EDUCATION
for Anesthesia and Respiratory Care

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COVID-19: Observations in Germany and ECMO considerations

Presented by: Dr. Armin Kalenka and Dr. Philipp Lepper
Date: Thursday, May 7
Time: 8:00 AM PST | 10:00 AM CST | 11:00 AM EST | 5:00 PM CEST
Duration: 90 minutes

WHAT WILL BE COVERED

- Observations of COVID-19 dynamics in Germany
- Pragmatic treatment of COVID-19 patients with respiratory distress
- Considerations and criteria for ECMO treatment
- Long-term care of COVID-19 disease and treatment options

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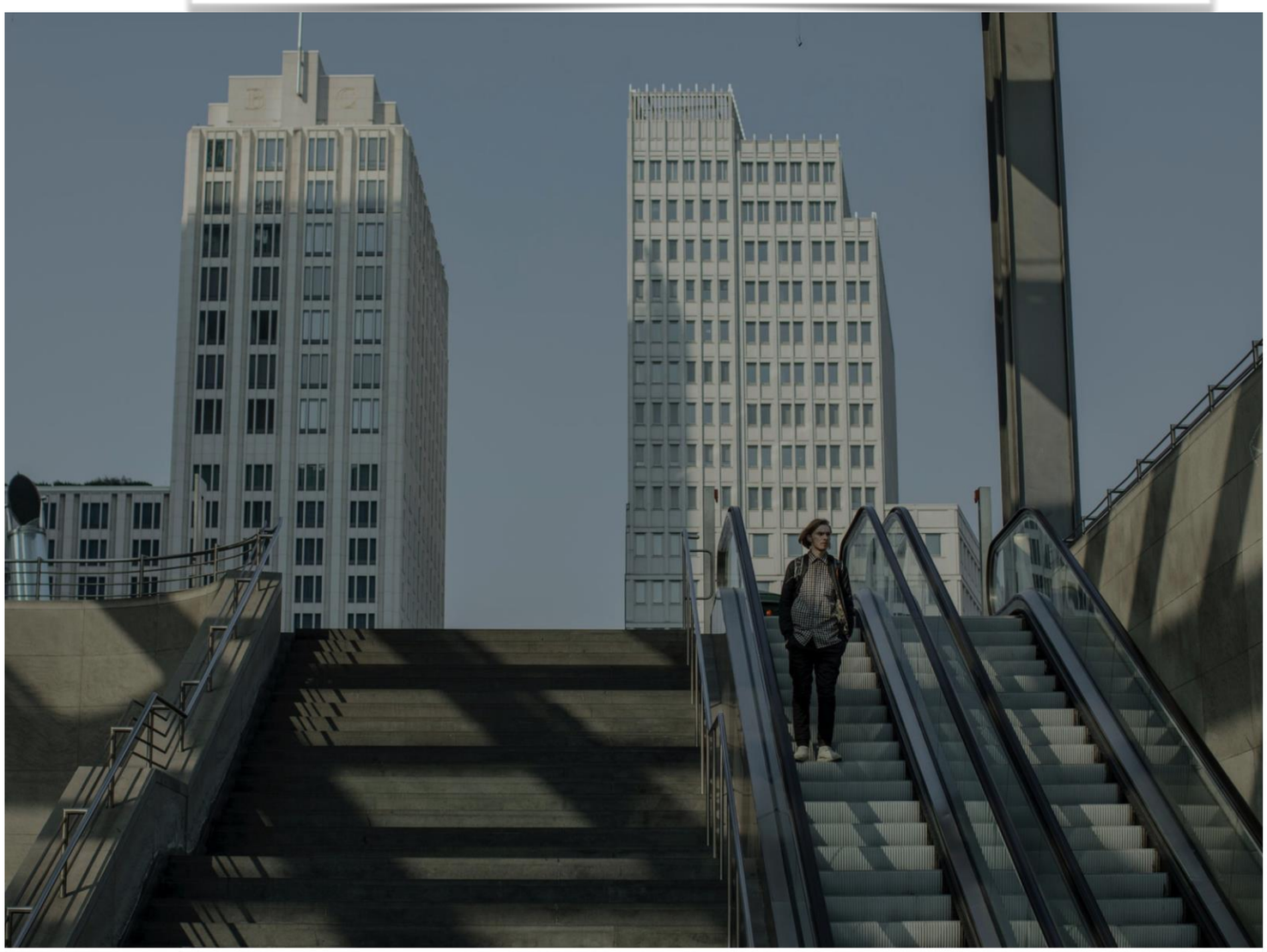
The New York Times

A German Exception? Why the Country's Coronavirus Death Rate Is Low

The pandemic has hit Germany hard, with more than 100,000 people infected. But the percentage of fatal cases has been remarkably low compared to those in many neighboring countries.



In the heart of Berlin, Potsdamer Platz was nearly empty on Saturday, as people heeded orders to stay at home.
Emile Ducke for The New York Times

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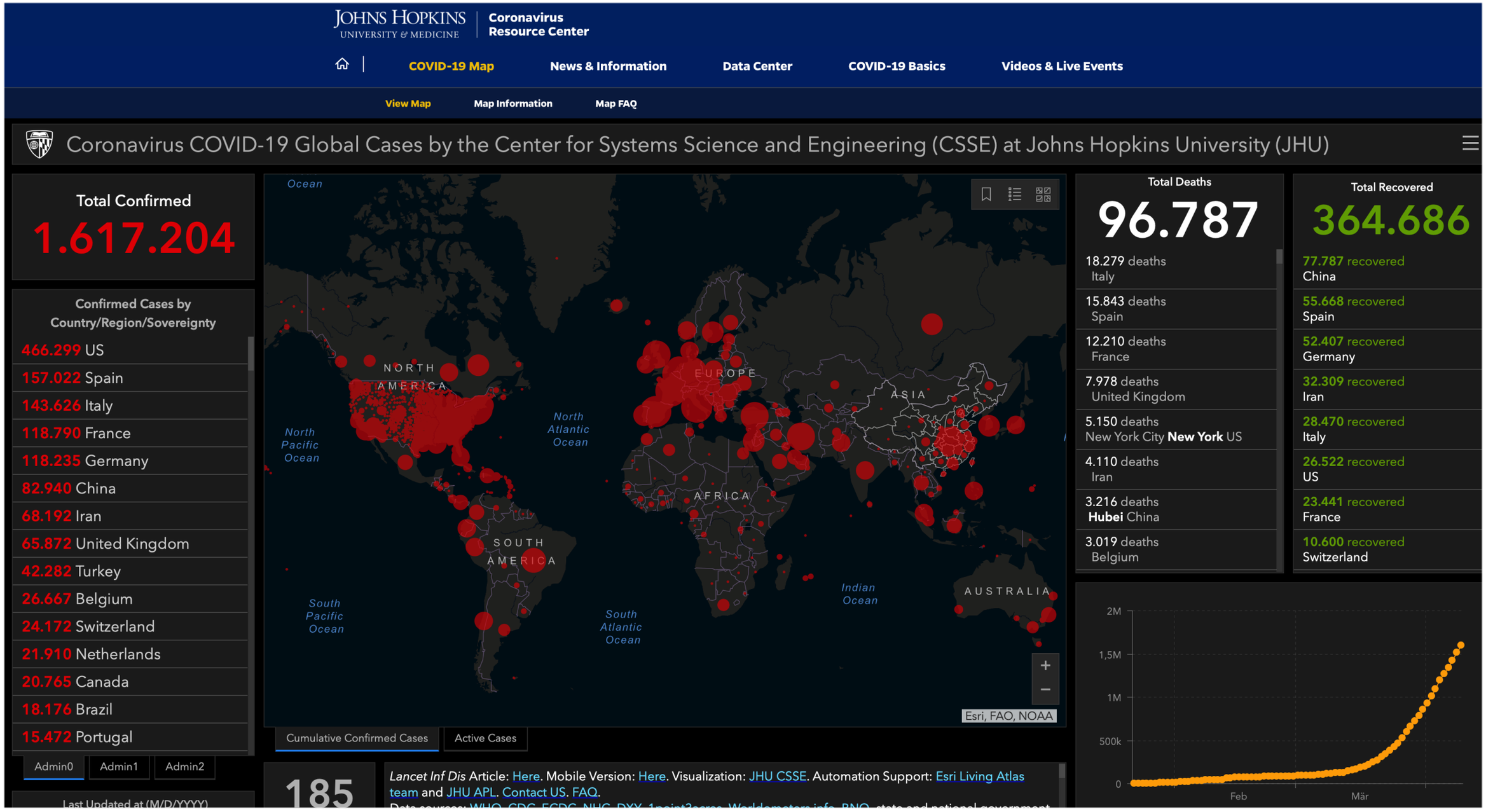
Easter Friday 10th April 15:00



https://coronavirus.jhu.edu/map.html

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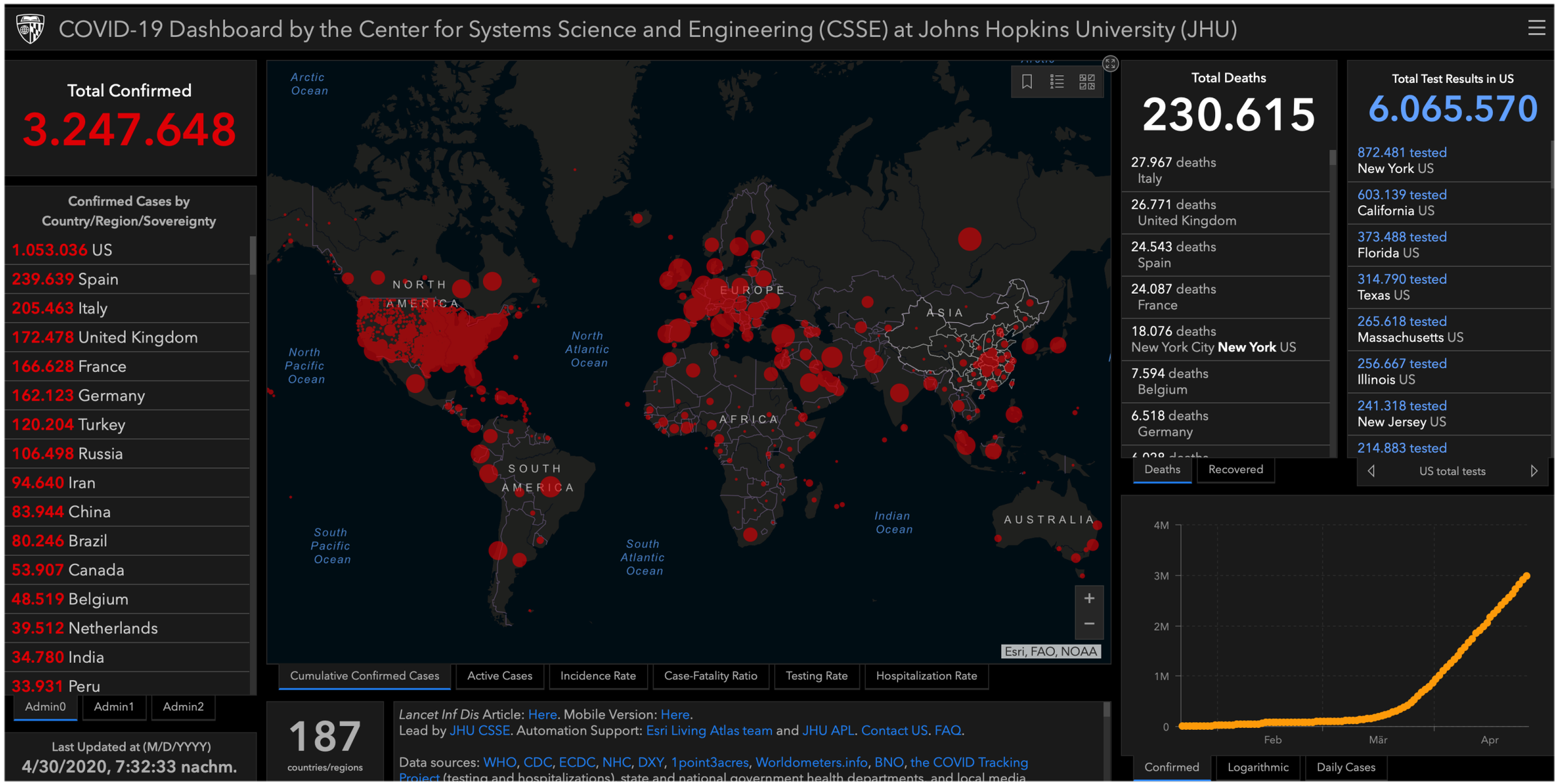
30th April 20:00



https://coronavirus.jhu.edu/map.html

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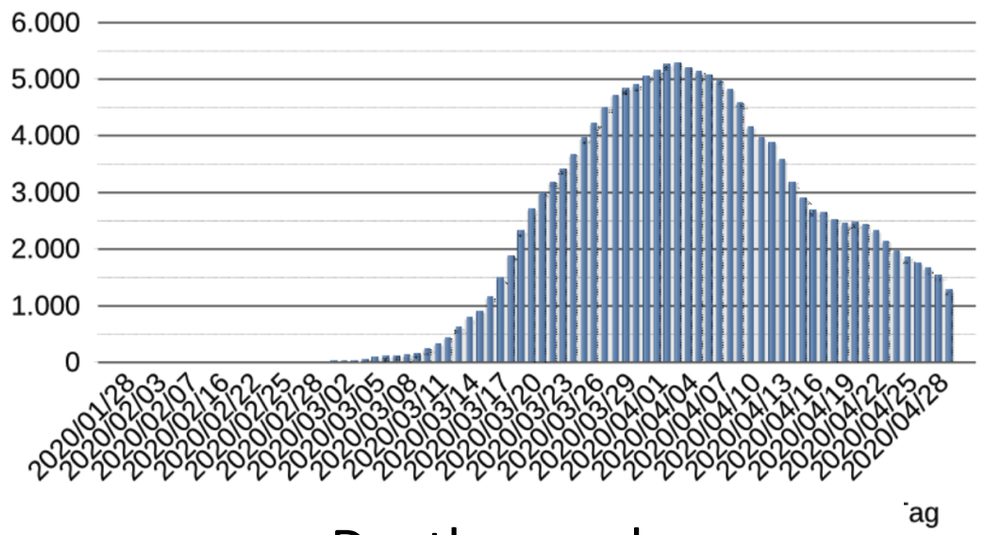
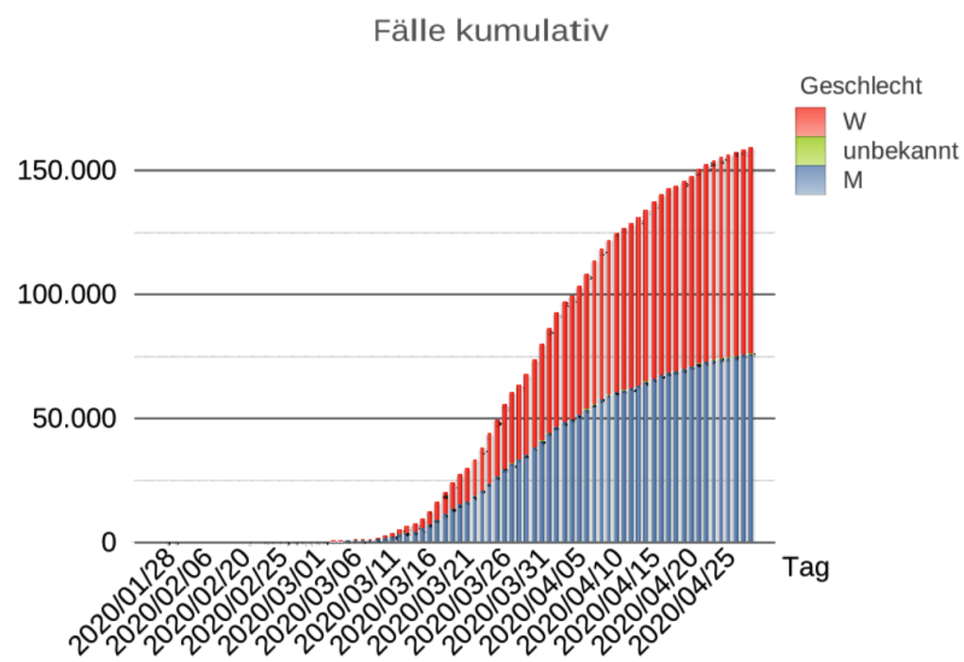
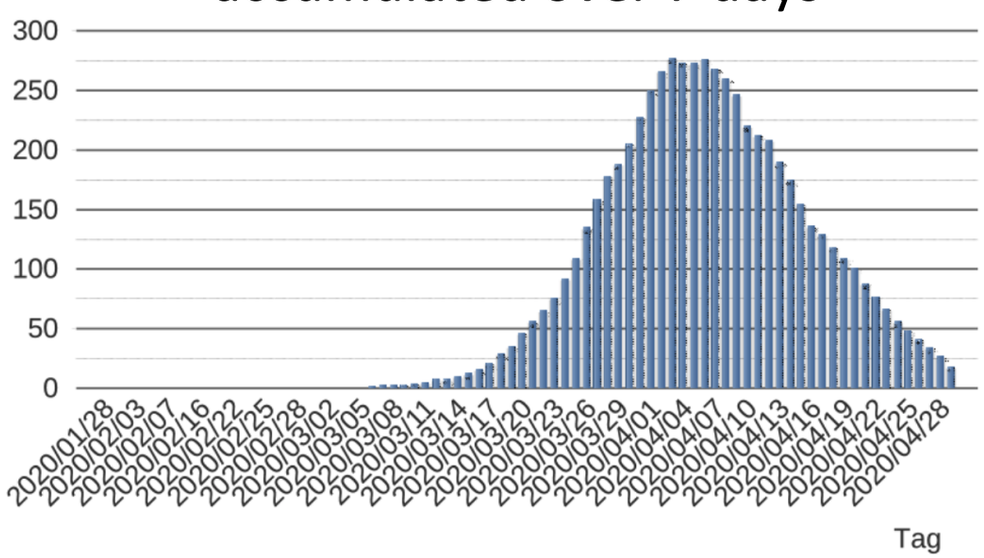
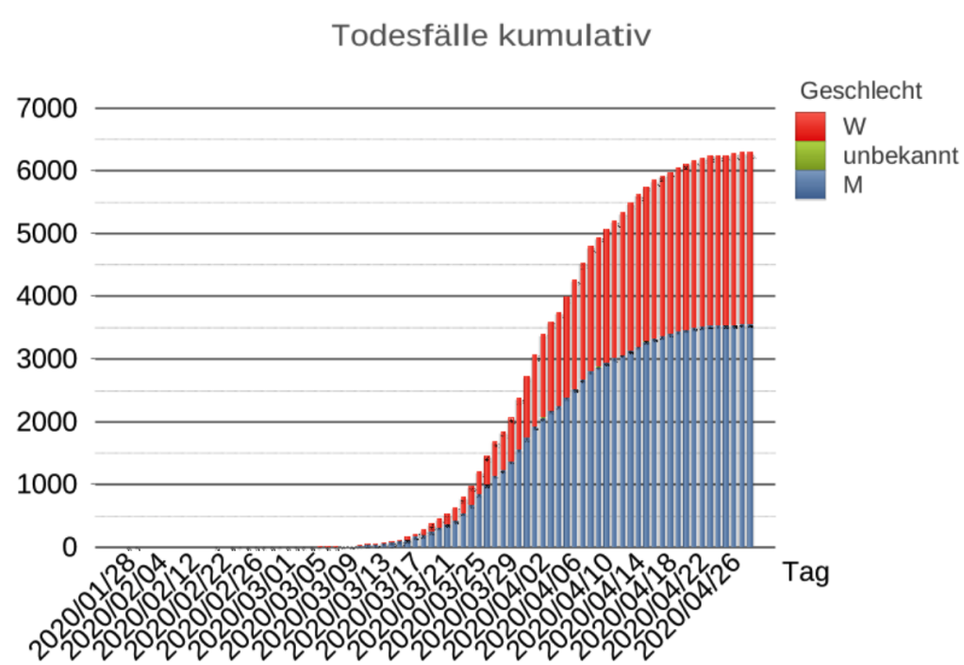
Cases per day
accumulated over 7 days





