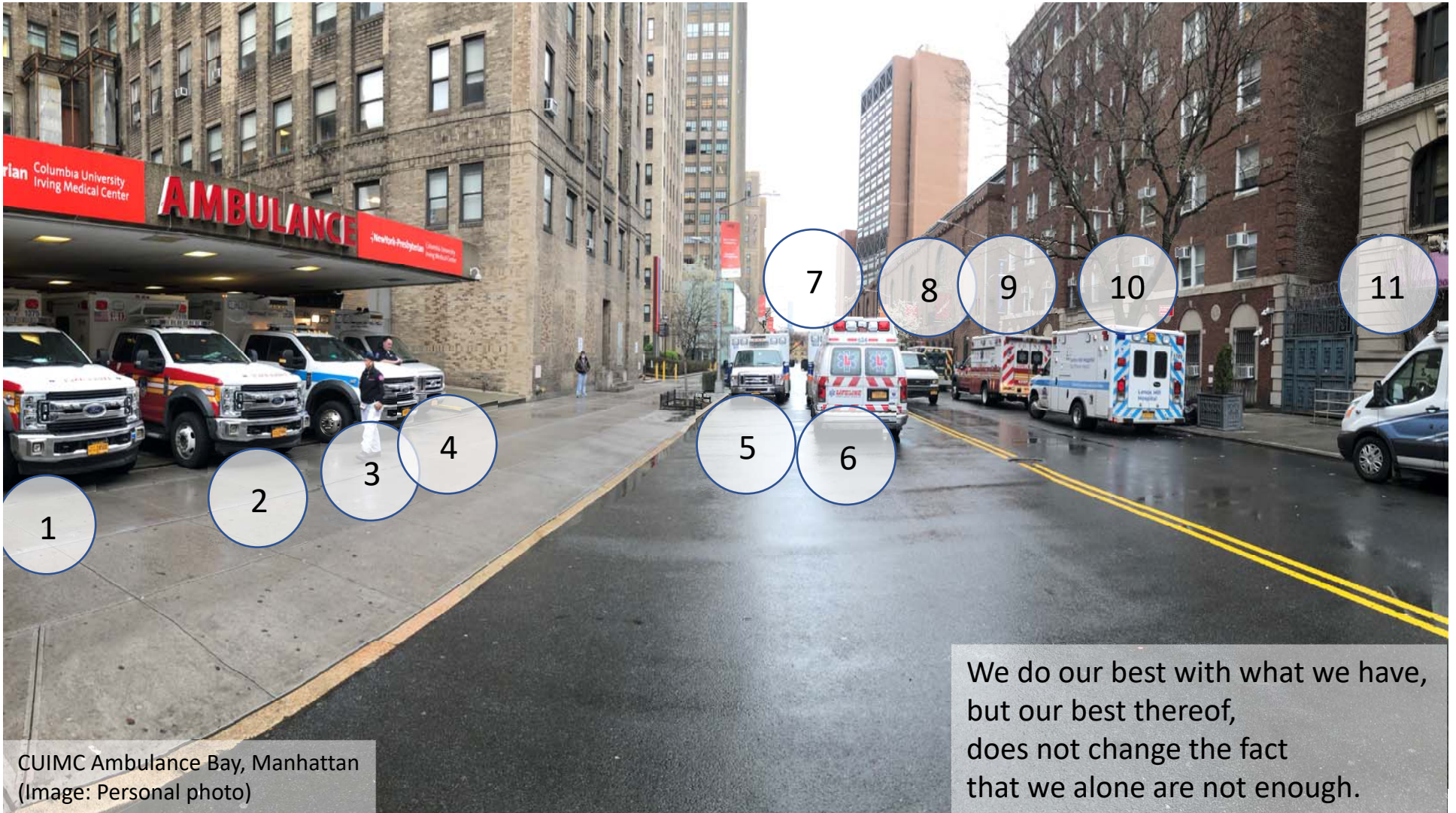
Outside Bellevue Hospital, Manhattan (Image: NY Post)

Hundreds die here every day, too many for the morgues, so bodies pile in refrigerated trucks outside the wards.

Patients die abruptly and alone because they must to stop spread of the contagion as our protective gear exhaust.



Outside Jacobi Hospital, Bronx (Image: NY Post)



CUIMC Ambulance Bay, Manhattan
(Image: Personal photo)

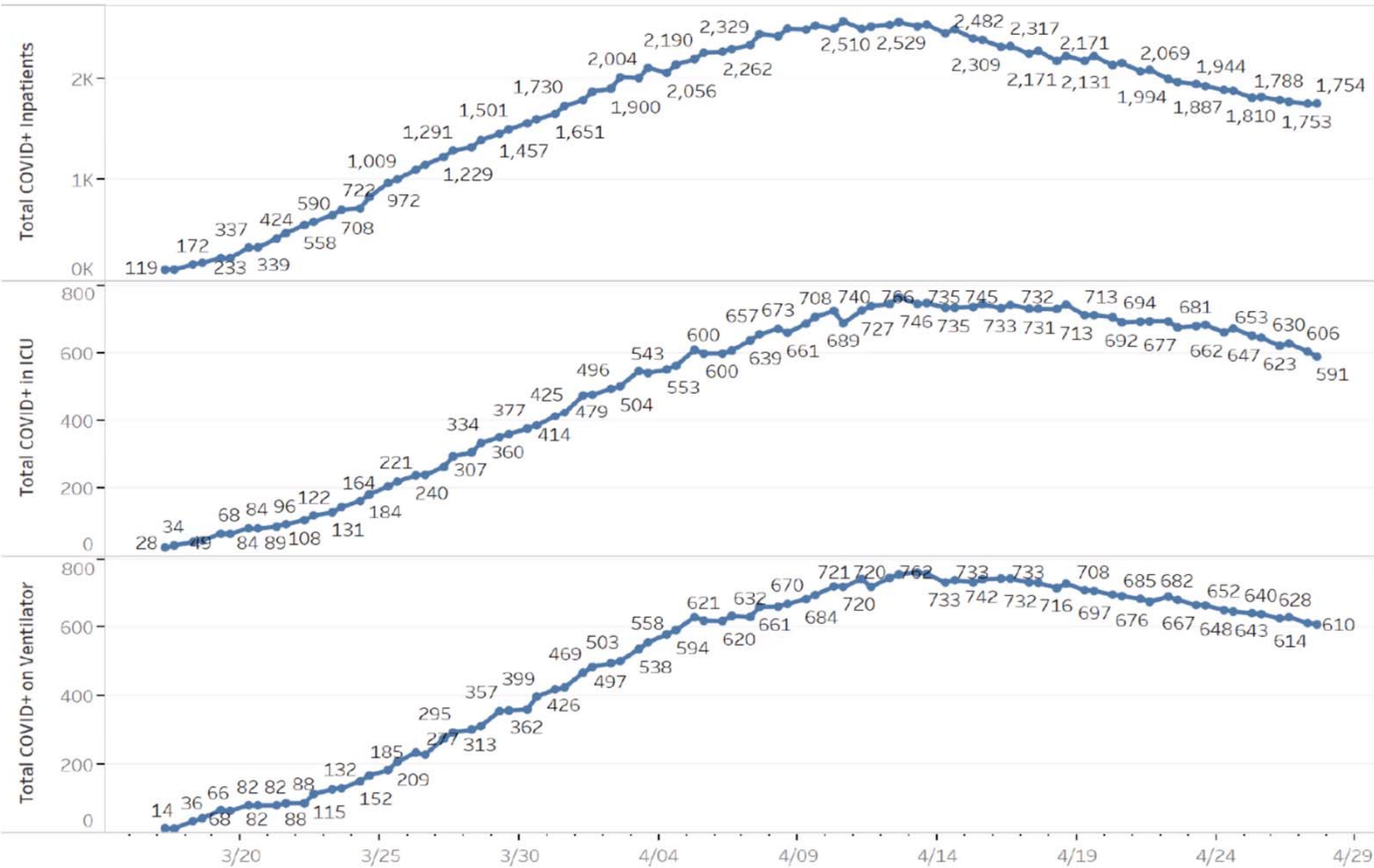
We do our best with what we have,
but our best thereof,
does not change the fact
that we alone are not enough.

Help's not coming in force.
So, is this the end of our arc?
Or can our best be enough
for you, New York?



CUIMC Main Entrance, Manhattan
(Image: Personal photo)

Overall COVID+, ICU, Vent Utilization



Our hospital network normally has:

- ~2600 inpatient beds
 - ~350 ICU beds
- (across 9 hospitals)

NYP-Columbia's main hospital:

- Normal ICU capacity: ~110 beds
- Peak Covid ICU census: >230 patients
- Intubated Covid-ARDS patients in:
 - Operating rooms
 - Cardiac cath lab
 - Newly converted stepdown beds
 - Adjacent children's hospital
 - Field hospital
 - ER converted to ICU

First SARS-CoV-2 case in all of NYS was identified on March 1



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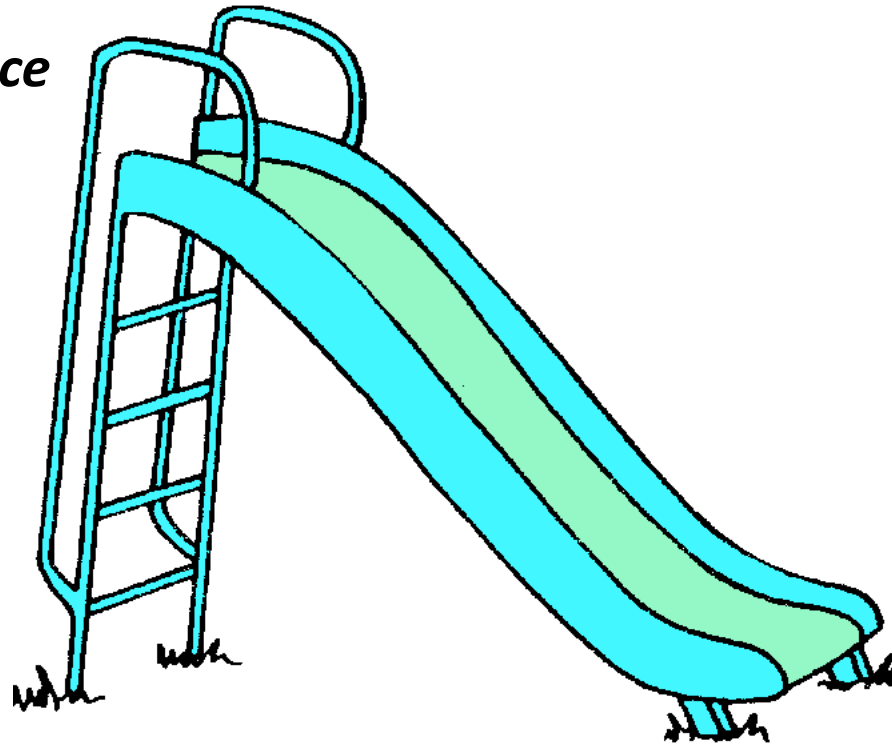
COVID19-Positive Admissions through May 10

Hospital	Total Admits	Total Disch	Total Deaths	% Deaths of Admits
NYP Allen	817	756	180	22.0%
NYP Brooklyn Methodist	1,453	1,298	385	26.5%
NYP Columbia Univ	2,045	1,765	443	21.7%
NYP Hudson Valley	352	324	97	27.6%
NYP Lawrence	595	533	120	20.2%
NYP Lower Manhattan	384	360	74	19.3%
NYP Morgan Stanley Children's	241	216	1	0.4%
NYP Queens	2,232	2,084	577	25.9%
NYP Weill Cornell	1,447	1,181	222	15.3%
NYP-WD	60	44	0	0%
TOTAL (NewYork- Presbyterian)	9,626	8,561	2,099	21.8%

* Data through May 10, 2020. Deaths may lag due to delayed reporting.