Deaths per day
accumulated over 7 days





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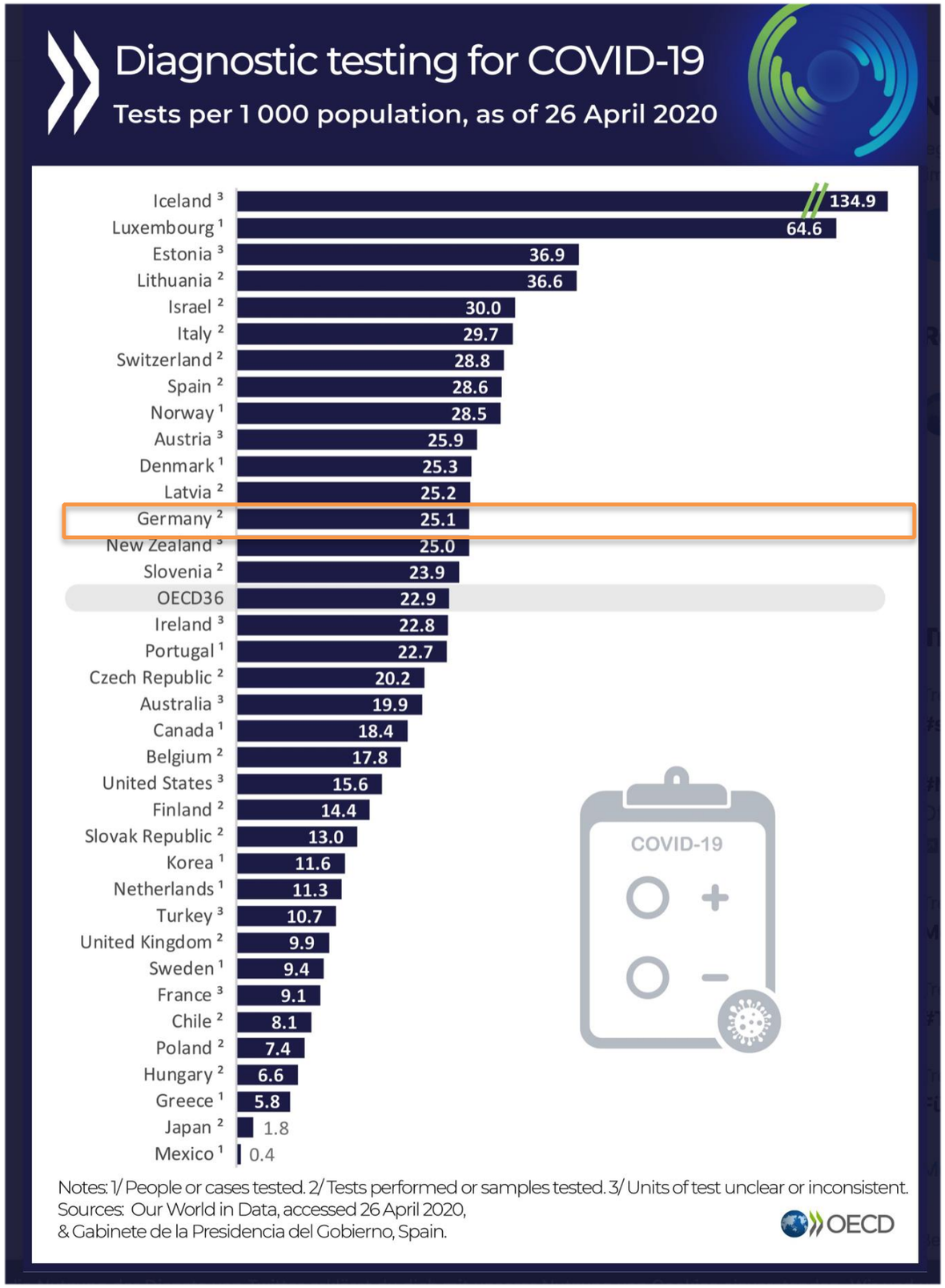

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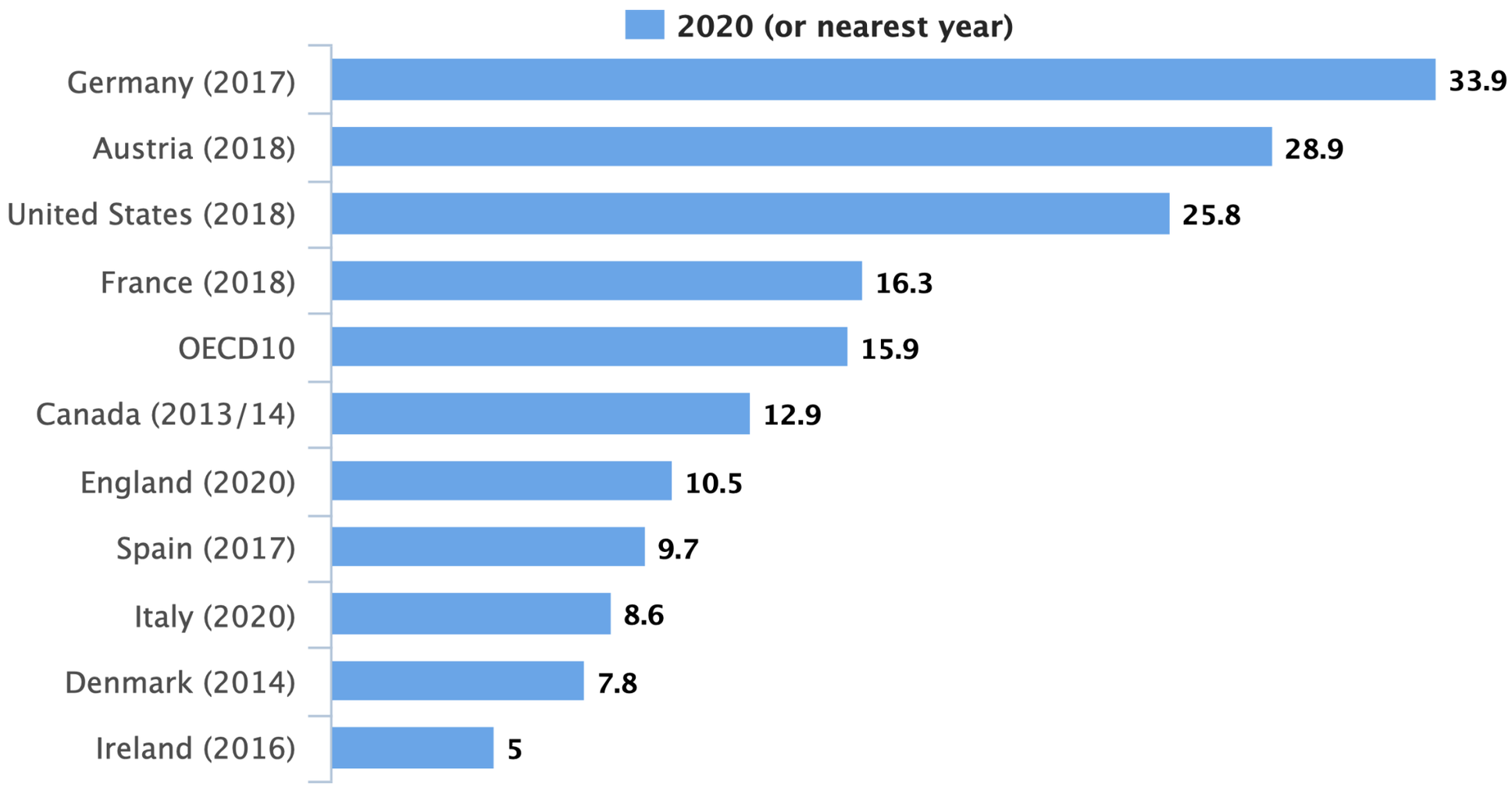
Capacity of intensive care beds in selected OECD countries, per 100 000 population



Source: OECD Policy Brief on The Policy Response to the Covid-19 Crisis

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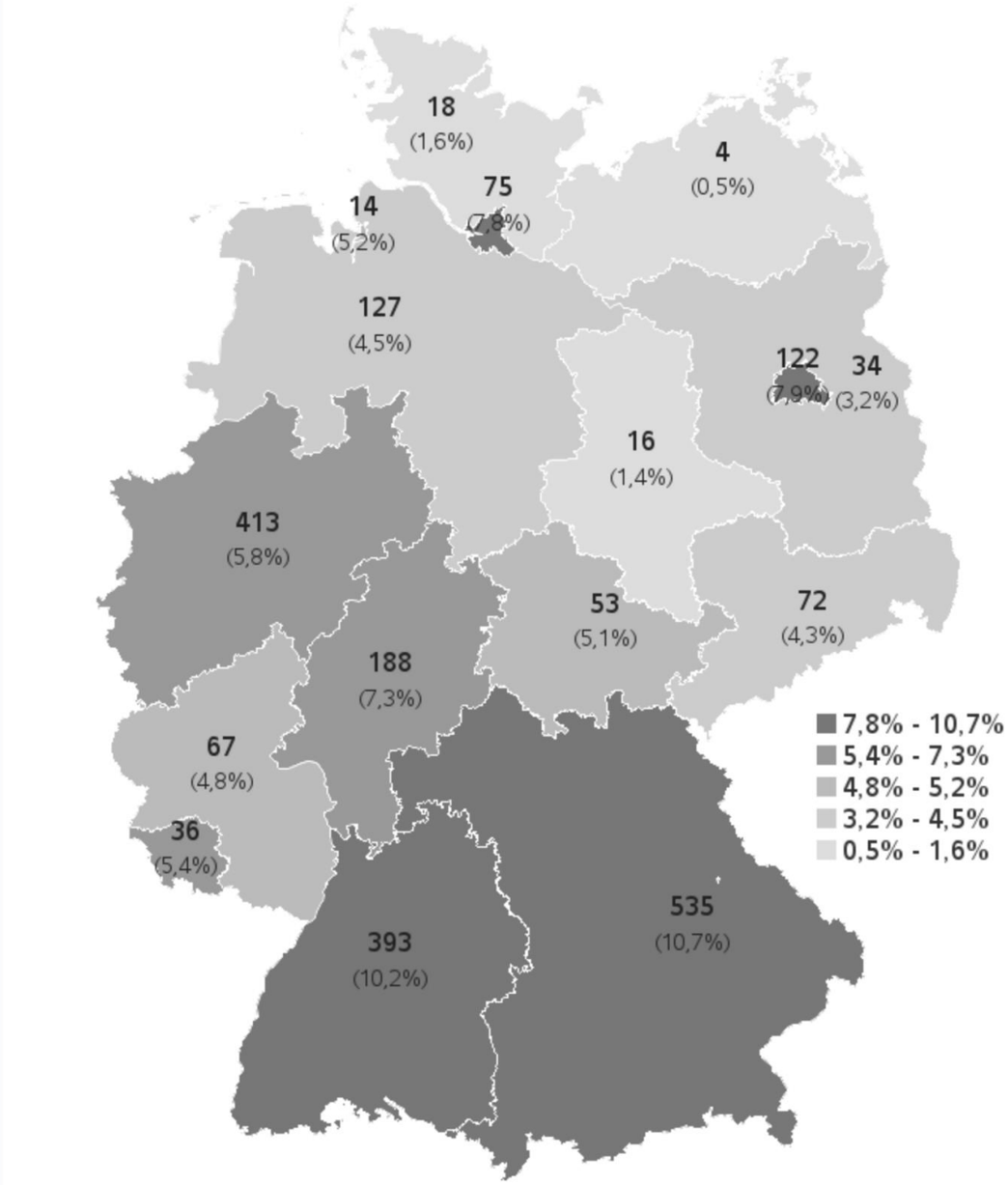
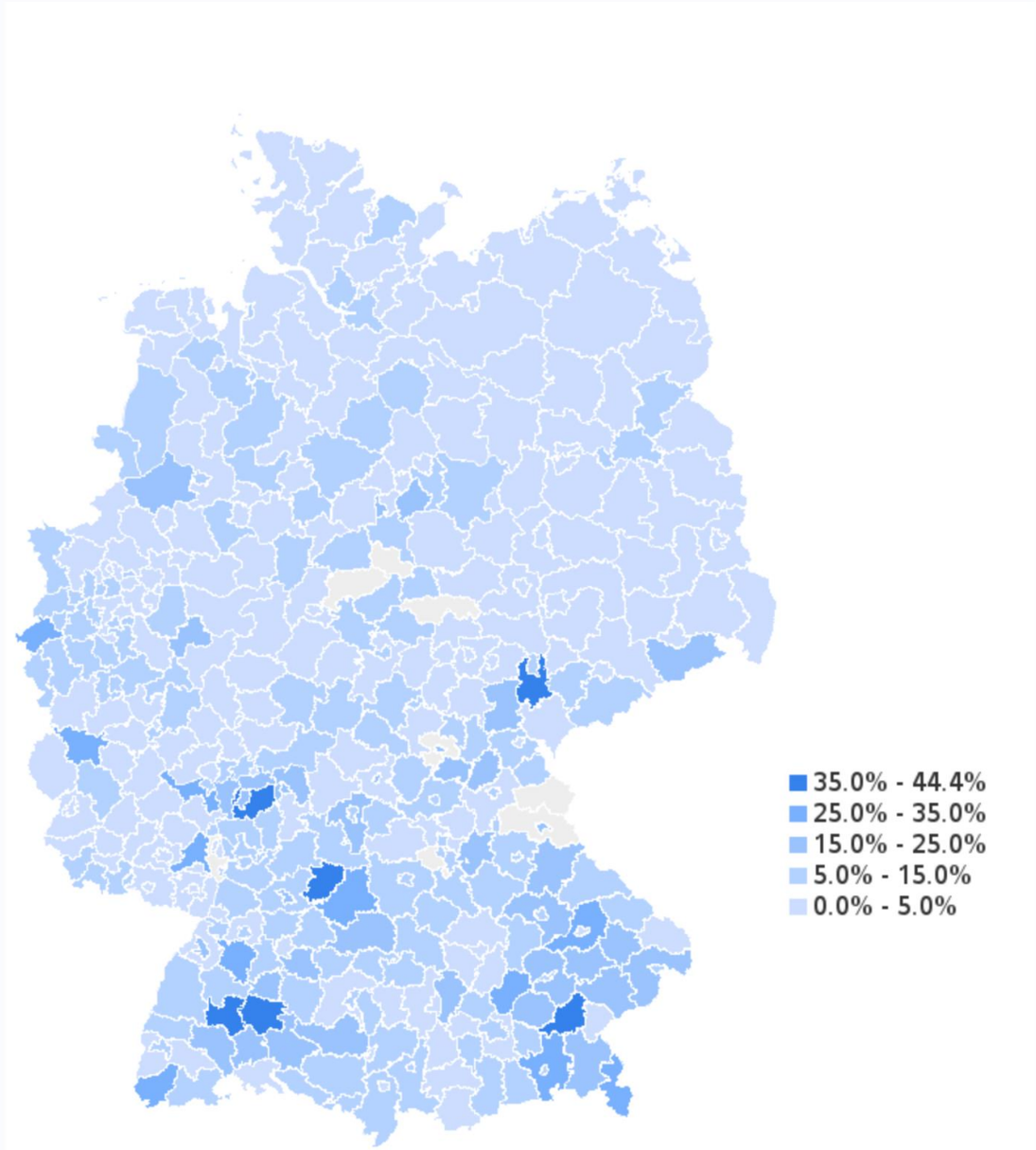
Anzahl COVID-19 Patient/innen in intensivmedizinischer Behandlung & Anteil COVID-19 Patienten/innen pro Intensivbett



Oberste Zahl: Anzahl aller COVID-19 Patienten/innen in intensivmedizinischer Behandlung
In Klammern: Anteil COVID-19 Patienten/innen pro Intensivbett

Die dargestellten Zahlen basieren auf den jeweils aktuellsten Meldungen von 1.414 Meldebereichen* aus den letzten 60 Stunden.
Stand: 01.05.2020 / 12:00

Anteil COVID-19 Patient/innen pro Intensivbett aggregiert auf Kreisebene



Die dargestellten Zahlen basieren auf den jeweils aktuellsten Meldungen von 1.414 Meldebereichen* aus den letzten 60 Stunden.
Stand: 01.05.2020 / 12:00