Shifting Standards of Care with Covid Surge

Best Practice



Crisis Standards

The best you can do given the resources, staff, & context



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March 23, 2020



State of New York
Executive Chamber

No. 202.10

EXECUTIVE ORDER

Continuing Temporary Suspension and Modification of Laws
Relating to the Disaster Emergency

Subdivision (2) of section 6527, Section 6545, and Subdivision (1) of Section 6909 of the Education Law, to the extent necessary to provide that all physicians, physician assistants, specialist assistants, nurse practitioners, licensed registered professional nurses and licensed practical nurses shall be immune from civil liability for any injury or death alleged to have been sustained directly as a result of an act or omission by such medical professional in the course of providing medical services in support of the State's response to the COVID-19 outbreak, unless it is established that such injury or death was caused by the gross negligence of such medical professional;

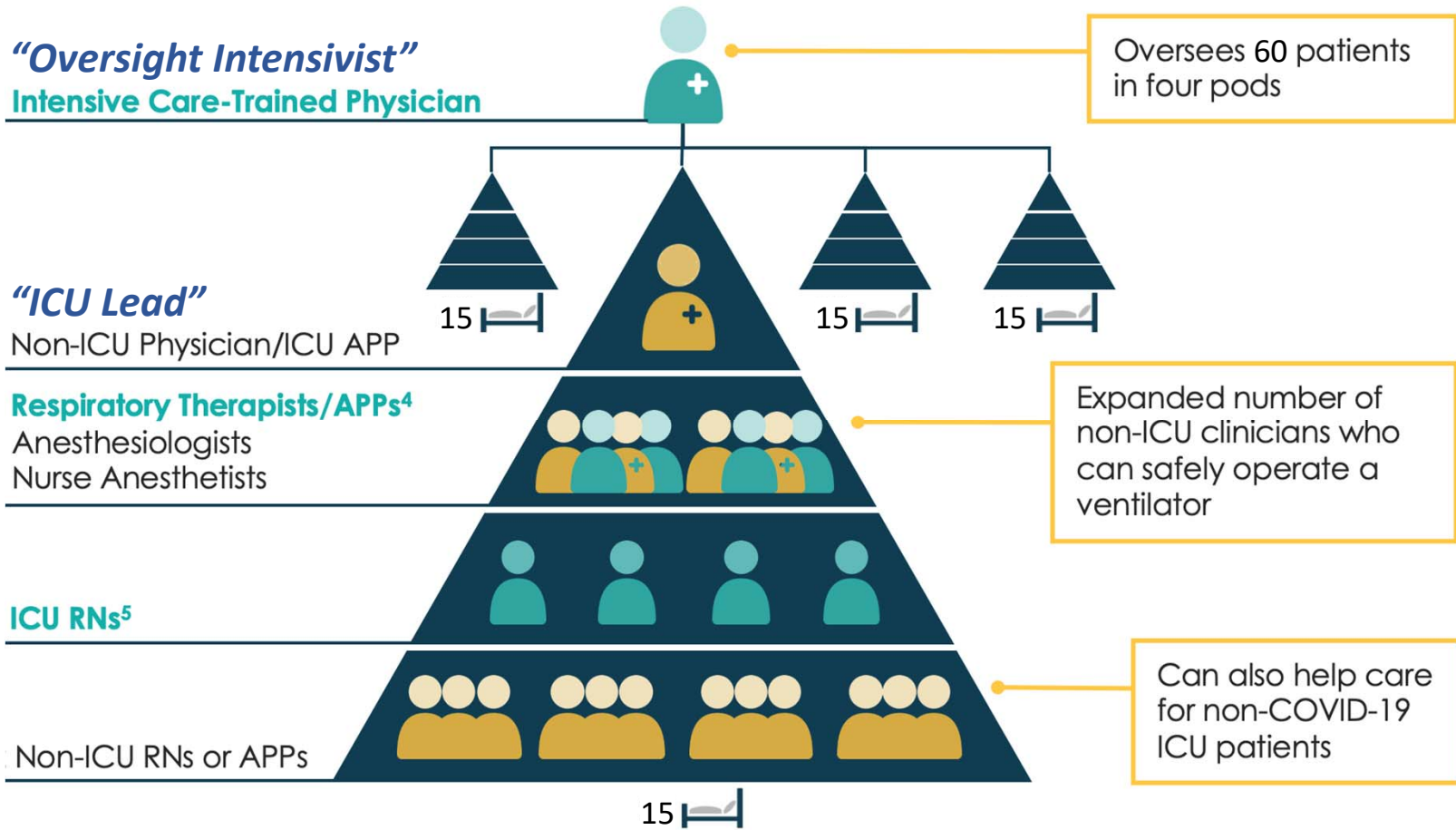


Image adapted from SCCM, Gist Healthcare, and Ontario Health Plan for an Influenza Pandemic Work Group

Ventilator Shortages

Considerations:

- Size
- Monitoring
- Alarms
- PEEP
- Exhalation valve
- CO₂
- Staffing
- Contact isolation

Full-feature ICU



Anesthesia machine



LTV



NIV



Context...

There Aren't Enough Ventilators to Cope With the Coronavirus

Mar 18, 2020 – New York Times

N.Y. May Need 18,000 Ventilators Very Soon. It Is Far Short of That.

The task force found that in 2015, there were about 7,250 ventilators in New York hospitals and about 1,900 in nursing homes. But the vast majority of them were already being used. Even with the state's own emergency stockpile, the group found there were only 2,800 available. *Mar 17, 2020 – New York Times*

New York has only six days' worth of ventilators left.

The governor said that there were 2,200 ventilators in the state's stockpile and that about 350 new patients a day need them. At that pace, he said, "2,200 disappears very quickly."

April 2, 2020 – New York Times



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What Happens When No Ventilators are Left?

... and you still have multiple potentially rescuable patients?



VENTILATOR ALLOCATION GUIDELINES

New York State Task Force on Life and the Law
New York State Department of Health

November 2015

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. 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. Reassess as needed.</p>	<p>No significant organ failure</p> <p>AND/OR</p> <p>No requirement for lifesaving resources</p>

What Happens When No Ventilators are Left?

... and you still have multiple potentially rescuable patients?

The New York Times

March 26, 2020

'The Other Option Is Death': New York Starts Sharing of Ventilators

To keep coronavirus patients breathing, hospitals are pioneering a little-tested method.



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Tim

Joint Statement on Multiple Patients Per Ventilator

March 26, 2020

12:00 p.m.