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www.intensivregister.de

Covid-19 Patients

Ventilated Covid-19 patients

free ICU beds

	Fälle COVID-19 aktuell in Behandlung	Fälle COVID-19 aktuell beatmet	Prozentualer Anteil beatmeter Patienten	Intensivbetten aktuell belegt	Intensivbetten aktuell frei	Gesamtzahl aktuell betreibbarer Intensivbetten
Summe	**2.167**	**1.561**	**72,0 %**	**20.123**	**12.955**	**33.078**
Baden-Württemberg	393	272	69,2 %	2.198	1.656	3.854
Bayern	535	391	73,1 %	3.147	1.840	4.987
Berlin	122	97	79,5 %	1.081	454	1.535
Brandenburg	34	17	50,0 %	598	471	1.069
Bremen	14	8	57,1 %	168	102	270
Hamburg	75	62	82,7 %	584	372	956
Hessen	188	143	76,1 %	1.675	892	2.567
Mecklenburg-Vorpommern	4	3	75,0 %	541	280	821
Niedersachsen	127	85	66,9 %	1.586	1.242	2.828
Nordrhein-Westfalen	413	305	73,8 %	4.482	2.643	7.125
Rheinland-Pfalz	67	44	65,7 %	808	594	1.402
Saarland	36	26	72,2 %	361	306	667
Sachsen	72	48	66,7 %	1.057	618	1.675
Sachsen-Anhalt	16	12	75,0 %	688	488	1.176
Schleswig-Holstein	18	13	72,2 %	540	557	1.097
Thüringen	53	35	66,0 %	609	440	1.049

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normal ICU beds

max. ICU beds

occupied ICU beds

free ECMO beds

IVENA eHealth - Interdisziplinärer Versorgungsnachweis

HESSEN Hessisches Ministerium für Soziales und Integration

Abmelden | Regelversorgung | Übersicht KHS | Alarmierungen | Schließungen | MANV | Sonderlage | Mehr

Sie sind angemeldet als **Armin Kalenka** (Version **4.1.0**)

Normalpflegebetten ohne ITS und IMC - KHS gesamt | ITS/IMC Betten mit Beatmung - KHS gesamt | ITS/IMC Betten ohne Beatmung - KHS gesamt | Abgänge | PSA-Bestand | PSA-Bedarf

Automatisch aktualisieren | Anzeige aktualisieren

Sonderlage: ITS/IMC Betten mit Beatmung - KHS gesamt

Gesamtsumme	1408	2151	494	979	204	55	860	39				
Leitstelle Bergstraße	**Soll-Betten**	**Max.-Betten (Soll-Betten mit Not-Beatmung)**	**Davon Betten mit OP-Beatmung**	**Belegte Betten**	**davon belegte Betten (mit Covid gesichert)**	**davon belegte Betten (mit Covid Verdacht)**	**Anz. freie Betten**	**Anz. freie Betten mit ECMO**	**Telefon Koordination**	**Bemerkungen**		
Heilig-Geist Hospital	5 heute 11:32	7 heute 11:32	2 heute 11:32	4 heute 11:32	3 heute 11:32	0 heute 11:33	3 heute 11:34	0 heute 11:37	06251132943 23.03. 09:51			
Kreis-KH Bergstraße	8 heute 13:56	19 heute 13:56	5 heute 13:56	1 heute 13:56	1 heute 13:56	0 heute 13:57	17 heute 13:57	0 heute 13:57	062527019211 0 heute 13:57	27.03. 11:30		
Schön Klinik Lorsch	1 heute 09:02	6 heute 09:02	5 heute 09:02	0 heute 09:02	0 heute 09:02	0 heute 09:02	1 heute 09:02	0 heute 09:03	062515915011 09.04. 12:04	1 Gerät HGH Verliehe n OP-Beatmung Vorlauf : 2-3h alle Notbeatmungen g ehen zu Lasten der 6 I MC-Betten 09.04. 14:50		
St. Josef Krankenhaus	1 09.04. 13:03	3 09.04. 13:03	2 09.04. 13:03	0 09.04. 13:03	0 09.04. 13:03	0 09.04. 13:02	1 09.04. 13:02	0 09.04. 13:02	06204703140 19.03. 19:05	Notbetten brauchen Z eitlichen Vorlauf 19.03. 16:46		
St. Marien Krankenhaus	3 09.04. 15:35	4 09.04. 15:35	0 09.04. 15:36	1 09.04. 15:36	0 09.04. 15:36	0 09.04. 15:36	2 09.04. 15:36	0 09.04. 15:36	06206-509555 09.04. 15:36	09.04. 10:07		
Summe	18	39	14	6	4	0	24	0				
Leitstelle Darmstadt-Dieburg	**Soll-Betten**	**Max.-Betten (Soll-Betten mit Not-Beatmung)**	**Davon Betten mit OP-Beatmung**	**Belegte Betten**	**davon belegte Betten (mit Covid gesichert)**	**davon belegte Betten (mit Covid Verdacht)**	**Anz. freie Betten**	**Anz. freie Betten mit ECMO**	**Telefon Koordination**	**Bemerkungen**		
Krankenhaus Jugenheim-Seeheim	18 heute 10:44	27 heute 10:44	3 heute 10:44	14 heute 10:44	5 heute 10:44	0 heute 10:44	13 heute 10:44	0 heute 10:44	06257/508-311 09.04. 11:46			
Kreisklinik Groß-Umstadt	8 heute 09:03	11 heute 09:03	3 heute 09:03	3 heute 09:03	0 heute 09:03	0 heute 09:03	8 heute 09:04	0 heute 09:04	06078/79-270 1 21.03. 16:41			
Summe	26	38	6	17	5	0	21	0				
Leitstelle Darmstadt	**Soll-Betten**	**Max.-Betten (Soll-Betten mit Not-Beatmung)**	**Davon Betten mit OP-Beatmung**	**Belegte Betten**	**davon belegte Betten (mit Covid gesichert)**	**davon belegte Betten (mit Covid Verdacht)**	**Anz. freie Betten**	**Anz. freie Betten mit ECMO**	**Telefon Koordination**	**Bemerkungen**		

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30th April 20:00

normal ICU beds max. ICU beds occupied ICU beds free ECMO beds

IVENA eHealth - Interdisziplinärer Versorgungsnachweis

Hessisches Ministerium für Soziales und Integration

Abmelden | Regelversorgung | Übersicht KHS | Alarmierungen | Schließungen | MANV | Sonderlage | Mehr

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Sonderlage: ITS/IMC Betten mit Beatmung - KHS gesamt

Gruppierung: Versorgungsbereich bzw. Leitstelle | Anzeigen

Gesamtsumme	1456	2247	505	1004	162	47	912	35			
Leitstelle Bergstraße	**Soll-Betten**	**Max.-Betten (Soll-Betten mit Not-Beatmung)**	**Davon Betten mit OP-Beatmung**	**Belegte Betten**	**davon belegte Betten (mit Covid gesichert)**	**davon belegte Betten (mit Covid Verdacht)**	**Anz. freie Betten**	**Anz. freie Betten mit ECMO**	**Telefon Koordination**	**Bemerkungen**	
Heilig-Geist Hospital Bensheim Lev2	6 heute 16:06	7 heute 16:06	1 heute 16:06	2 heute 16:07	1 heute 16:07	0 heute 16:07	4 heute 16:07	0 heute 16:07	06251132943 23.03. 09:51		
Klinik für Psychiatrie, Psychotherapie Heppenheim Lev4											
Kreis-KH Bergstraße Heppenheim Lev2	8 heute 15:52	19 heute 15:52	5 heute 15:52	7 heute 15:52	2 heute 15:52	0 heute 15:52	12 heute 15:52	0 heute 15:52	062527019211 0 heute 15:53	27.03. 11:30	
Schön Klinik Lorsch Lev3	2 heute 06:09	6 heute 06:09	4 heute 06:09	0 heute 06:09	0 heute 06:09	0 heute 06:09	2 heute 06:09	0 heute 06:09	06251591318 oder 062515915011 heute 06:09	OP-Beatmung Vorlauf: 2-3h alle Notbeatmungen gehen zu Lasten der 6 IMC-Betten heute 06:10	
St. Josef Krankenhaus Viernheim Lev3	1 heute 11:32	3 heute 11:32	2 heute 11:32	0 heute 11:32	0 heute 11:32	0 heute 11:32	1 heute 11:32	0 heute 11:32	06204703140 21.04. 11:34	Notbetten brauchen Zeitlichen Vorlauf 19.03. 16:46	
St. Marien Krankenhaus Lampertheim Lev2	3 heute 10:59	3 heute 10:59	0 heute 10:59	0 heute 10:59	0 heute 10:59	0 heute 10:59	3 heute 10:59	0 heute 10:59	06206-509555 17.04. 15:22	27.04. 10:46	
Summe	20	38	12	9	3	0	22	0			
Leitstelle Darmstadt-Dieburg	**Soll-Betten**	**Max.-Betten (Soll-Betten mit Not-Beatmung)**	**Davon Betten mit OP-Beatmung**	**Belegte Betten**	**davon belegte Betten (mit Covid gesichert)**	**davon belegte Betten (mit Covid Verdacht)**	**Anz. freie Betten**	**Anz. freie Betten mit ECMO**	**Telefon Koordination**	**Bemerkungen**	
Krankenhaus Jugenheim-Seeheim Lev2	18 heute 07:15	27 heute 07:15	2 heute 07:15	14 heute 07:15	10 heute 07:15	0 heute 07:15	13 heute 07:15	0 heute 07:15	06257/508-311 09.04. 11:46		
Kreisklinik Groß-Umstadt Lev2	8 heute 07:51	11 heute 07:51	0 heute 07:51	3 heute 07:51	0 heute 07:51	0 heute 07:51	8 heute 07:51	0 heute 07:51	06078/79-2701 21.03. 16:41		
Summe	26	38	2	17	10	0	21	0			
Leitstelle Darmstadt	**Soll-Betten**	**Max.-Betten (Soll-Betten mit Not-Beatmung)**	**Davon Betten mit OP-Beatmung**	**Belegte Betten**	**davon belegte Betten (mit Covid gesichert)**	**davon belegte Betten (mit Covid Verdacht)**	**Anz. freie Betten**	**Anz. freie Betten mit ECMO**	**Telefon Koordination**	**Bemerkungen**	

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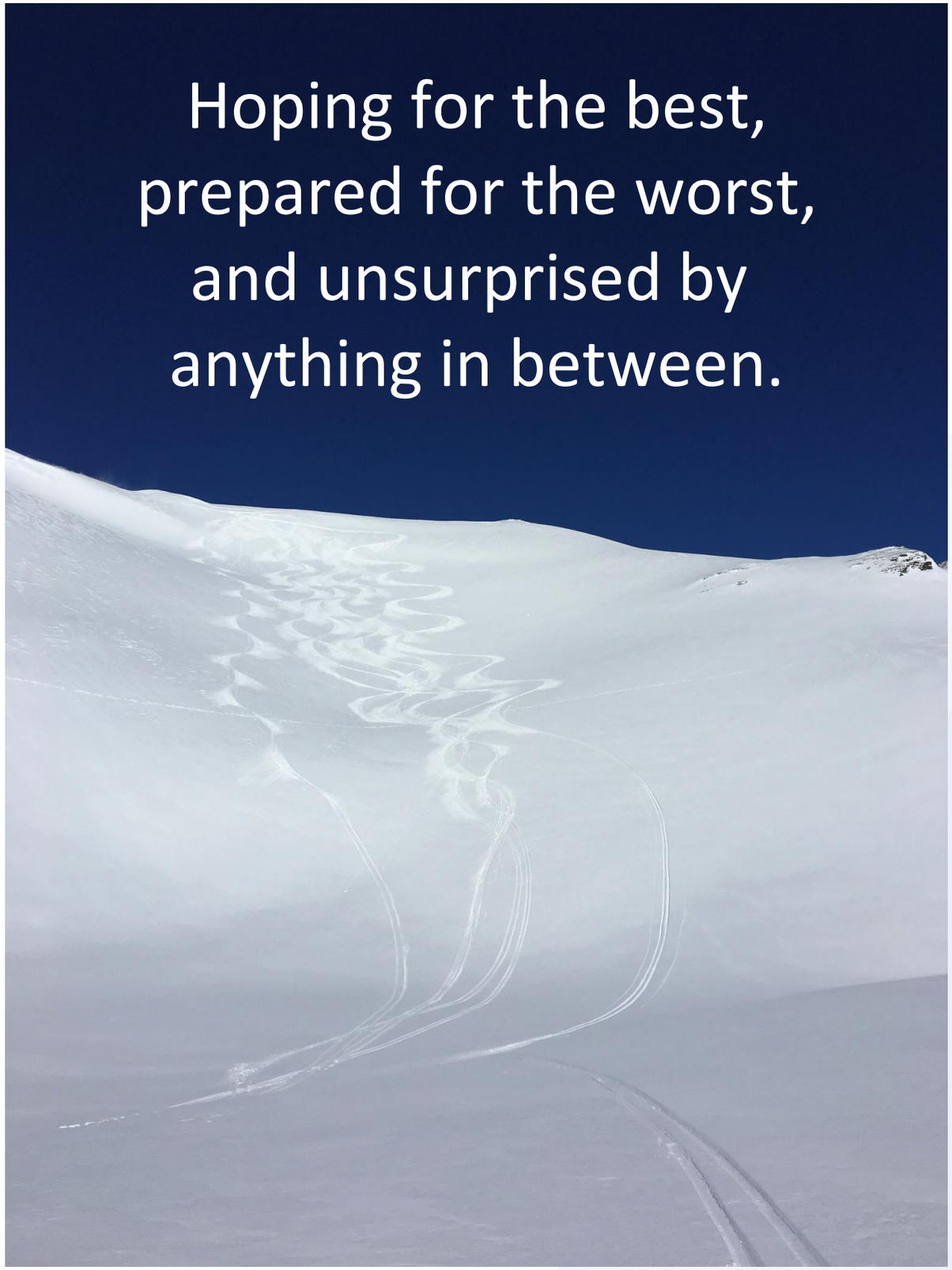

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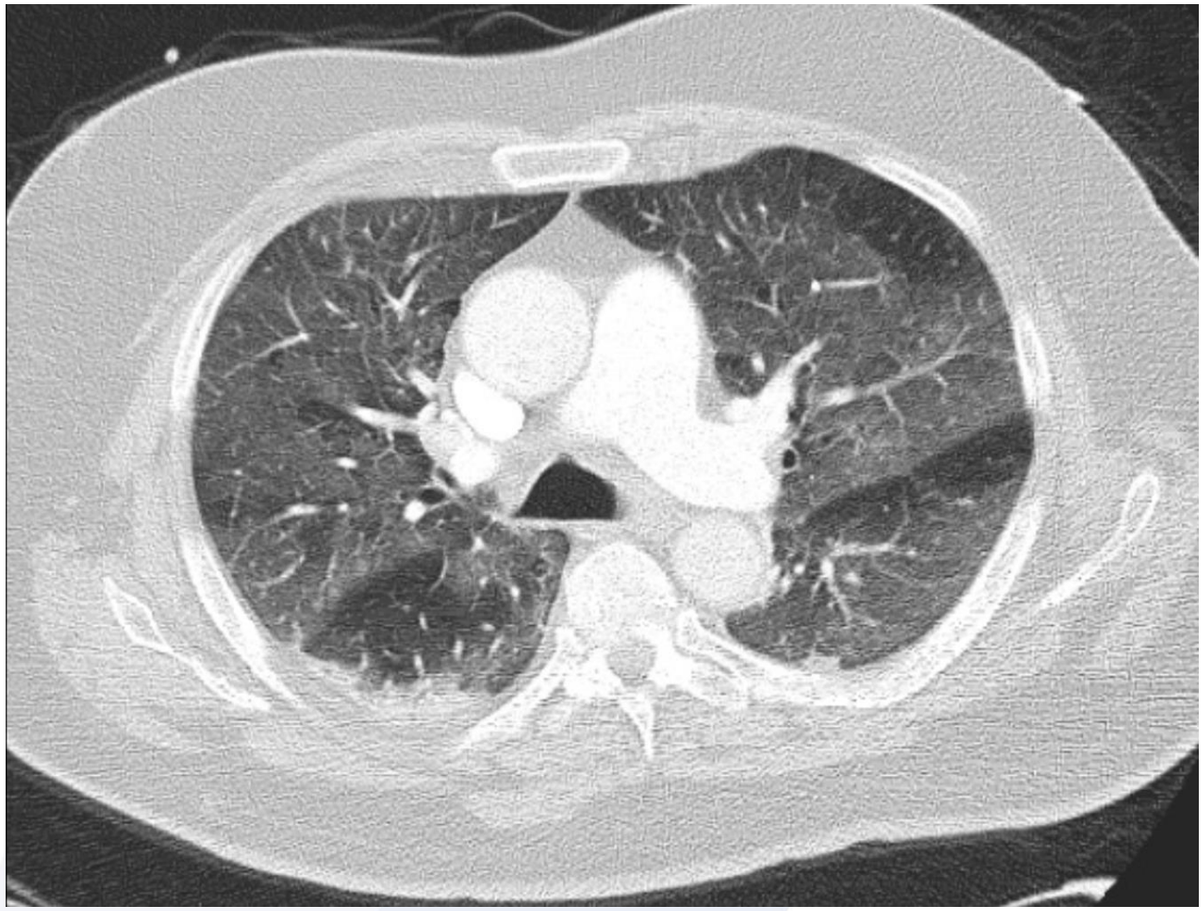
Individualized approach for COVID-19 pneumonia



What is best?

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Best practice in mechanical ventilation?