Sun		
Mar 15	<p>The Society of Critical Care Medicine (SCCM), American Association for Respiratory Care (AARC), American Society of Anesthesiologists (ASA), Anesthesia Patient Safety Foundation (ASPF), American Association of Critical-Care Nurses (AACN), and American College of Chest Physicians (CHEST) issue this consensus statement on the concept of placing multiple patients on a single mechanical ventilator.</p>	protocol nsth. ine
22 Dress rehe. with leader	<p>The above-named organizations advise clinicians that sharing mechanical ventilators should not be attempted because it cannot be done safely with current equipment. The physiology of patients with COVID-19-onset acute respiratory distress syndrome (ARDS) is complex. Even in ideal circumstances, ventilating a single patient with ARDS and nonhomogenous lung disease is difficult and is associated with a 40%-60% mortality rate. Attempting to ventilate multiple patients with COVID-19, given the issues described here, could lead to poor outcomes and high mortality rates for all patients cohorted. In accordance with the exceedingly difficult, but not</p>	
29	<p>uncommon, triage decisions often made in medical crises, it is better to purpose the ventilator to the patient most likely to benefit than fail to prevent, or even cause, the demise of multiple patients.</p>	
5		



U.S. PUBLIC HEALTH SERVICE COMMISSIONED CORPS

March 31, 2020

Optimizing Ventilator Use during the COVID-19 Pandemic

In addition to these measures, a possible crisis standard of care strategy, currently contemplated by several centers, is the ventilation of two patients with a single mechanical ventilator. As pointed out by six organization including the Society of Critical Care Medicine and the American Society of Anesthesiologists, there are significant technical challenges that must be overcome (Appendix B); and such a strategy should only be considered as an absolute last resort, judged against the alternatives of long term “hand bagging” or death. These decisions must be made on an individual institution, care-provider, and patient level. However, we do know that many institutions are evaluating this practice, and protocols are being developed and tested, and in some places, preliminarily implemented.



Timeline

Because this is a real discussion by many clinicians, the intent here is to provide additional information to support patient-provider decision making during times of crisis standards of care.

Therefore, attached are technical documents developed by academic leaders assembled at FEMA, in order to provide an example of the type of circuits, setups, and anticipated problems that one might face if this strategy is employed - in a crisis care, life-or-death, situation (Appendix C). In addition, we are attaching a protocol developed by Columbia University as an additional example for your review (Appendix D). In addition, we wanted to provide comments from the FDA and CDC related to the circuits and materials used in Appendix C.

CDC Statement: The infection control implications of co-venting are not firmly established, since it would not meet general established standards for infection control for ventilated patients. However, with the criteria specified and if done with currently established infection control interventions to reduce healthcare-associated infections, including ventilator associated infections, any additional risk is likely to be small and would likely be appropriate in a crisis standard of care.

FDA Statement: FDA does not object to the creation and use of the T-connector that meets specifications described in the instructions provided to us for use in placing more than one patient on mechanical ventilation when the number of patients who need invasive mechanical ventilation exceeds the supply of available ventilators and the usual medical standards of care has been changed to crisis care in the interest of preserving life. The FDA's no objection applies during the duration of the declared COVID-19 emergency.

During this crisis, we need to have open and transparent communication of best practices and lessons learned. We will provide updates as they become available. We stand with you, our professional colleagues, as we move forward to fully engage this crisis in our ICUs and ORs, hospitals, hospital ships, and alternative care facilities.

Sun	Mon
Mar 15	16
22 Dress rehearsal with leadership	23 NYS- app OR-2
29	30 Leac read
5	6

Call T in anic	Sat
col, k	21 Test protocol on anesth. machine
p	28
	4
	11

Timeline for Ventilator Sharing

"I don't think this can be done safely but will explore."

Dir predictions of imminent city-wide ventilator rationing

Call BTT in panic

Sun	Mon	Tue	Wed	Thu	Fri	Sat
Mar 15	16	17 Call re: feasibility	18 Develop strategy at bench	19 Write protocol, back	20 Write protocol, back	21 Test protocol on anesth. machine
22 Dress rehearsal with leadership	23 NYS+ethics approval, open OR-as-ICU	24 Vent-sharing launch	25 Protocol public via GNYHA	26	27 EHR scale-up	28
29	30 Leadership: ready to scale	31 HHS wide dissemination	Apr 1 Building more OR-as-ICU space Multiple academic centers around	2	3 US adopt protocol	4
5	6 Local ventilator supply starts to improve	7	8	9	10	11 Surge peaks next week

Multi-society condemnation but HHS private support

Public Health Initiative

Before proceeding...

- New York Governor executive order
- Initiative directed by hospital leadership
- Hospital ethics committee approval
- Hospital IRB concurrence that not research
 - Consent: obtained with explicit acknowledgement that it would benefit society but not directly benefit the patient until/unless ventilator supply exhausted
- Rationale: Gain some experience in controlled setting...
 - To determine if a realistic option
 - To permit rapid scaling when necessary
 - To plan movement of patients & ventilators throughout city



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Ventilator Sharing: Dual-Patient Ventilation with a Single Mechanical Ventilator for Use during Critical Ventilator Shortages

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Murray Olson, RRT⁶
Laureen L. Hill, MD, MBA⁶
Dean Hess, PhD, RRT³
B. Taylor Thompson, MD⁷

Full protocol online at:
protocols.nyp.org

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Ventilator Sharing

- The greatest danger lies in the simplicity of the configuration.
- The plumbing is simple. Safe execution requires careful patient selection & management by intensivists with appropriate expertise adhering to a pre-planned protocol.

Key Safety Measures

- *Pressure-control*: Mechanical change in 1 patient doesn't affect other
- *Paralytics*: Prevent patient triggering & between-patient pendelluft
- *Patient-specific inline monitors & alarms*
- *Medical-grade supplies*
- *Redundant safety checks* throughout protocol
- *Infection control*: multiple antimicrobial filters, pathogen-matched
- *Compatibility criteria*: ensure both patients fully supported with settings

... and many others

Initial Compatibility Criteria

Table 1: Recommended initial patient compatibility criteria. If patients do not meet all of these criteria, pairing them on a single ventilator is not recommended.		
Parameter	Acceptable Limit in Either Patient	Acceptable Difference Between Patients (patient A – patient B)
Anticipated time needing invasive ventilation	72 hours or higher	
Tidal volume	4-8 mL/kg PBW	
Driving pressure (ΔP = plateau pressure – PEEP)	5-16 cmH ₂ O	0-6 cmH ₂ O ^a
Respiratory rate	12-30 breaths/min	0-8 breaths/min
PEEP	5-18 cmH ₂ O	0-5 cmH ₂ O
FiO ₂	21-60%	
pH	7.30 or higher	
Oxygen saturation	92-100%	
Ventilator titration	No recent major changes as judged clinically	
Neuromuscular blockade	No contraindication to initiation if not already receiving	
Respiratory infectious status	Both patients have same respiratory pathogen	None
Asthma or COPD	No severe baseline disease nor current exacerbation	
Hemodynamic stability	No rapid vasopressor increase	