- **V_T**: 6 ml/kg pbw for all patients and P_{AW} < 28
  - NEJM 2000
- **PEEP**: ARDS network table based on Oxygenation
  - NEJM 2000 or NEJM 2004
- **High PEEP**: for severe ARDS
  - JAMA 2010
- **Prone**: for severe ARDS
  - NEJM 2013
- **NMB**: for severe ARDS or not?
  - NEJM 2010/JAMA 2019
- **No NIV** for severe ARDS
  - AJRCCM 2017

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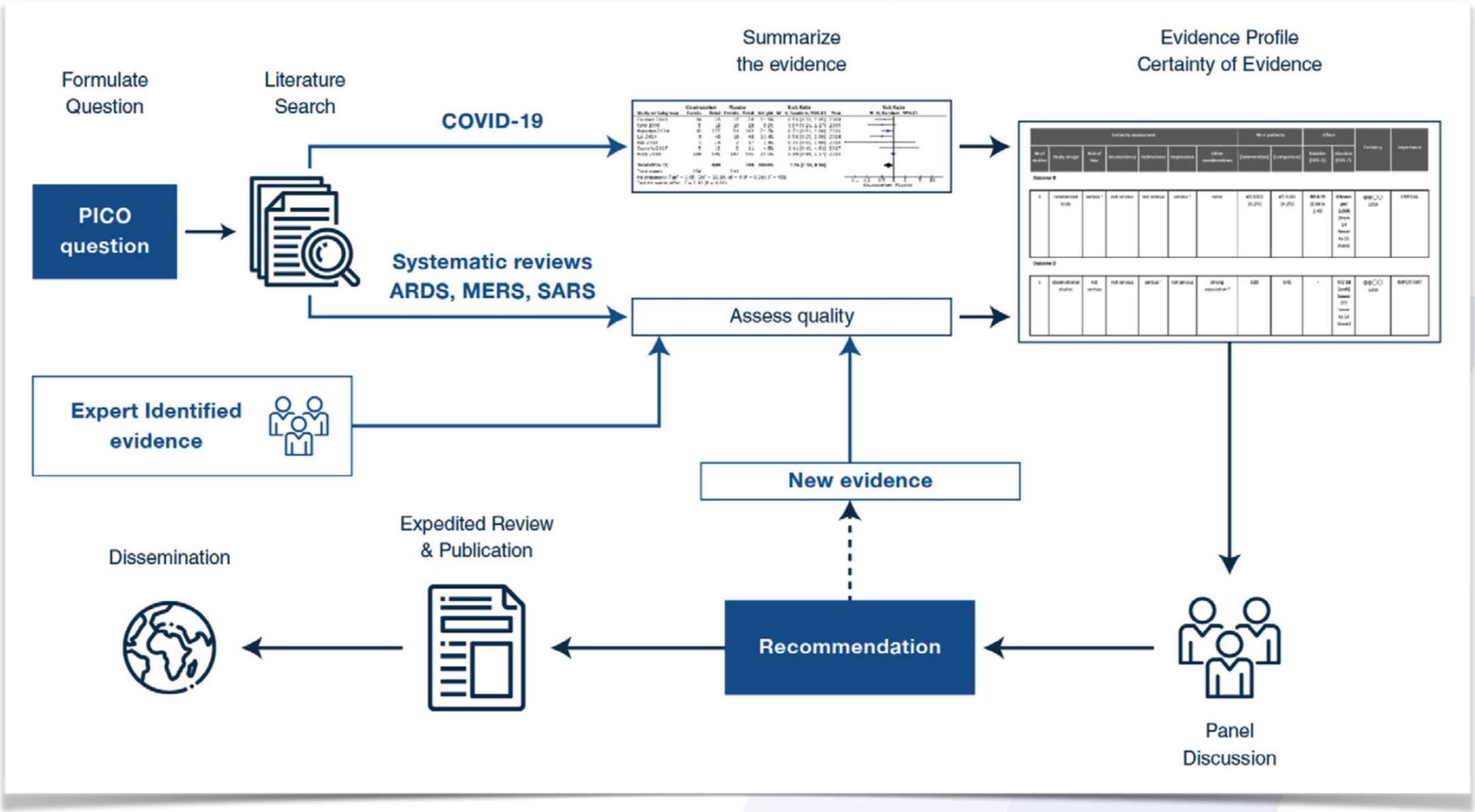

This article is being co-published in Critical Care Medicine (DOI: 10.1097/CCM.0000000000004363) and Intensive Care Medicine (DOI: 10.1007/s00134-020-06022-5).

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Ventilation:

23	In adults with COVID-19, we ***suggest*** starting supplemental oxygen if the peripheral oxygen saturation (Spo_2) is < 92%, and ***recommend*** starting supplemental oxygen if Spo_2 is < 90%	Weak Strong
24	In adults with COVID-19 and **acute hypoxemic respiratory failure on oxygen**, we ***recommend*** that Spo_2 be maintained no higher than 96%.	Strong
25	For adults with COVID-19 and **acute hypoxemic respiratory failure** despite conventional oxygen therapy, we ***suggest*** using HFNC over conventional oxygen therapy.	Weak
26	In adults with COVID-19 and **acute hypoxemic respiratory failure**, we ***suggest*** using HFNC over NIPPV.	Weak
27	In adults with COVID-19 and **acute hypoxemic respiratory failure**, if HFNC is not available and there is no urgent indication for endotracheal intubation, we ***suggest*** a trial of NIPPV with close monitoring and short-interval assessment for worsening of respiratory failure.	Weak
28	**We were not able to make a recommendation** regarding the use of helmet NIPPV compared with mask NIPPV. It is an option, but we are not certain about its safety or efficacy in COVID-19.	No recommendation
29	In adults with COVID-19 receiving NIPPV or HFNC, we ***recommend*** close monitoring for worsening of respiratory status, and early intubation in a controlled setting if worsening occurs.	Best practice statement
30	In mechanically ventilated adults with COVID-19 and ARDS, we ***recommend*** using low tidal volume (Vt) ventilation (Vt 4-8 mL/kg of predicted body weight), over higher tidal volumes (Vt>8 mL/kg).	Strong
31	For mechanically ventilated adults with COVID-19 and **ARDS**, we ***recommend*** targeting plateau pressures (Pplat) of < 30 cm H_2O.	Strong
32	For mechanically ventilated adults with COVID-19 and moderate to severe ARDS, we ***suggest*** using a higher PEEP strategy, over a lower PEEP strategy. **Remarks**: If using a higher PEEP strategy (i.e., PEEP > 10 cm H_2O), clinicians should monitor patients for barotrauma.	Strong
33	For mechanically ventilated adults with COVID-19 and ARDS, we ***suggest*** using a conservative fluid strategy over a liberal fluid strategy.	Weak
34	For mechanically ventilated adults with COVID-19 and **moderate to severe ARDS**, we ***suggest*** prone ventilation for **12 to 16 hours**, over no prone ventilation.	Weak
35.1	For mechanically ventilated adults with COVID-19 and **moderate to severe ARDS**, we ***suggest*** using, as needed, intermittent boluses of neuromuscular blocking agents (NMBA), over continuous NMBA infusion, to facilitate protective lung ventilation.	Weak
35.2	In the event of persistent ventilator dyssynchrony, the need for ongoing deep sedation, prone ventilation, or persistently high plateau pressures, we ***suggest*** using a continuous NMBA infusion for up to 48 hours.	Weak
36	In mechanically ventilated adults with COVID-19 ARDS, we ***recommend against*** the routine use of inhaled nitric oxide.	Weak

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COVID-19 is an emerging, rapidly evolving situation.
Get the latest public health information from CDC: https://www.coronavirus.gov .
Get the latest research from NIH: https://www.nih.gov/coronavirus.

The new PubMed site will become the default in mid-May.
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COVID-19 is an emerging, rapidly evolving situation.
Get the latest public health information from CDC: https://www.coronavirus.gov .
Get the latest research from NIH: https://www.nih.gov/coronavirus.

The new PubMed site will become the default in mid-May.
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✓ Randomized Controlled Trial
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1. Effect of High vs Low Doses of Chloroquine Diphosphate as Adjunctive Therapy for Patients Hospitalized With **Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2)** Infection: A Randomized Clinical Trial.

Related searches
sars cov 2 genome
sars cov 2 treatment

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Intensive Care Med (2016) 42:282–283
DOI 10.1007/s00134-015-4120-7

EDITORIAL

Jean-Louis Vincent
Carlos Santacruz

Do we need ARDS?

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Covid-19 Does Not Lead to a “Typical” Acute Respiratory

Distress Syndrome

n = 16

Luciano Gattinoni[1], Silvia Coppola[2], Massimo Cressoni[3], Mattia Busana[1], Sandra Rossi[4], Davide Chiumello[2]

After considering that, all we can do ventilating these patients is “buying time” with minimum additional damage: the lowest possible PEEP and gentle ventilation. We need to be patient.

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Intensive Care Med
https://doi.org/10.1007/s00134-020-06033-2

EDITORIAL

COVID-19 pneumonia: different respiratory treatments for different phenotypes?

Luciano Gattinoni[1*], Davide Chiumello[2], Pietro Caironi[3,4], Mattia Busana[1], Federica Romitti[1], Luca Brazzi[5] and Luigi Camporota[6]

Once intubated and deeply sedated, the Type L patients, if hypercapnic, can be ventilated with volumes greater than 6 ml/kg (up to 8–9 ml/kg), as the high compliance results in tolerable strain without the risk of VILI. Prone positioning should be used only as a rescue maneuver, as the lung conditions are "too good" for the prone position effectiveness, which

Type H patients should be treated as severe ARDS, including higher PEEP, if compatible with hemodynamics, prone positioning and extracorporeal support.

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Quotes Wiki

I think, therefore I ~~am~~ was... confused.

Benjamin Hoff

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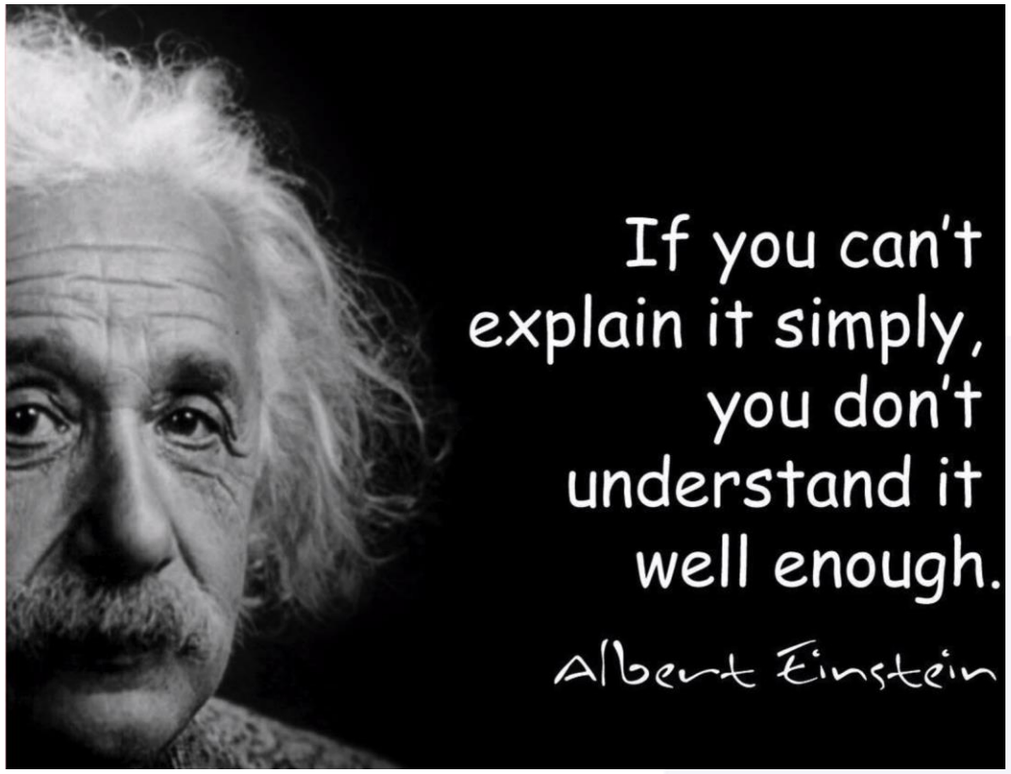
Gattinoni's dichotomous model



Type L

- Low elastane
- Low VA/Q mismatch
- Low lung weight
- Low recruit ability

Type H

- High elastane
- High R-L shunt
- High lung weight
- High recruitability

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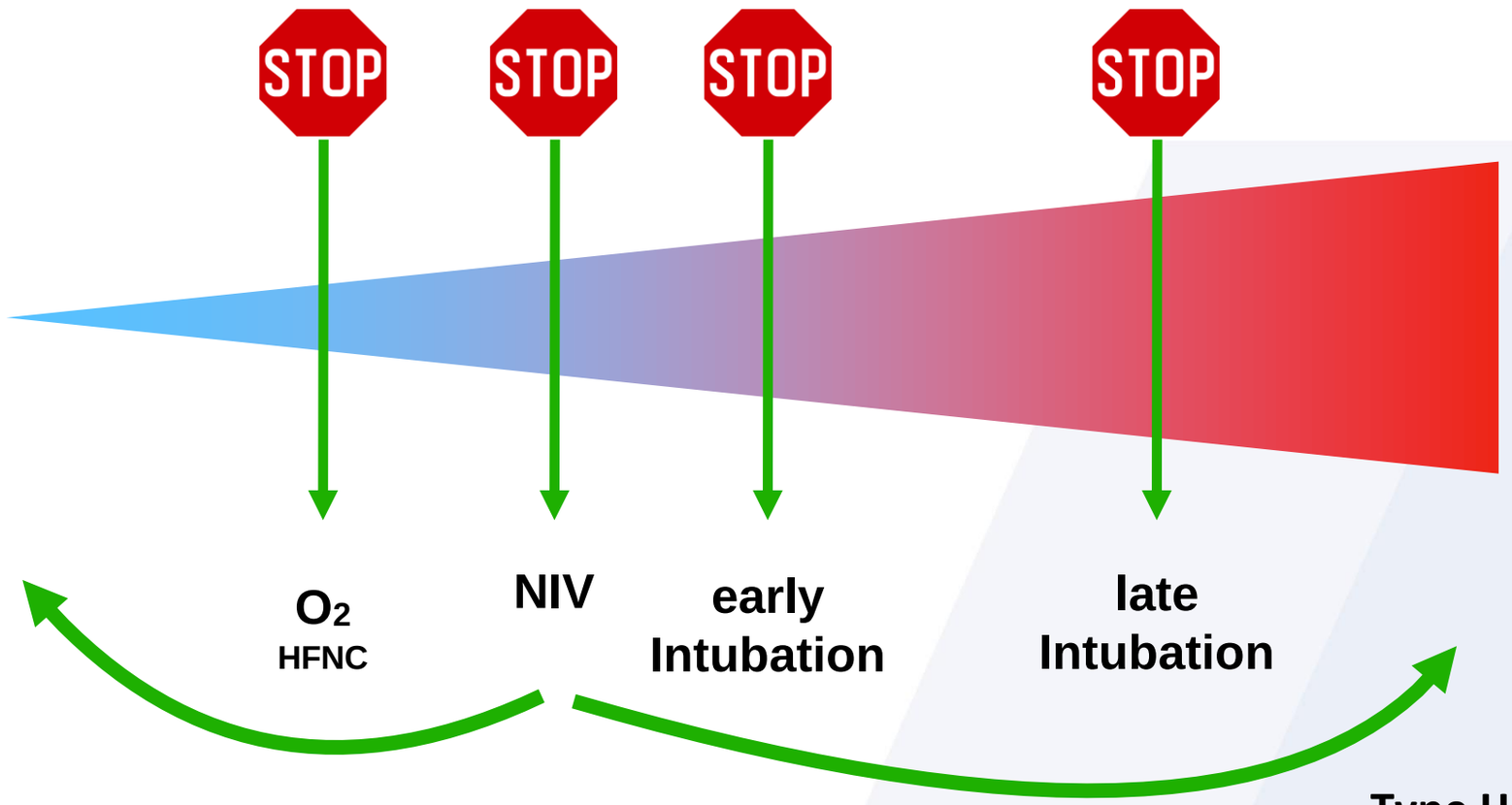
Lung damage progression (SARS CoV 2 + P-SILI)



Type L

- Low elastane
- Low VA/Q mismatch
- Low lung weight
- Low recruit ability

Type H

- High elastane
- High R-L shunt
- High lung weight
- High recruitability

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Individualized approach for COVID-19 associated ARDS (CARDS)

We are not treating ARDS or CARDS

we are treating Hypoxia

and respiratory distress

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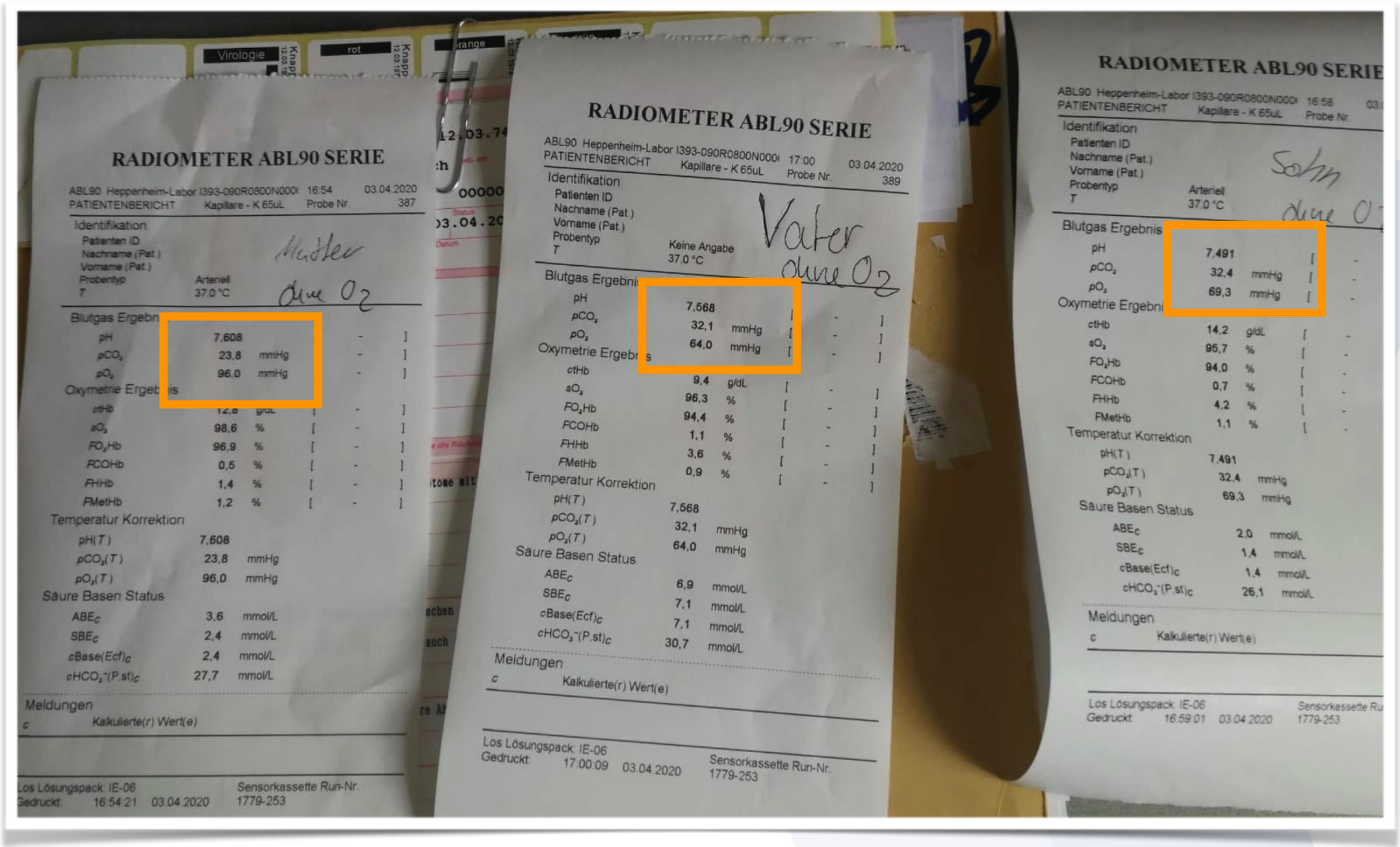
Hypoxia prevented by hyperventilation



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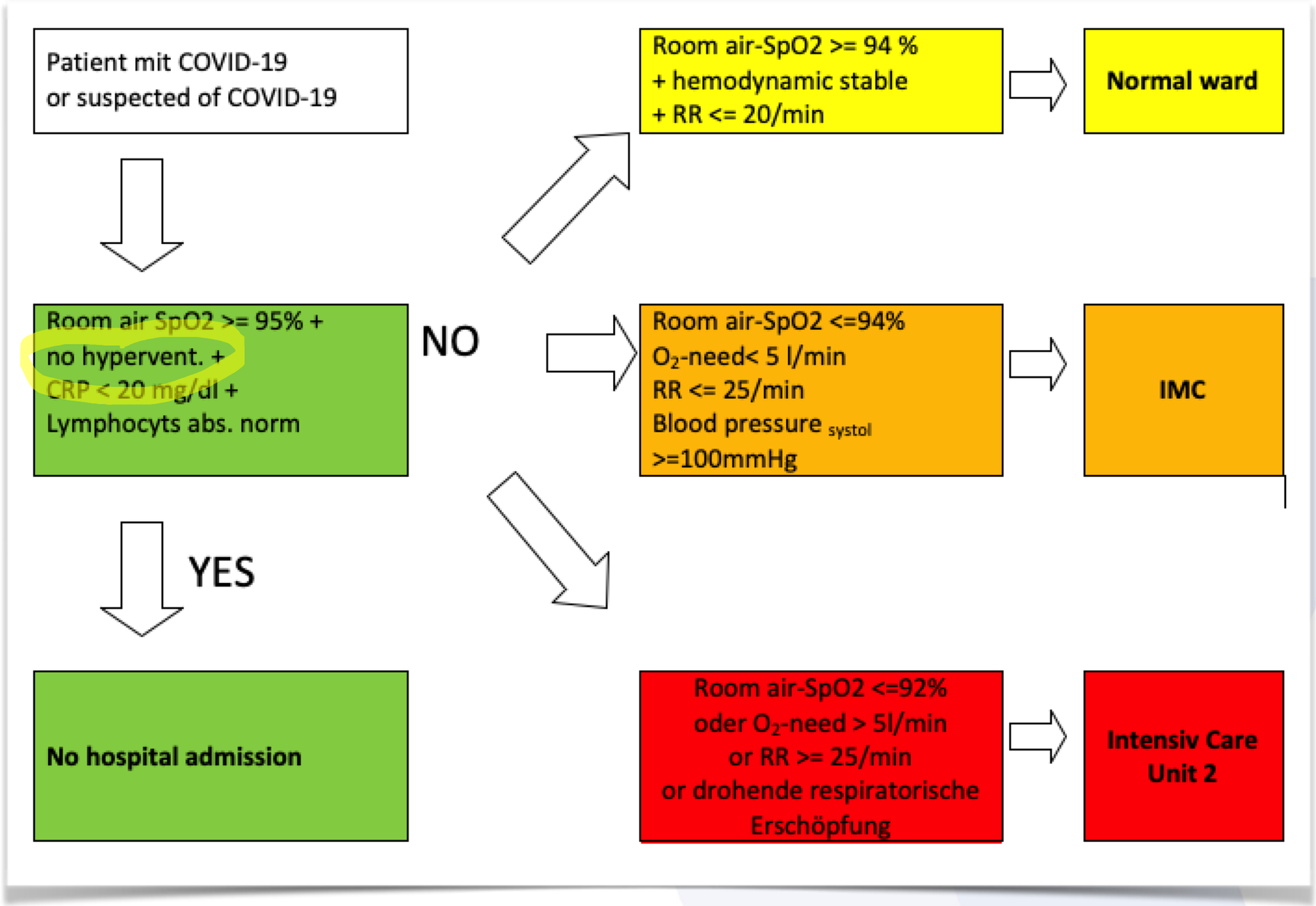

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Intensive Care Med (2020) 46:606–618
https://doi.org/10.1007/s00134-020-05942-6

NARRATIVE REVIEW

Respiratory drive in the acute respiratory distress syndrome: pathophysiology, monitoring, and therapeutic interventions

Elena Spinelli[1], Tommaso Mauri[1,2*], Jeremy R. Beitler[3], Antonio Pesenti[1,2] and Daniel Brodie[3]

Excessive effort to breathe due to high respiratory drive may lead to patient self-inflicted lung injury (P-SILI), even in the absence of mechanical ventilation.

Give O_2 until hyperventilation is decreasing independent of S_pO_2

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NIV in Covid-19

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Intubation in Covid-19: harm more than benefit?

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Medizinische Klinik
Intensivmedizin und Notfallmedizin

Guidelines and Recommendations

Med Klin Intensivmed Notfmed
https://doi.org/10.1007/s00063-020-00689-w

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[5] ARDS Network Germany, Berlin, Germany
[6] Department of Intensive Care, University Medical Center Hamburg-Eppendorf, Hamburg, Germany

German recommendations for critically ill patients with COVID-19

In general, we advise to be rather restrictive with HFNC and NIV in the context of COVID-19. In patients with severe hypoxemia ($P_aO_2/F_iO_2 \leq 200$ mm Hg) we suggest performing early intubation and

personal protection equipment (PPE) are essential in the care of patients

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Deutsche Gesellschaft für Pneumologie und Beatmungsmedizin e.V. (DGP)

Position Paper for the State of the Art Application of Respiratory Support in Patients with COVID-19

German Respiratory Society

Autoren
M. Pfeifer[1,2,3], S. Ewig[4], T. Voshaar[5], W. Randerath[6,7], T. Bauer[8], J. Geiseler[9], D. Dellweg[10], M. Westhoff[11,12], W. Windisch[12,13], B. Schönhofer[14], S. Kluge[15], P. M. Lepper[16]

A significant proportion of patients with respiratory failure presents with relevant hypoxemia, often also caused by a high inspiratory oxygen fraction (FiO2) including NHF, and this hypoxemia cannot be not completely corrected. In this situation, CPAP/NIV therapy can be administered under use of a mouth and nose mask or a respiratory helmet as therapy escalation, as long as the criteria for endotracheal intubation are not fulfilled.

personal protection equipment (PPE) are essential in the care of patients

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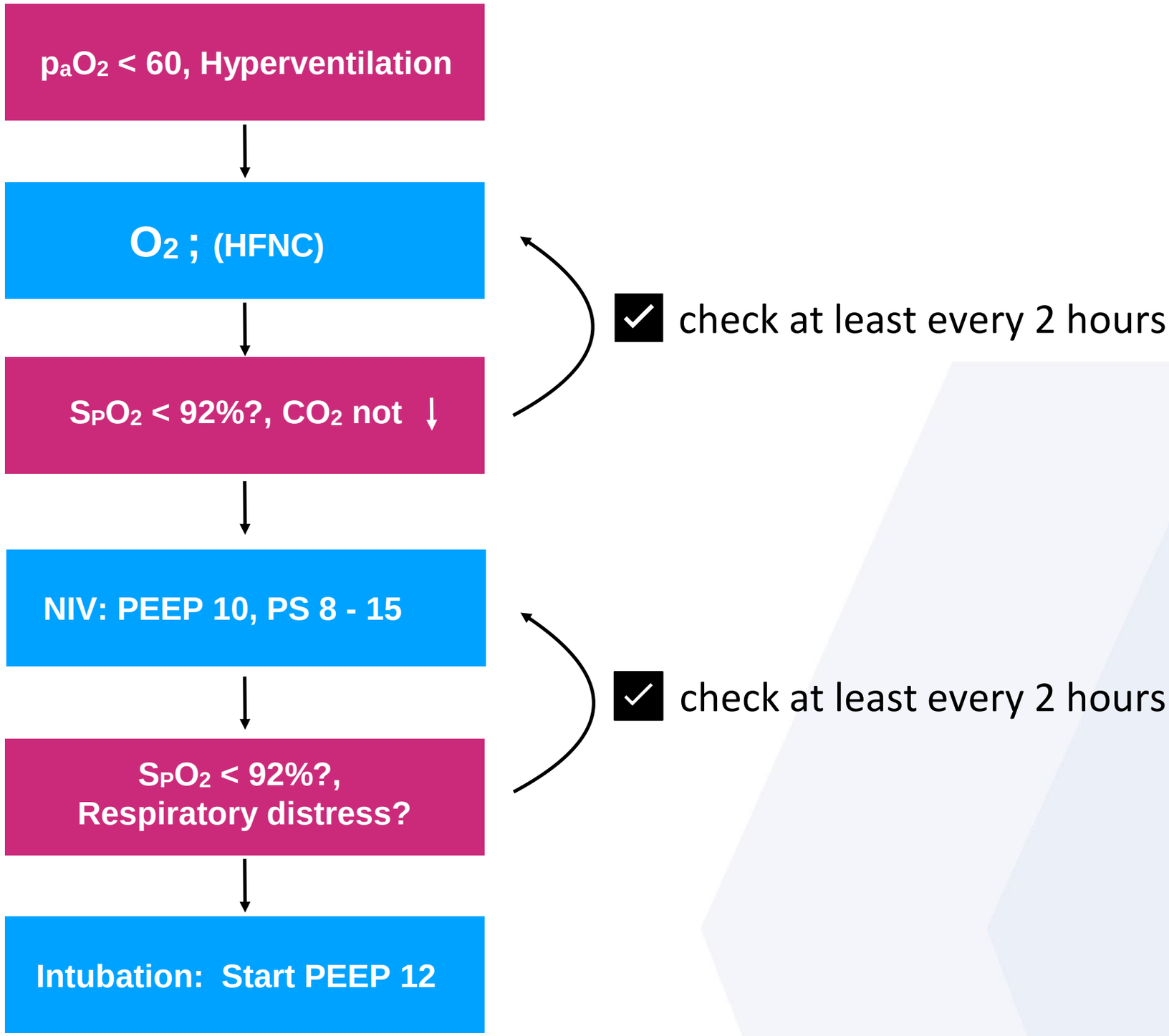

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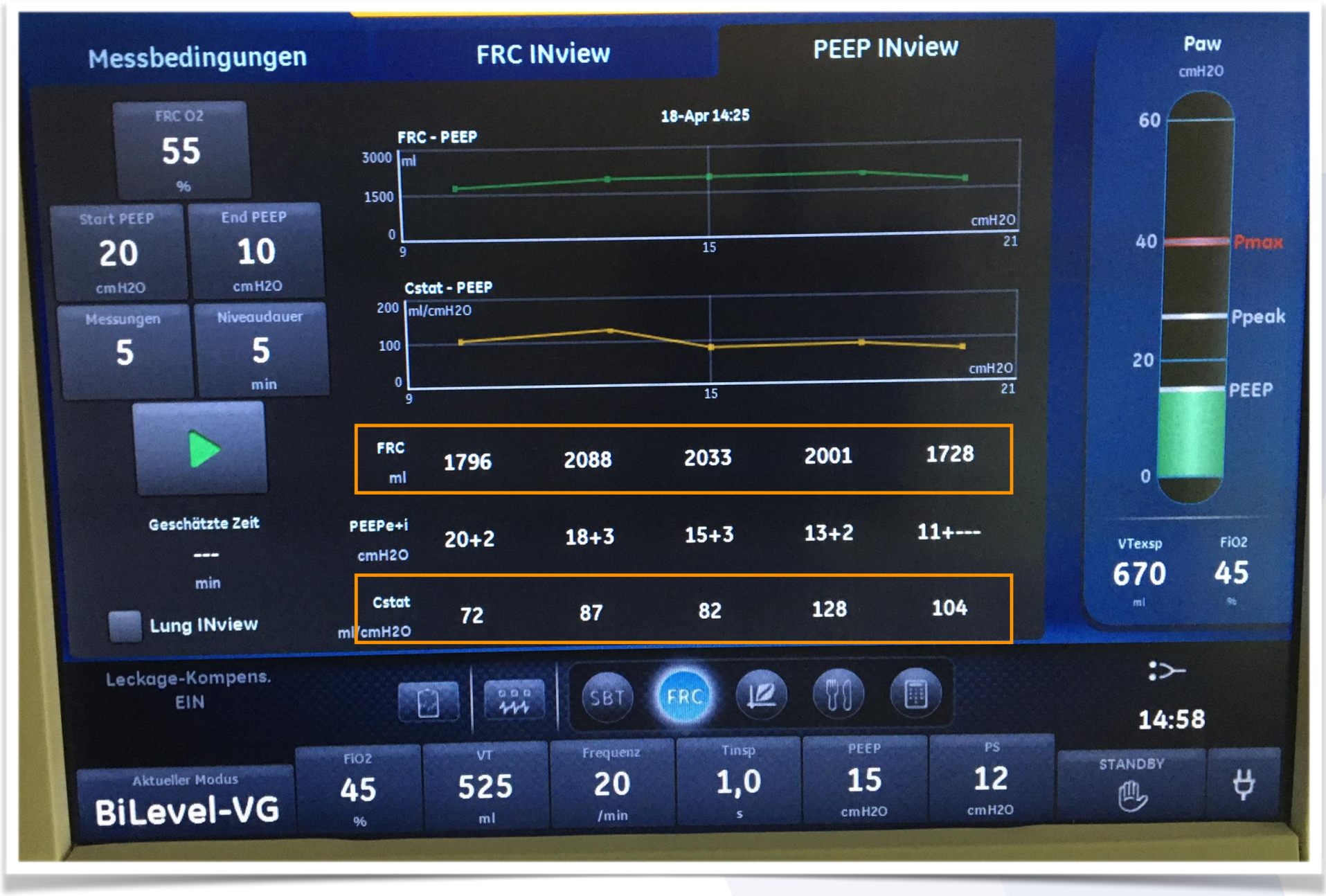
L- Type Covid-19



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Research

JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

Effect of a Low vs Intermediate Tidal Volume Strategy on Ventilator-Free Days in Intensive Care Unit Patients Without ARDS

A Randomized Clinical Trial

Writing Group for the PReVENT Investigators

POPULATION

621 Men **340** Women

ICU patients without ARDS expected to be intubated for more than 24 hours

Median age: **68** years (IQR, 59-76)

LOCATIONS

6 ICUs in the Netherlands

INTERVENTIONS

961 Patients randomized

477 Randomized
475 Analyzed

Low tidal volume
Started at tidal volume of 6 mL/kg; tidal volume then decreased in steps of 1 mL/kg predicted body weight

484 Randomized
480 Analyzed

Intermediate tidal volume
Started at tidal volume of 10 mL/kg; if plateau pressure exceeded 25 cm H_2O, tidal volume was decreased in steps of 1 mL/kg predicted body weight

PRIMARY OUTCOME

Number of ventilator-free days and alive at day 28

JAMA. 2018;320(18):1872-1880

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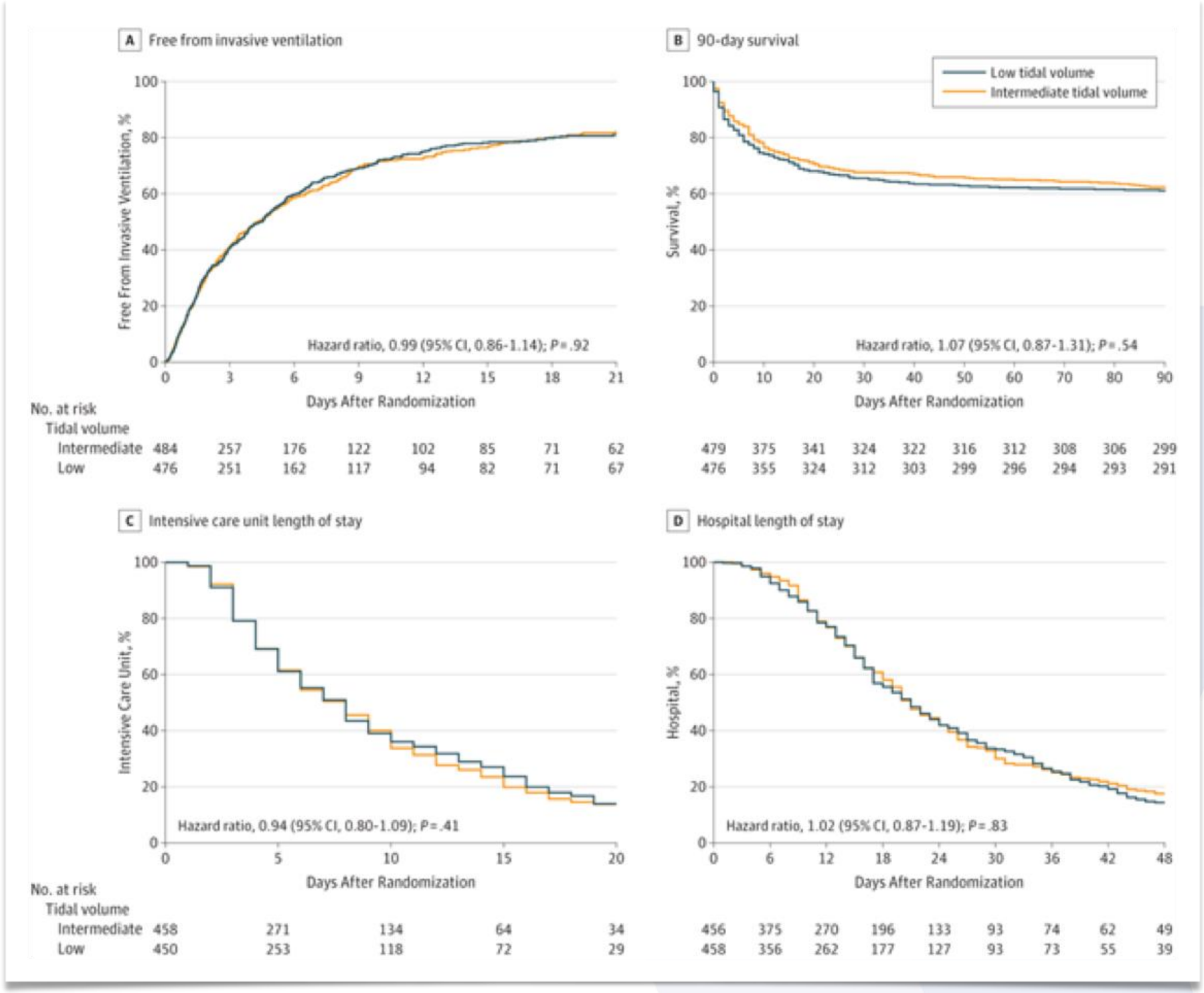