Match Ventilator Settings Before Sharing

- Once a potentially compatible pair identified:
 - Deep sedation & **paralysis**
 - Initiate **PCV** in each patient
 - Match patients on **PEEP & FiO₂**
 - Match **driving pressure, inspiratory time, & RR**
- Safety checks at several steps
 - Minute-volume within ± 2 liters/min of baseline
 - Auto-PEEP < 5 cm H₂O
 - SpO₂ and ABG within specified ranges
 - Set ventilator to be shared to **same settings with test lungs to confirm circuit function** before transitioning patients

Characteristic	Patient 1A	Patient 1B	Patient 2A	Patient 2B	Patient 3A	Patient 3B
Age, yr	62	74	58	73	43	59
Sex	Female	Male	Female	Female	Male	Male
Height, cm	162.6	182.9	157.5	175.0	165.1	190.5
Weight, kg	68.0	98.9	122.5	85.0	80.0	105.9
Body mass index, kg/m ²	25.7	29.6	49.4	27.8	29.3	29.2
Predicted body weight, kg	54.8	77.8	50.1	66.1	61.6	84.7
Vasopressor-dependent shock before sharing	Yes	Yes	Yes	Yes	Yes	Yes
Modified SOFA score before sharing ^a	10	10	12	13	10	11
Days hospitalized before intubation	1.0	3.1	1.1	1.0	1.0	6.1
Days intubated before ventilator sharing	5.6	2.5	0.7	7.9	1.8	3.6

Characteristic	Patient 1A	Patient 1B	Patient 2A	Patient 2B	Patient 3A	Patient 3B
Age, yr	62	74	58	73	43	59
Sex	Female	Male	Female	Female	Male	Male
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Days intubated before ventilator sharing	5·6	2·5	0·7	7·9	1·8	3·6
Respiratory parameters prior to Matching						
Tidal volume, mL (mL/kg PBW)	330 (6·0)	480 (6·2)	400 (8·0)	490 (7·4)	375 (6·1)	370 (4·4)
Driving pressure, cm H ₂ O	14	16	24	22	19	20
Peak inspiratory pressure, cm H ₂ O	31	25	30	34	37	30
Plateau pressure, cm H ₂ O	28	24	34	32	31	30
Respiratory rate, breaths/min	26	19	24	25	26	28
PEEP, cm H ₂ O	14	8	10	10	12	10
FiO ₂	0·5	0·6	0·7	0·5	0·3	0·6
Respiratory system compliance, mL/cm H ₂ O (mL/kg PBW/cm H ₂ O)	24 (0·43)	30 (0·39)	17 (0·33)	22 (0·34)	20 (0·32)	19 (0·22)
Minute volume, L/min	8·6	9·1	9·6	12·3	9·8	10·4
PaO ₂ /FiO ₂ ^b	148	152	76	110	180	266
Duration of sharing, hours	48·25		47·5		47·0	



Characteristic	Patient 1A	Patient 1B	Patient 2A	Patient 2B	Patient 3A	Patient 3B
Age, yr	62	74	58	73	43	59
Sex	Female	Male	Female	Female	Male	Male
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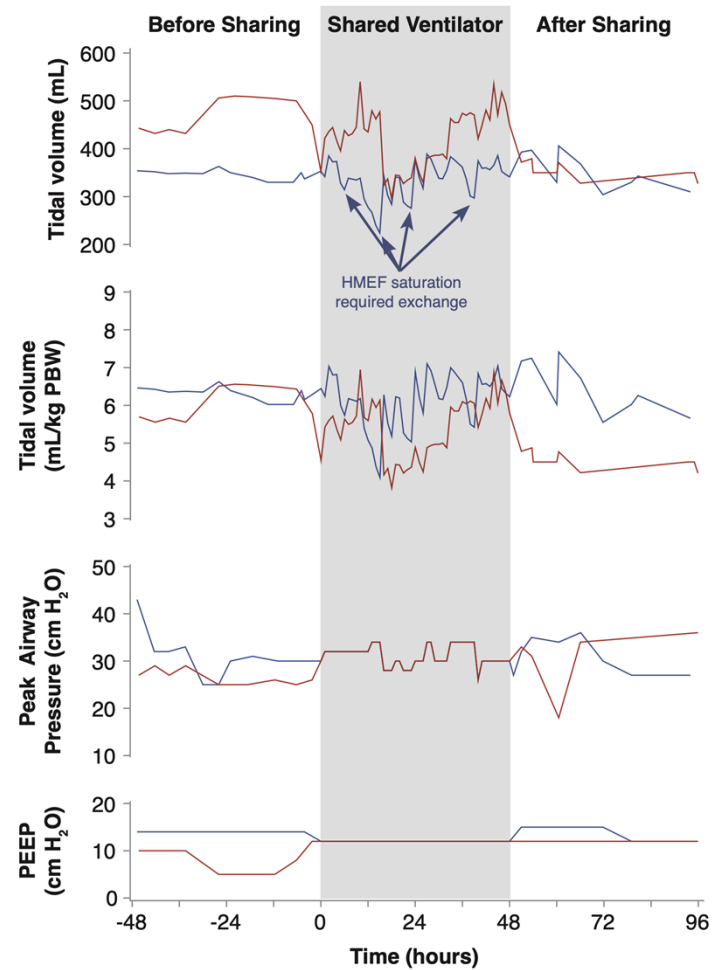
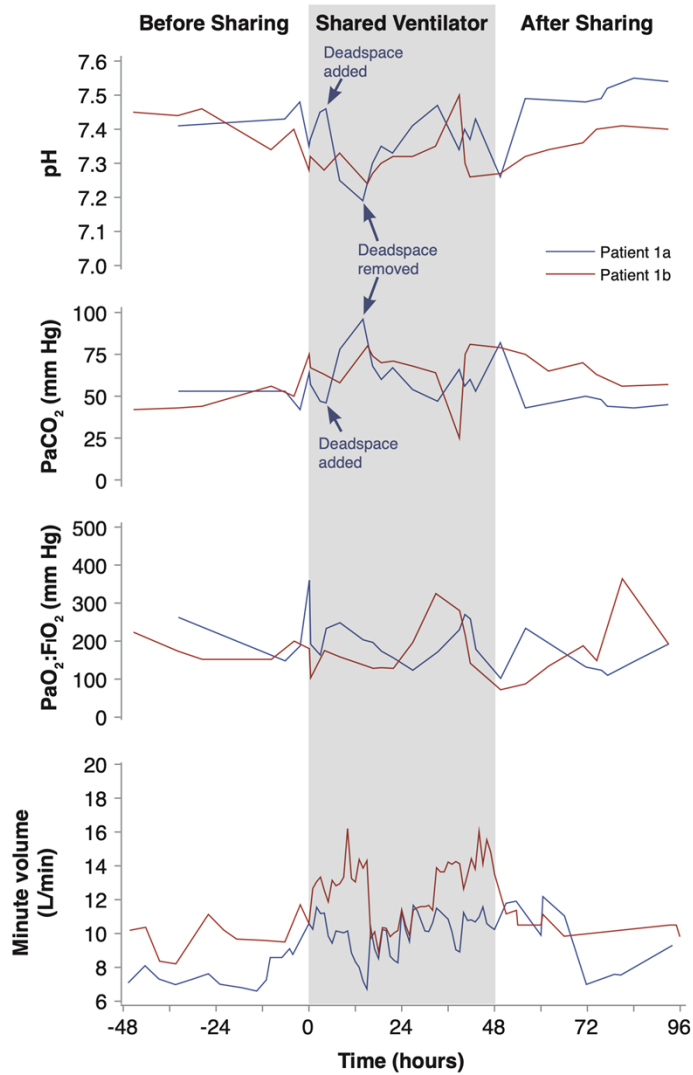