JAMA. 2018;320(18):1872-1880

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Δ P = PIP - PEEP

eTable 1 – Respiratory variables during the first three days of ventilation

	After titration on day of randomization			Day 1			Day 2			Day 3		
	Low Tidal Volume	Intermediate Tidal Volume	*p* value	Low Tidal Volume	Intermediate Tidal Volume	*p* value	Low Tidal Volume	Intermediate Tidal Volume	*p* value	Low Tidal Volume	Intermediate Tidal Volume	*p* value
Number of patients	452	463		391	410		321	343		272	296	
V_T, mL/kg PBW	5.9 (5.2 – 6.7)	9.1 (7.9 – 10.0)	< 0.001	6.6 (5.5 – 8.7)	9.3 (8.1 – 10.1)	< 0.001	7.4 (5.8 – 9.7)	9.1 (7.7 – 10.3)	< 0.001	7.3 (5.9 – 9.1)	9.1 (7.7 – 10.5)	< 0.001
Respiratory rate, bpm	23 (19 – 28)	16 (14 – 20)	< 0.001	22 (16 – 28)	16 (13 – 21)	< 0.001	20 (16 – 27)	17 (13 – 22)	< 0.001	21 (15 – 27)	16 (14 – 24)	< 0.001
MV, L/min	9.2 (7.5 – 10.9)	10.0 (8.5 – 12.3)	< 0.001	9.9 (8.2 – 12.0)	9.8 (8.1 – 12.0)	0.99	10.0 (8.3 – 12.0)	9.9 (8.0 – 12.0)	0.45	10.1 (8.2 – 12.2)	10.6 (8.6 – 13.2)	0.14
Plateau pressure, cmH_2O	18 (15 – 21)	21 (18 – 24)	< 0.001	17 (14 – 20)	20 (18 – 23)	< 0.001	18 (16 – 22)	21 (17 – 24)	0.02	20 (16 – 24)	22 (18 – 23)	0.18
PEEP, cmH_2O	8 (5 – 10)	8 (5 – 8)	0.33	6 (5 – 8)	7 (5 – 8)	0.64	6 (5 – 8)	6 (5 – 8)	0.58	7 (5 – 8)	6 (5 – 8)	0.29
Driving pressure, cmH_2O	10 (8 – 13)	14 (12 – 16)	< 0.001	10 (8 – 13)	13 (11 – 15)	< 0.001	10 (8 – 13)	14 (11 – 16)	< 0.001	11 (8 – 14)	14 (12 – 16)	< 0.001
FiO_2	0.45 (0.37 – 0.55)	0.40 (0.40 – 0.60)	0.66	0.38 (0.30 – 0.45)	0.35 (0.30 – 0.40)	0.02	0.35 (0.30 – 0.45)	0.35 (0.30 – 0.45)	0.94	0.35 (0.30 – 0.40)	0.35 (0.30 – 0.45)	0.63
PaO_2 / FiO_2, mmHg	210 (152 – 300)	214 (153 – 307)	0.49	230 (171 – 300)	243 (180 – 311)	0.21	225 (178 – 292)	240 (176 – 297)	0.62	236 (181 – 285)	235 (168 – 307)	0.89
$PaCO_2$, mmHg	43.5 (38.2 – 48.7)	36.0 (30.7 – 42.0)	< 0.001	39.7 (35.2 – 44.2)	35.2 (31.5 – 39.7)	< 0.001	39.7 (36.0 – 45.0)	37.5 (33.7 – 42.0)	< 0.001	41.9 (36.0 – 45.7)	38.0 (33.7 – 42.7)	< 0.001
pHa	7.31 (7.24 – 7.54)	7.39 (7.31 – 7.46)	< 0.001	7.38 (7.33 – 7.42)	7.43 (7.37 – 7.48)	< 0.001	7.41 (7.36 – 7.45)	7.43 (7.38 – 7.47)	< 0.001	7.44 (7.39 – 7.48)	7.45 (7.40 – 7.48)	0.02
pHa < 7.25	96 / 381 (25.2)	46 / 404 (11.4)	< 0.001	18 / 375 (4.8)	14 / 393 (3.6)	0.40	2 / 281 (0.7)	3 / 303 (1.0)	0.71	7 / 237 (3.0)	1 / 248 (0.4)	0.03
Respiratory acidosis*	132 / 381 (34.6)	49 / 404 (12.1)	< 0.001	42 / 375 (11.2)	21 / 393 (5.3)	0.003	29 / 281 (10.3)	21 / 303 (6.9)	0.14	17 / 237 (7.2)	8 / 248 (3.2)	0.05

Data are N (%) median (interquartile range)

V_T: tidal volume; PBW: predicted body weight; bpm: breaths per minute; MV: minute ventilation; PEEP: positive end-expiratory pressure; FiO_2: fraction of inspired oxygen: PaO_2: arterial oxygen pressure: $PaCO_2$: arterial pressure of carbon dioxide; pHa: arterial pH

* defined as pHa < 7.35 and $PaCO_2$ > 45 mmHg

The lower number of patients assessed for respiratory acidosis and pHa < 7.25 represent missing in ABG measurements

JAMA. 2018;320(18):1872-1880

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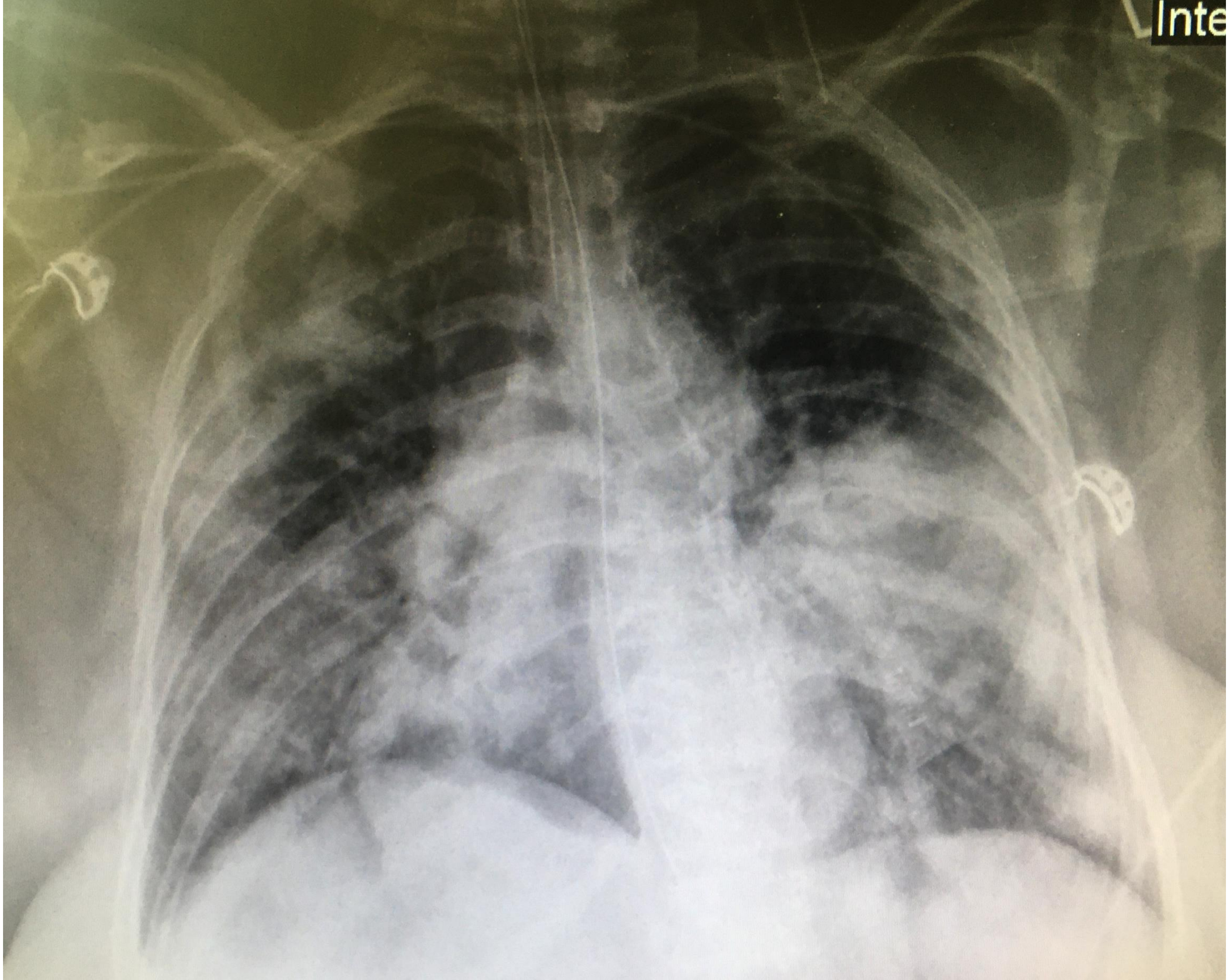
Inte

H- Type Covid-19

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one size does not fits all!

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Originalarbeit

Charakteristik von 50 hospitalisierten COVID-19-Patienten mit und ohne ARDS

Michael Dreher, Alexander Kersten, Johannes Bickenbach, Paul Balfanz, Bojan Hartmann, Christian Cornelissen, Ayham Daher, Robert Stöhr, Michael Kleines, Sebastian W. Lemmen, Jörg Christian Brokmann, Tobias Müller, Dirk Müller-Wieland, Gernot Marx, Nikolaus Marx

TABELLE 1

Patientencharakteristik

	N (%)		
	alle Patienten (N = 50)	ARDS-Patienten (n = 24)	Non-ARDS-Patienten (n = 26)
Alter – Jahre: Median (IQR)	65 (58–76)	62 (58–70)	68 (59–81)
weibliches Geschlecht	17 (34)	9 (38)	8 (31)
Komorbiditäten			
gesamt	50 (100)	24 (100)	26 (100)
arterielle Hypertonie	35 (70)	16 (67)	19 (73)
Adipositas (BMI ≥ 30 kg/m^2)	17 (34)	11 (46)	6 (23)
Übergewicht (BMI ≥ 25 kg/m^2, < 30 kg/m^2)	14 (28)	9 (38)	5 (19)

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High Positive End-Expiratory Pressure Is Associated with Improved Survival in Obese Patients with Acute Respiratory Distress Syndrome

Christian Bime, MD, MSc,[a,b] Mallorie Fiero, PhD,[c] Zhenqiang Lu, PhD,[b,d] Eyal Oren, PhD, MS,[c] Cristine E. Berry, MD, MHS,[a,b] Sairam Parthasarathy, MD,[a,b] Joe G.N. Garcia, MD[a,b]

	Nonobese				Obese			
Outcomes*	High PEEP‖	Low PEEP¶	Adjusted OR§ (95% CI)	*P* Value	High PEEP‖	Low PEEP¶	Adjusted OR§ (95% CI)	*P* Value
Mortality, %†	34	23	1.52 (0.9-2.6)	.13	18	32	0.4 (0.18-0.97)	.04
Unassisted breathing, %‡	74	76	1.02 (0.6-1.8)	.92	80	74	1.52 (0.65-3.55)	.34
Barotrauma, %	13	7	1.98 (0.9-4.4)	.09	3	6	0.35 (0.06-2.04)	.24

The American Journal of Medicine, Vol 130, No 2, February 2017

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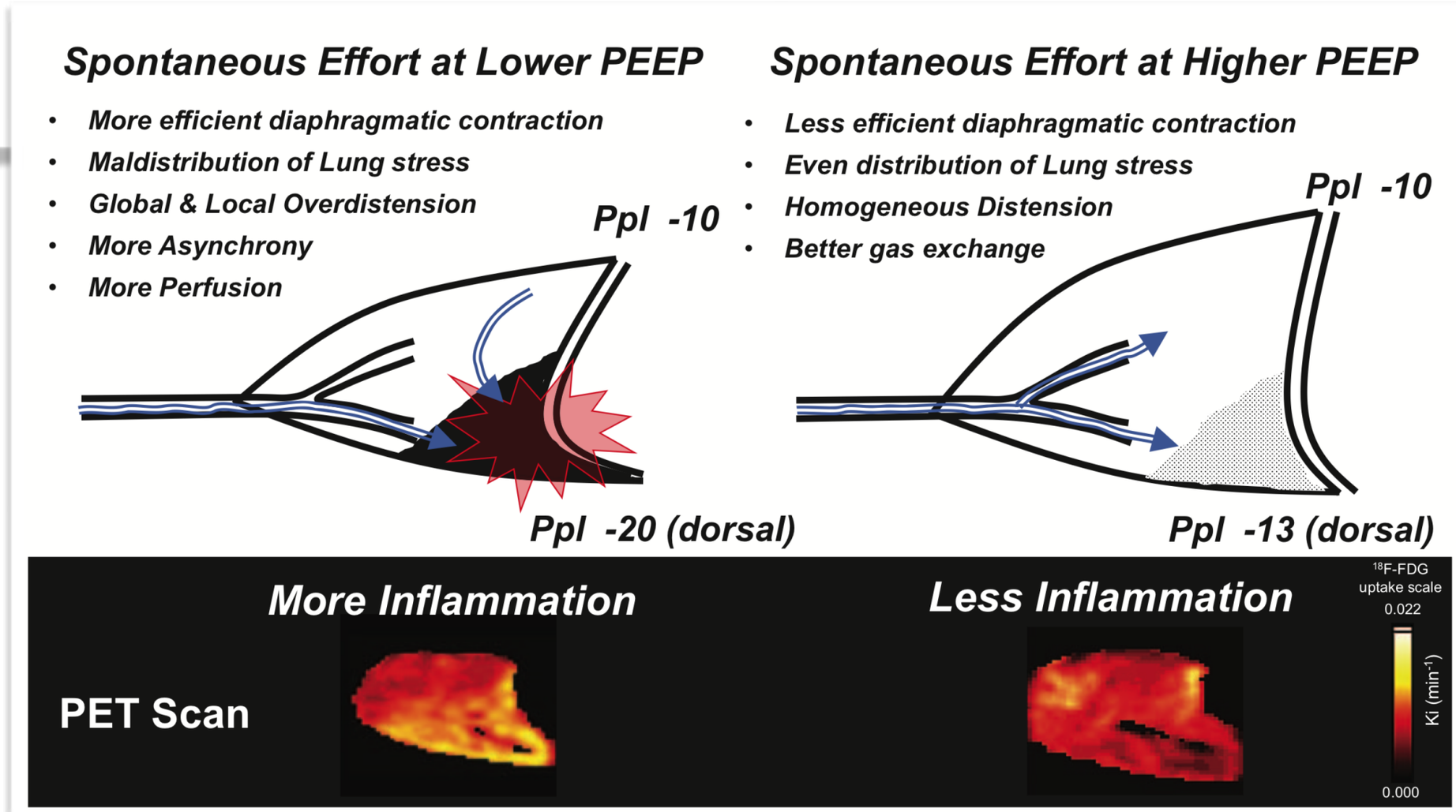
REVIEW

CURRENT OPINION

Patient self-inflicted lung injury and positive end-expiratory pressure for safe spontaneous breathing



Curr Opin Crit Care. 2020 Feb;26(1):59-65

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REVIEW

Lung protection in acute respiratory distress syndrome: what should we target?

Jeremy R. Beitler[a,b]

KEY POINTS

- A precision medicine approach to lung-protective ventilation requires weighing four key factors in each patient:
  - Biological predisposition to biophysical lung injury.
  - Presence and severity of spatial mechanical heterogeneity within the lung.
  - Anticipated benefits of escalating lung-protective interventions.
  - Potential unintended adverse effects of cointerventions, for example, deeper sedation, required to escalate the lung-protective strategy.