Video at: <https://www.atsjournals.org/doi/suppl/10.1164/rccm.202005-1586LE>
Beitler et al. *Am J Respir Crit Care Med*. 2020. In press.

1st Pair

Lessons Learned

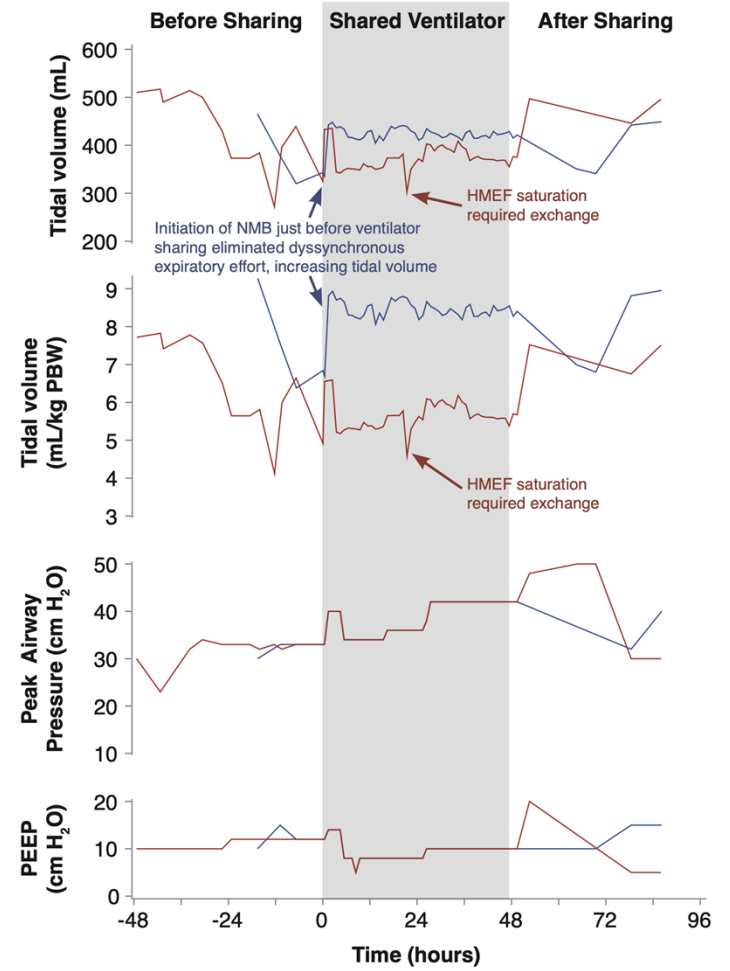
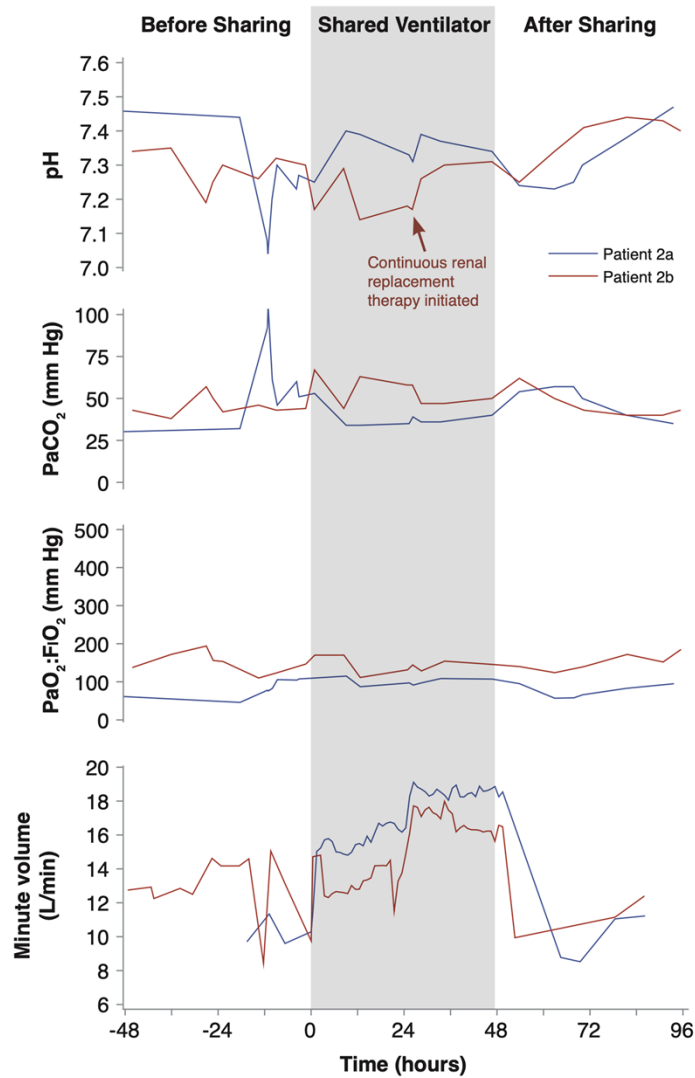
- Anesthesia machine
 - CO₂ absorbent
 - Alarm limits
 - Compliant extension tubing
 - Staff familiarity
- PCV with HMEF