Curr Opin Crit Care 2020, 26:26 – 34

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Ventilatory support in Covid-19

1. Covid-19 pneumonia is a heterogeneous picture
2. There is no one-size-fits-all approach
3. P-SILI is one key parameter
4. Oxygenation or P/F ratio is not helpful to titrate PEEP
   - ARDSnet table is useless
5. Do not „super optimize“ blood gases
   - pH 7.25
6. You have to individualize therapy
   - measure Δ P, IAP, EELV or esophageal pressure
7. See the whole patient

5. - 7. Adapted from Gattinoni et al Friday night ventilation:
A safety starting tool kit for mechanically ventilated patients. Minerva Anestesiol. 2014 Sep;80(9):1046-57

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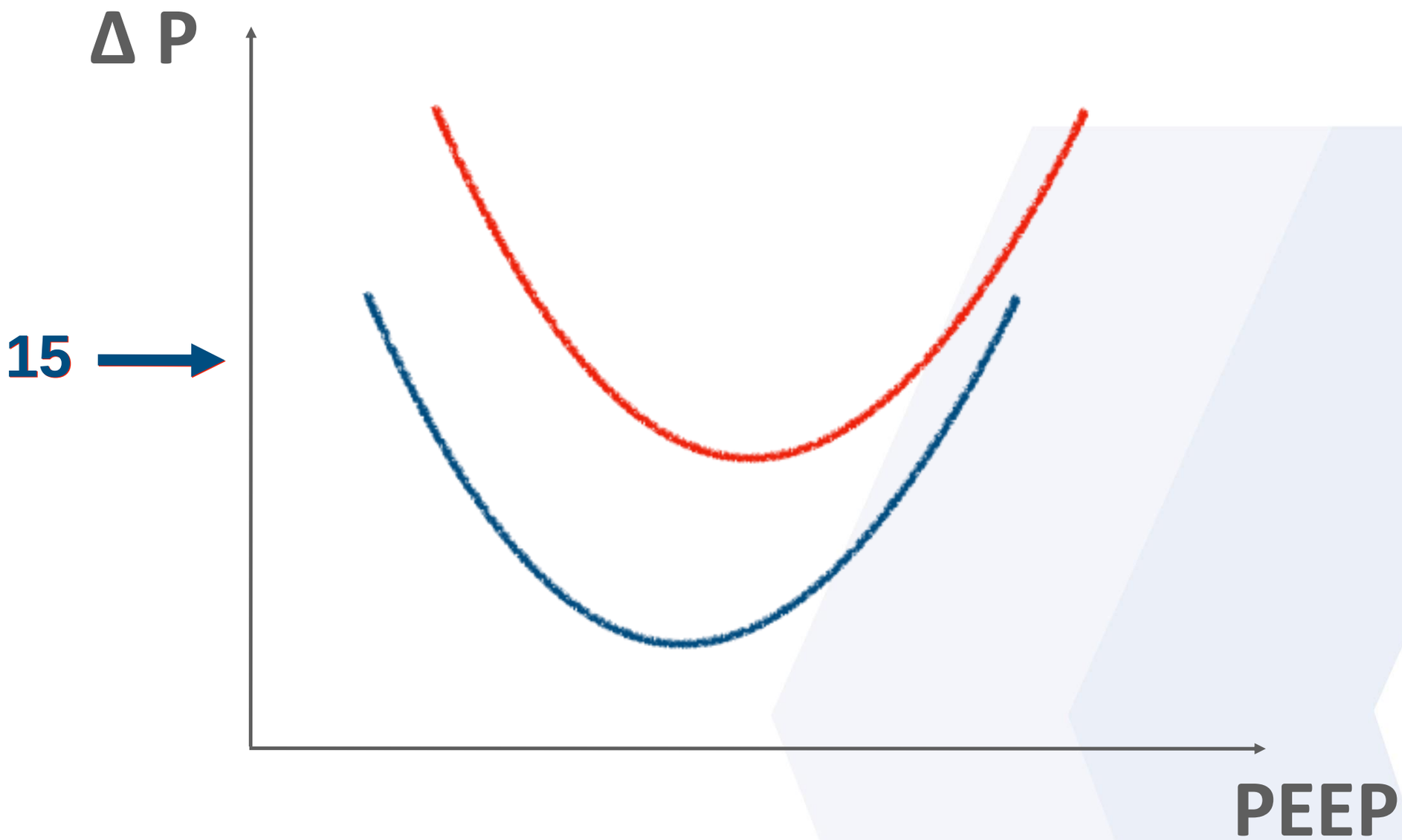
A very pragmatic approach



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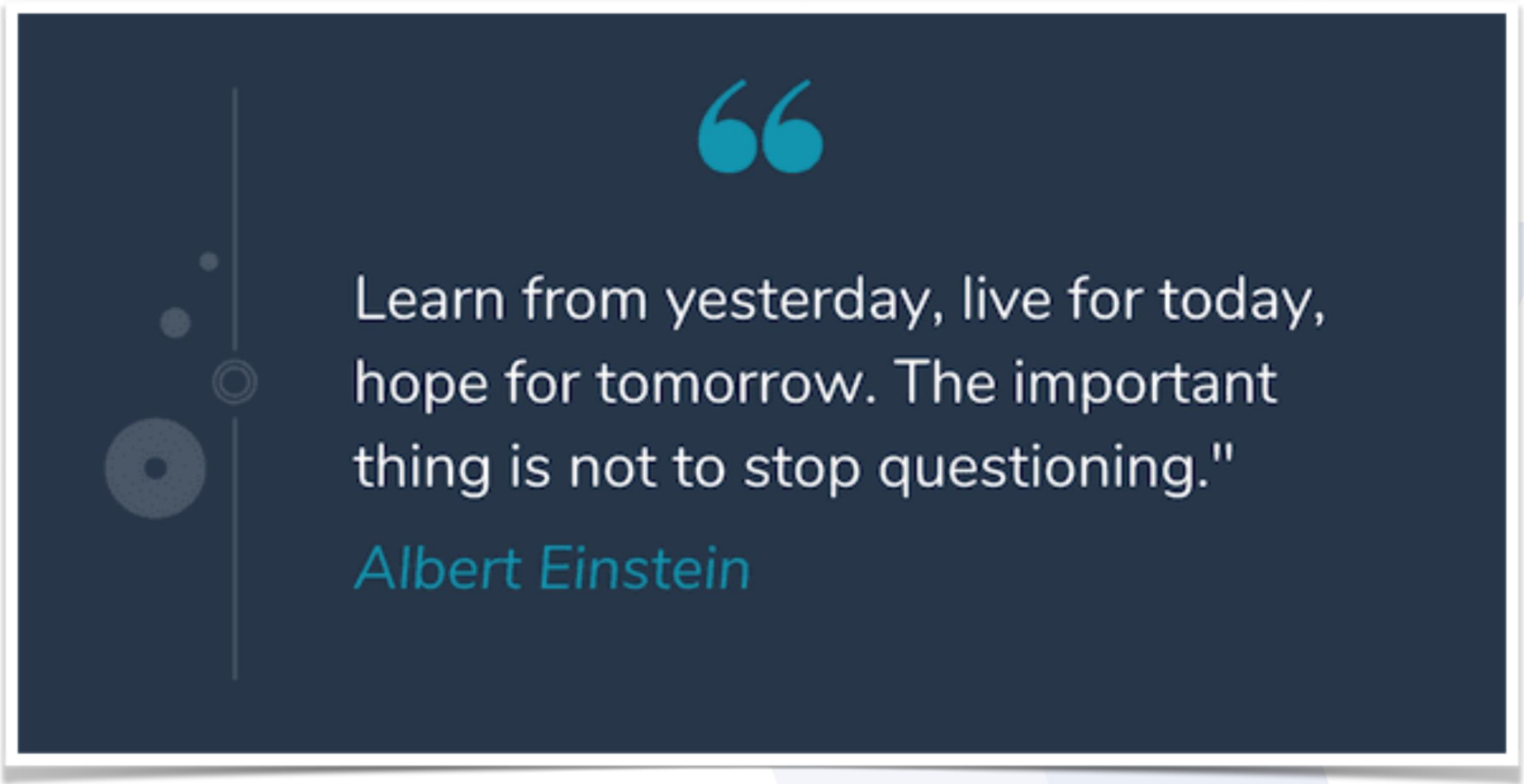

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des Saarlandes

COVID-19: ECMO considerations

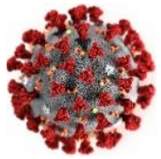
Philipp M. Lepper

Dept. of Internal Medicine V
ECLS Center Saar
University Hospital of Saarland

UKS COVID-19 ICU

UKS Universitätsklinikum des Saarlandes

- **24 bed ICU with dedicated ECMO-service (including mobile ECMO team)**
- **ICU solely for COVID + ICU patients**
- **Set up of airlock chamber and strict isolation of all COVID +**
- **PPE with overall, FFP3 mask, safety goggles + visor, double gloves**
- **First COVID + patient arrived March, 14th**
- **All „regular“ ICU procedures performed:**
  - Intubation
  - Tracheotomy
  - Bronchoscopy – single use for bronchoscopy and tracheostomy
- **No COVID-19 infections in health care workers (HCW) occured up to now**



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UKS COVID-19 ICU Part 1 (16 bed unit)

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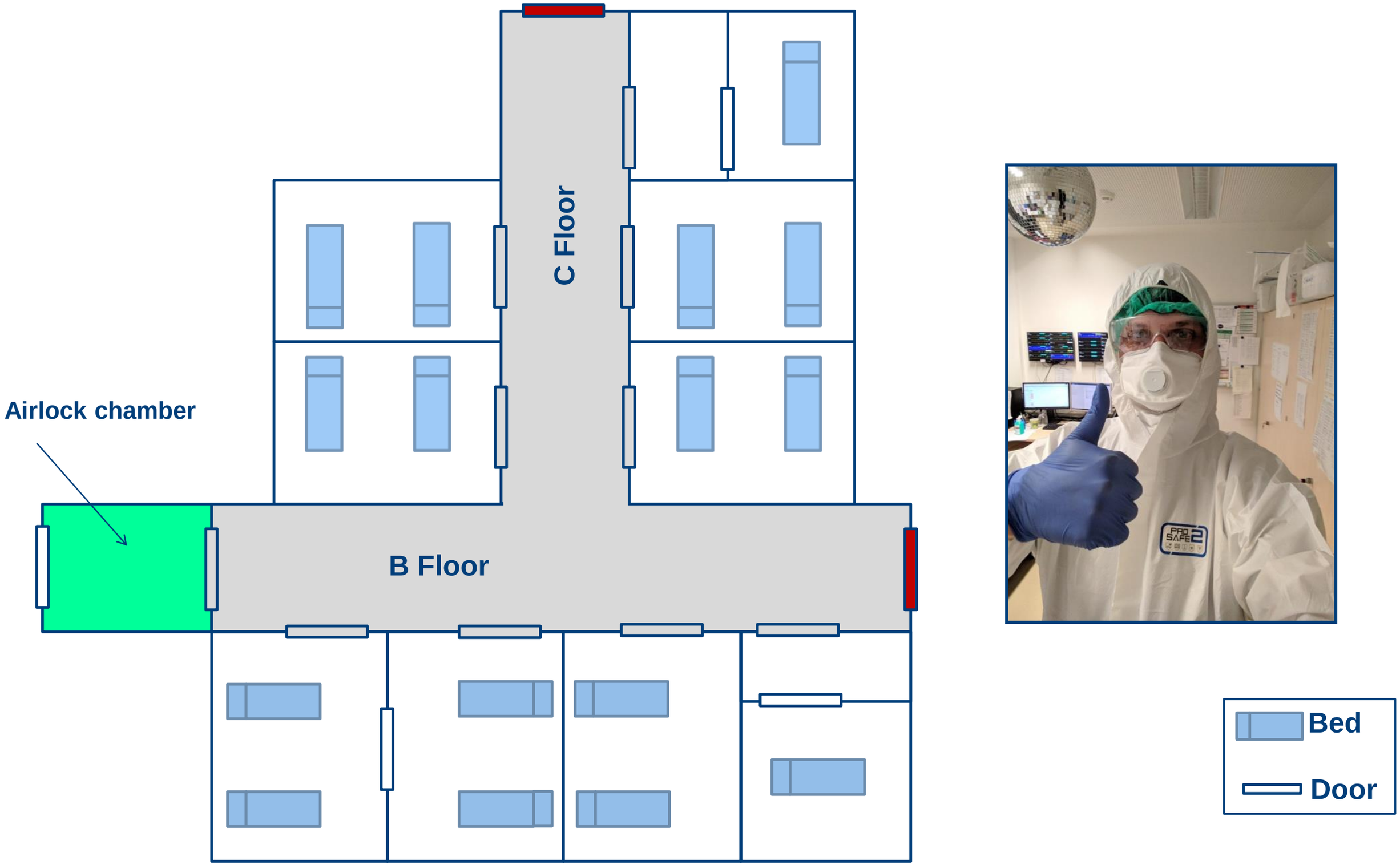

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COVID-19 Infection control

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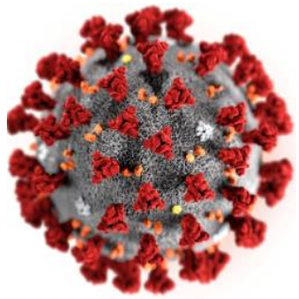

- **Education and re-education on PPE**
- **Strong emphasis on basic hygiene measures**
- **No visitors allowed on ICU (exemtion possible for relatives of dying patients)**
- **Enhanced surveillance for infection in HCW**
- **Stress and burn-out prophylaxis**
  - 4-shift model to reduce duration of shifts
  - Special provision of meals and drinks
  - Close supervision by psychotherapist offered
- **Personell of COVID ICU reinforced**
  - Staff of other ICUs with reduced service

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COVID-19: transfer of french patients

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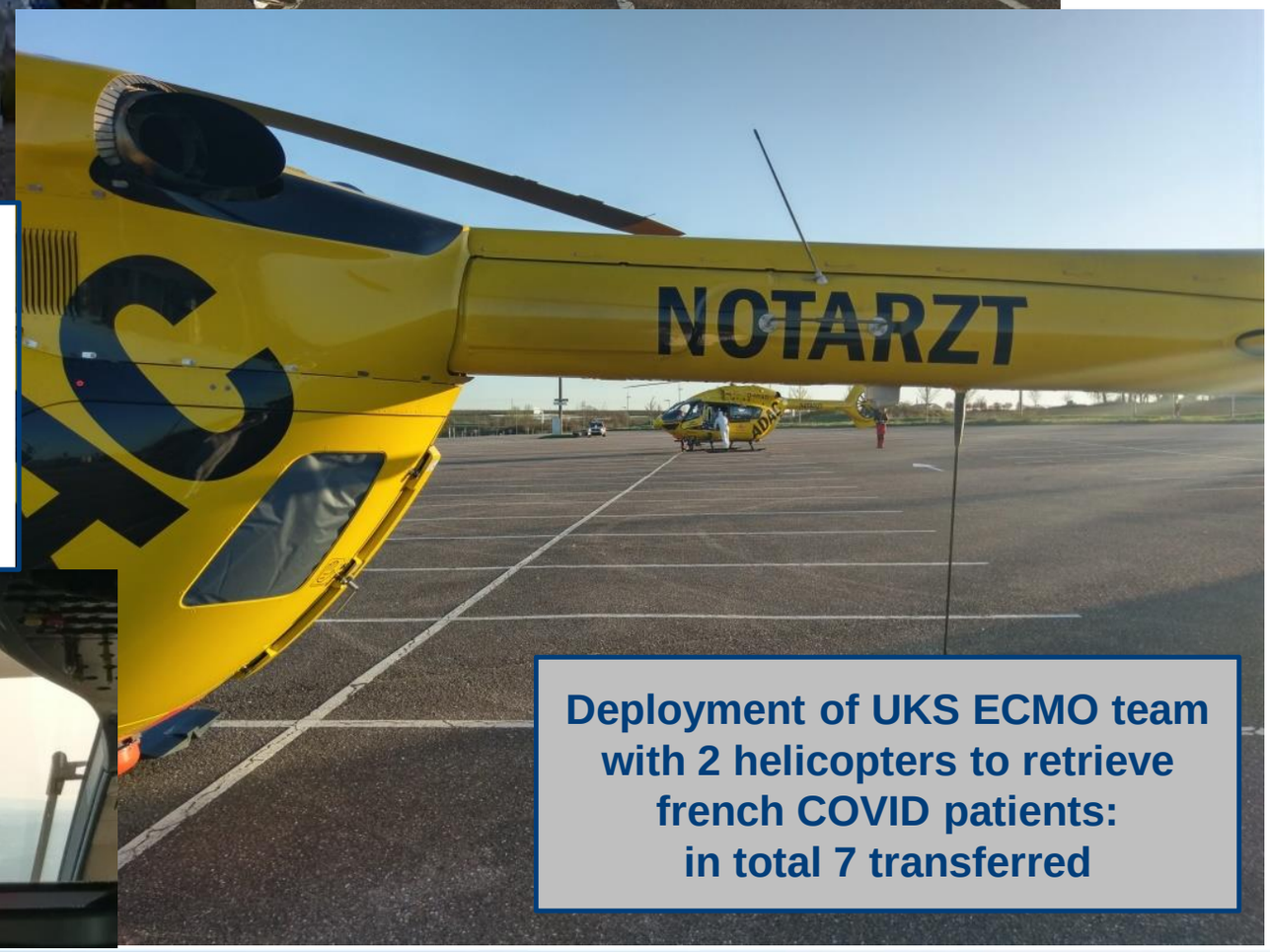
UKS ECMO Team
Tour de France



Deployment of UKS ECMO team with 2 helicopters to retrieve french COVID patients: in total 7 transferred