2nd Pair

Lessons Learned

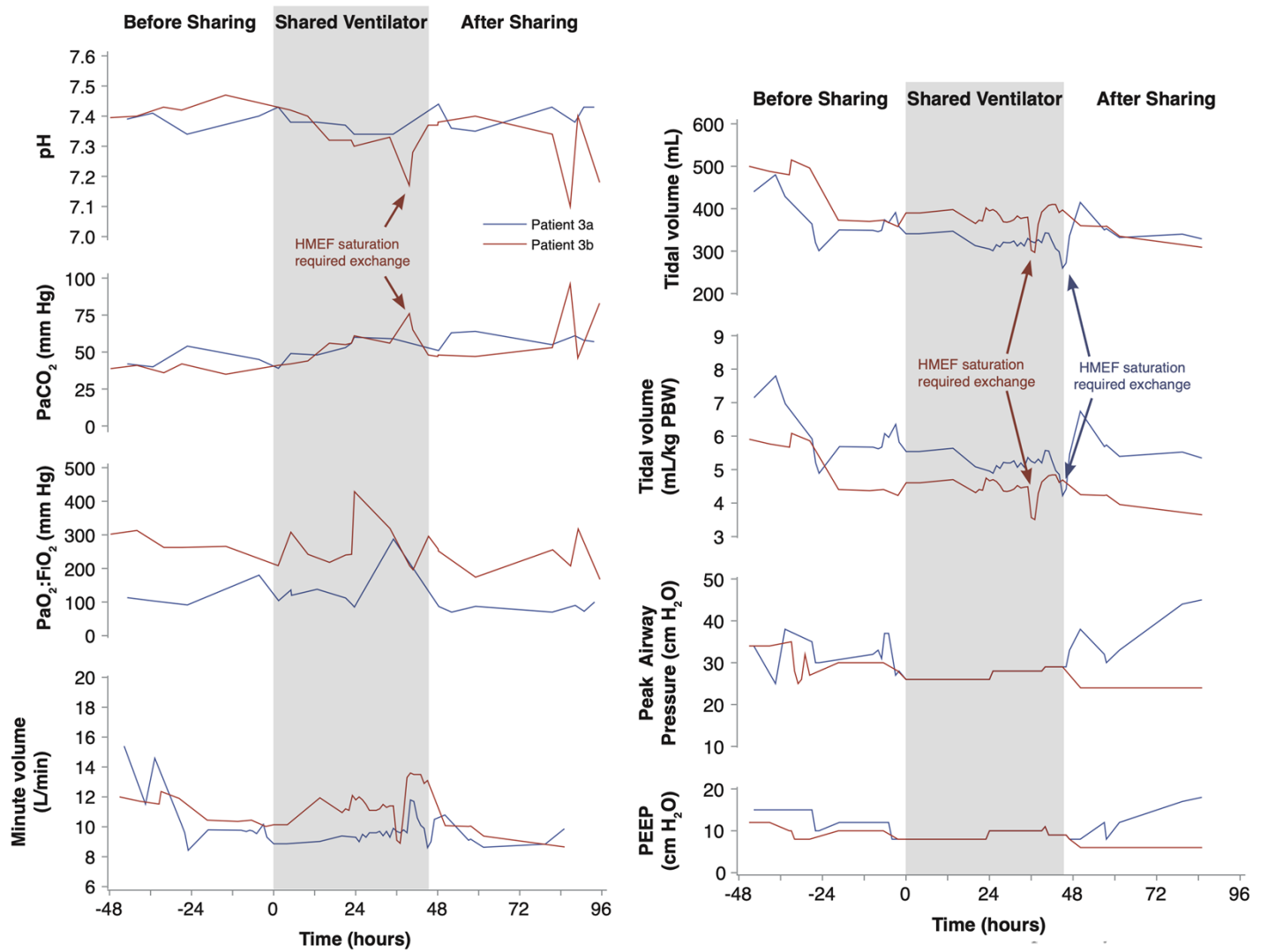
- Compatibility
 - Stability
 - ΔP on NMB
- ICU ventilator superior



3rd Pair

Lessons Learned

- EHR-based screening

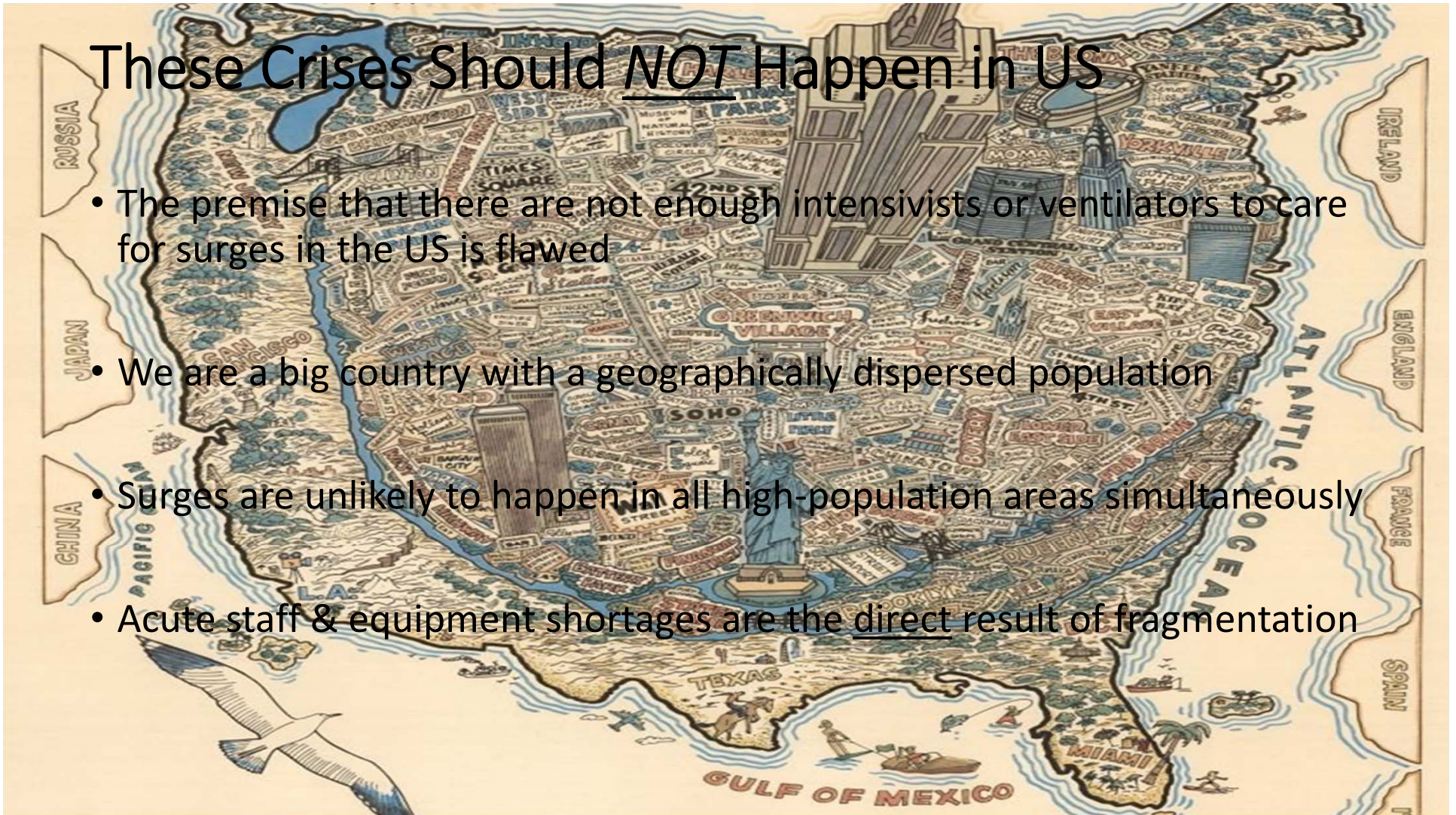


Ventilator Allocation Schema

Ventilator Cluster	Use
Transport ventilators (single-patient)	<ul style="list-style-type: none"> • Transport patients throughout hospital • Emergency department • Continuous support as single-patient ventilators in less severe cases as functionality and supply permit
Conventional single-patient ventilators	<p>Need for individualized support:</p> <ul style="list-style-type: none"> • Patient's ventilator needs must be individualized (Table 1) • Patient ready for active weaning from ventilator
Repurposed anesthesia machine ventilators (single-patient)	<ul style="list-style-type: none"> • In operating room or designated areas where space and technical expertise for anesthesia machine exist
Repurposed non-invasive ventilators that can be adapted to invasive ventilation (single-patient)	<ul style="list-style-type: none"> • Patients with less severe disease for whom level of support from this device is adequate • Ventilator weaning for patients near ready for extubation
Shared ventilators (dual-patient)	<ul style="list-style-type: none"> • For carefully paired patients only when deemed appropriate and necessary due to exhausted ventilator supply
Rescue ventilators (single-patient)	<ul style="list-style-type: none"> • Rescue a patient undergoing ventilator sharing who needs to be urgently placed back on single ventilator

These Crises Should NOT Happen in US

- The premise that there are not enough intensivists or ventilators to care for surges in the US is flawed
- We are a big country with a geographically dispersed population
- Surges are unlikely to happen in all high-population areas simultaneously
- Acute staff & equipment shortages are the direct result of fragmentation

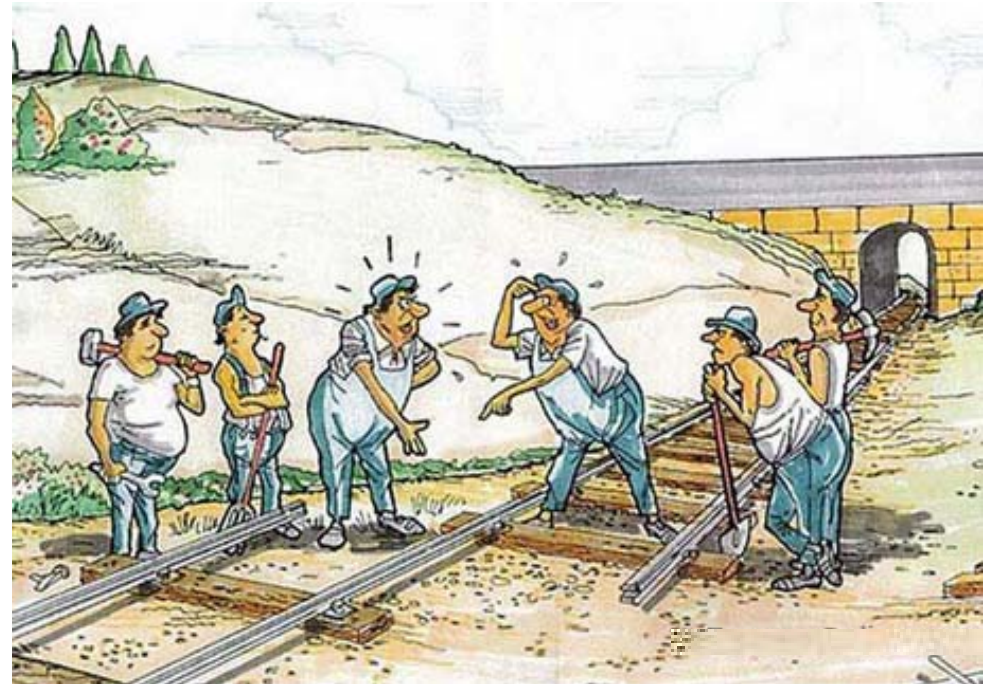




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From Many Healthcare Networks, One Health System?

- Coordinated movement
 - Of patients to areas of resources (local/regional)
 - Of resources to areas of need
 - Of HCWs to areas of need
- Interstate collaboration
 - Hospitals
 - Professional societies
- NYS took a positive 1st step
 - Daily bed & ventilator reporting to NYS
 - Recurring calls among hospital & ICU leaders
 - ... but it's not nearly enough



Conclusions

- Covid-19 surge put NYC healthcare system on brink of collapse
 - PPE, physical space, ED/ICU staff, & ventilators
- Ventilator shortages can arise very quickly during epidemic wave
- Ventilator-sharing could be a stop-gap to buy time for relocating resources... if done:
 - in pre-planned fashion
 - with well-matched patients
 - in centers with appropriate expertise
- More coordination would save more lives

Thank you.

Questions?

jrb2266@cumc.columbia.edu

Ventilator-sharing protocol & training video: protocols.nyp.org

Initial patient series: Beitler JR et al. Ventilator sharing during an acute shortage caused by the Covid-19 pandemic. *Am J Respir Crit Care Med.* 2020. Epub ahead of print.



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