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COVID-19; Case I

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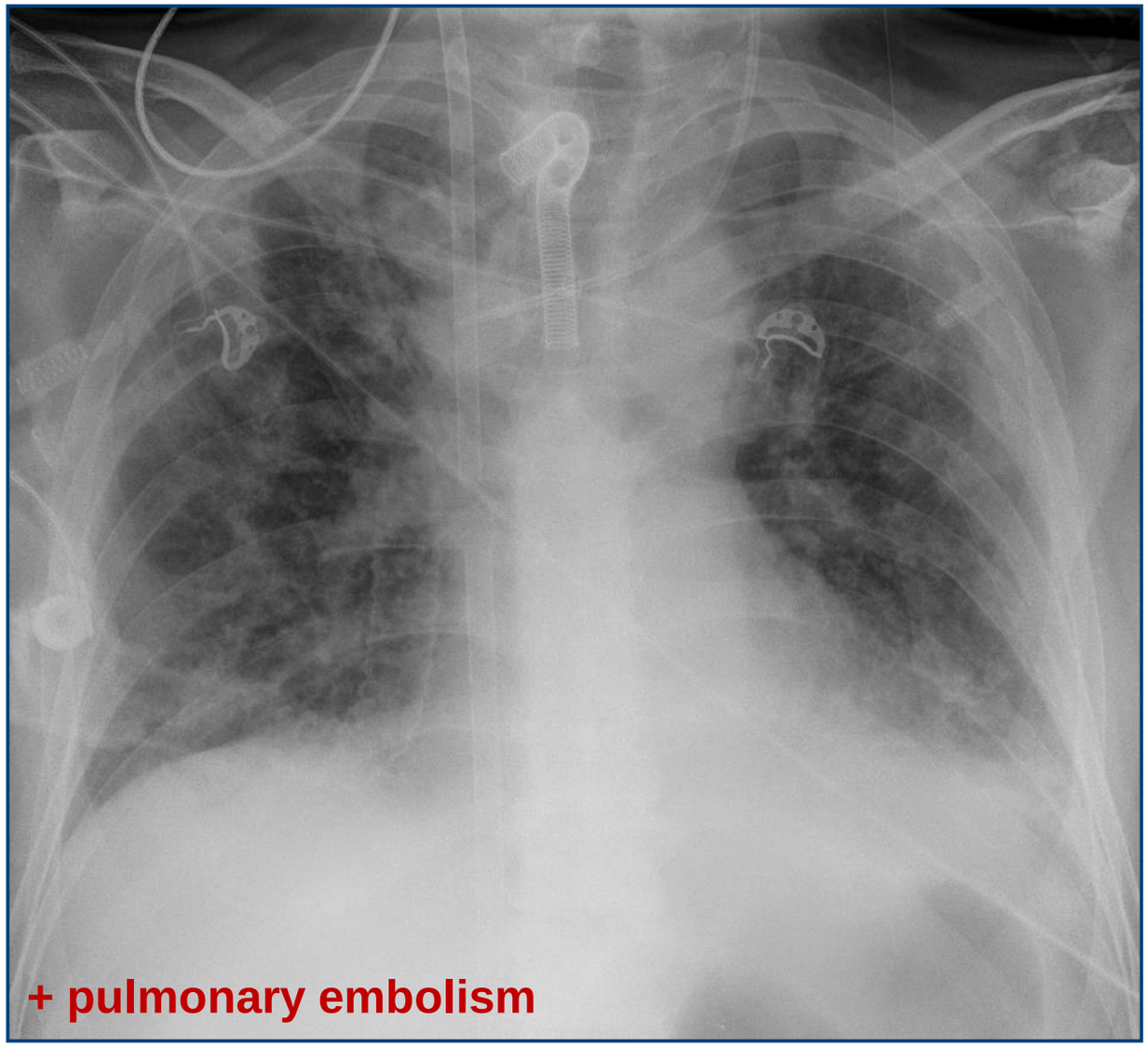
K., J.: 60 years old; otherwise healthy, no known previous conditions

• Intubation	26.03.	COVID +	15.03.
• Prone position	27.03. – 31.03.	Klebsiella aerogenes 3MRGN	10.04.
• Tracheotomy	31.03.		
• vvECMO	03.04. (OI 76)		
• awake ECMO since	29.04. (2 L BF, 7 L sweep-flow); to date 30 days on ECMO		

March 31st



May 2nd

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COVID-19: Case II

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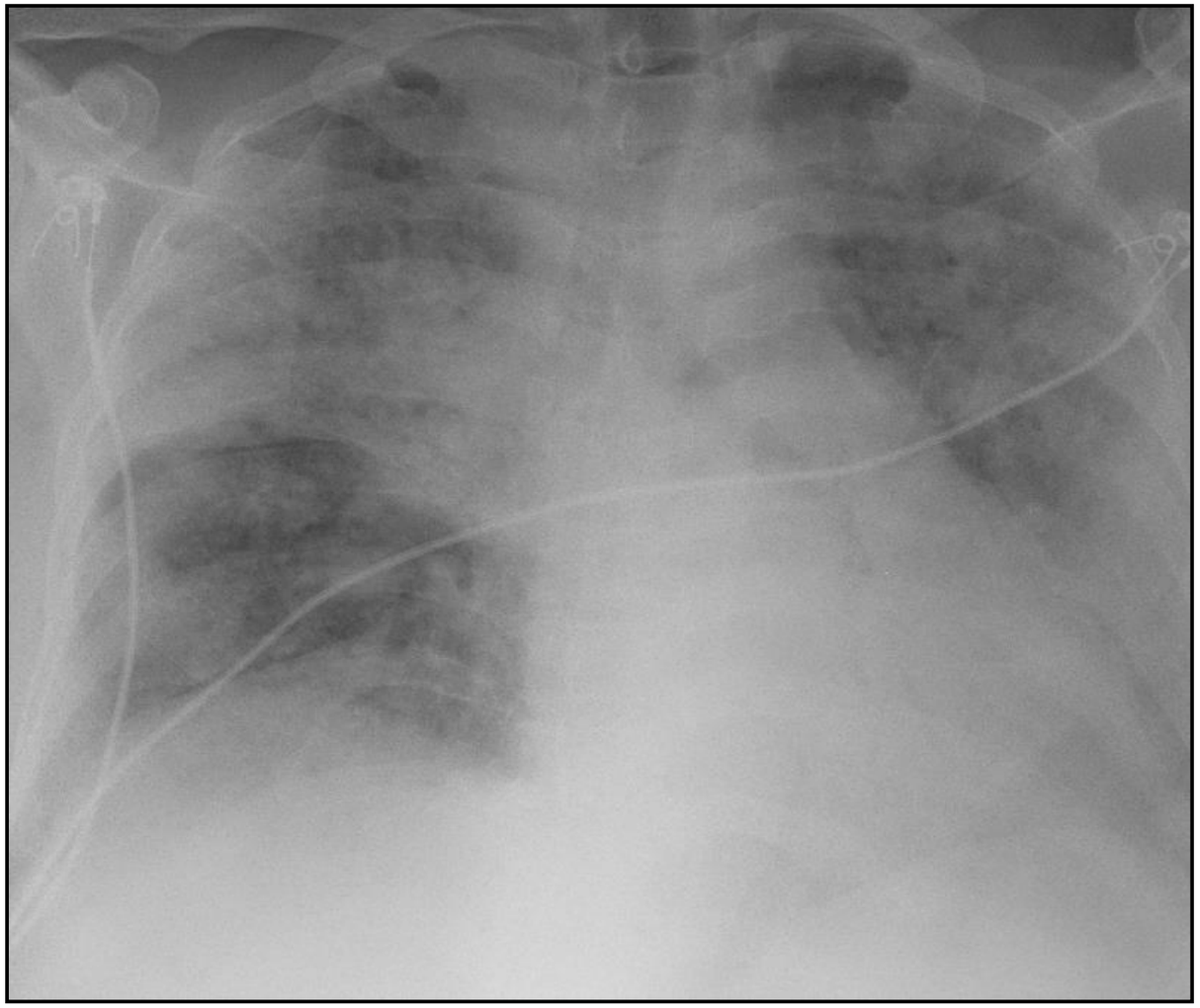
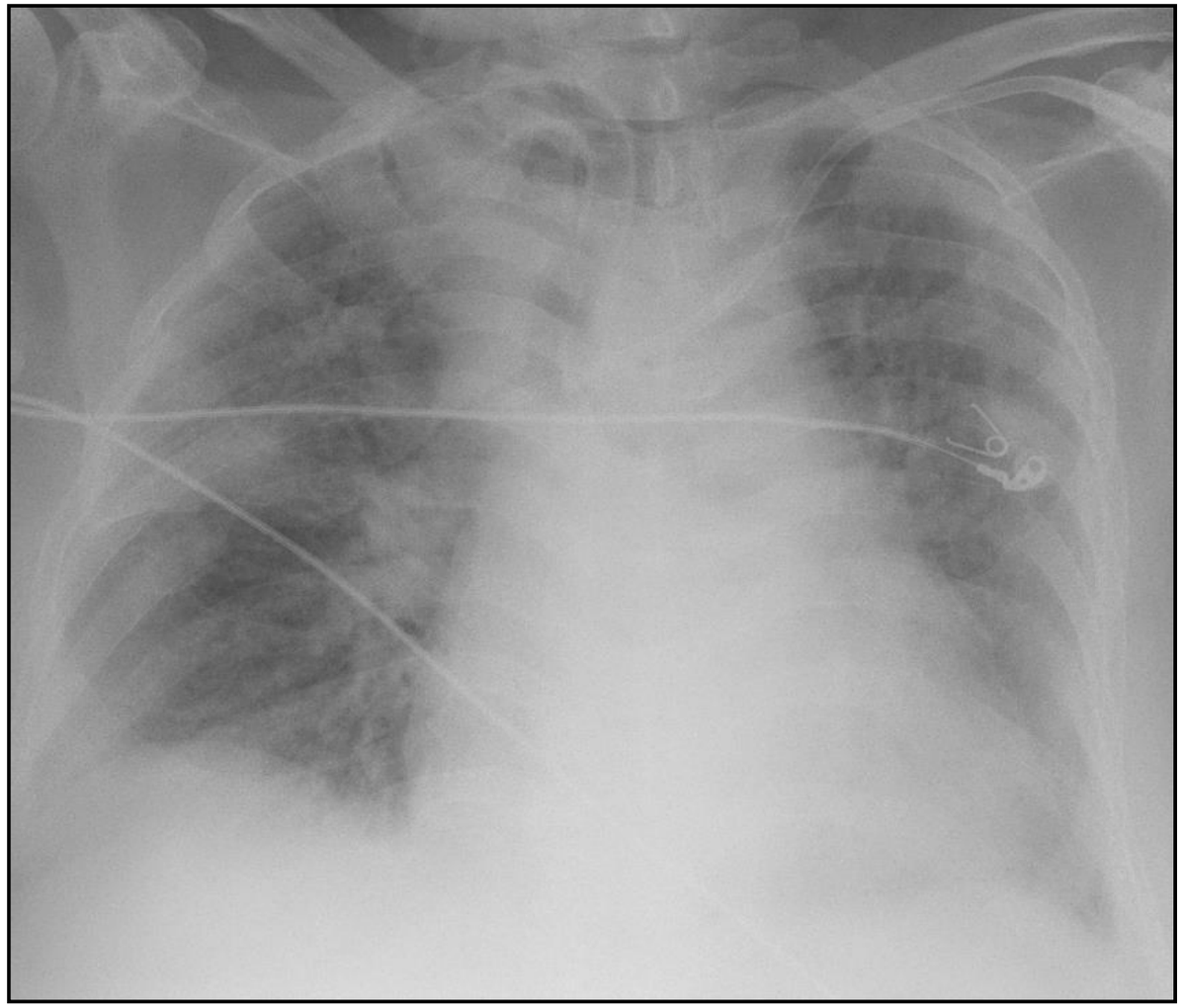
A., M.: 69 years old; art. Hypertension, Diabetes mellitus, Obesity

- Intubation 16.03.
- Prone position 17.03. – 23.03.
- Extubation 25.03.
- NIV 25.03. – 01.04.
- Reintubation 01.04.
- Tracheotomy 02.04.
- vvECMO 01.04. – 23.04. (OI 50)

COVID + 11.03.



March 31st



May 2nd

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COVID-19: Case III

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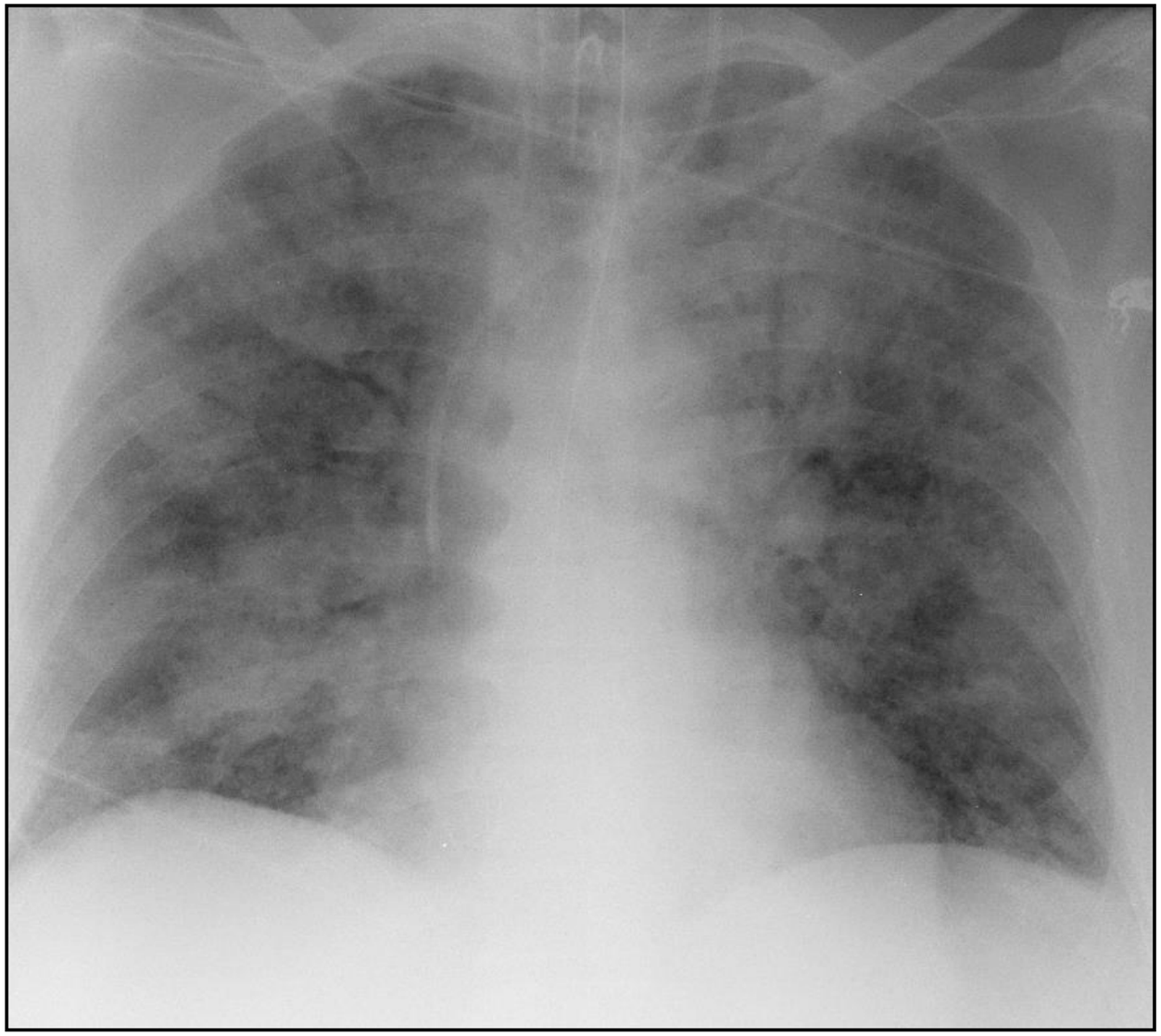
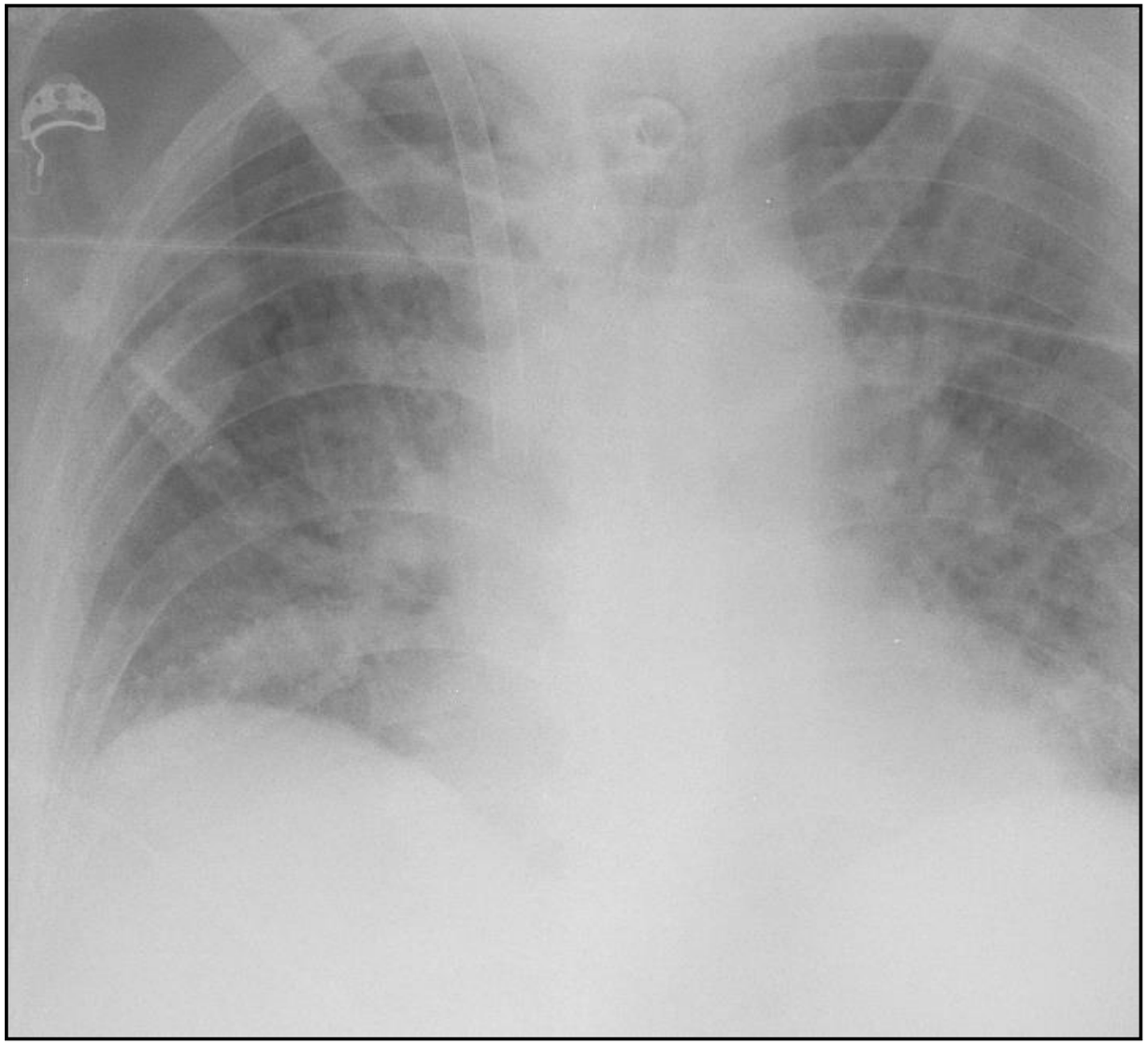
G., J.-L.: 60 years old; art. Hypertension, Obesity

- Intubation 19.03.
- Prone position n.d.
- Tracheotomy 28.03.
- vvECMO 28.03. (OI 77) – 02.05.

COVID + 12.03.



March 25th



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COVID-19: Case III

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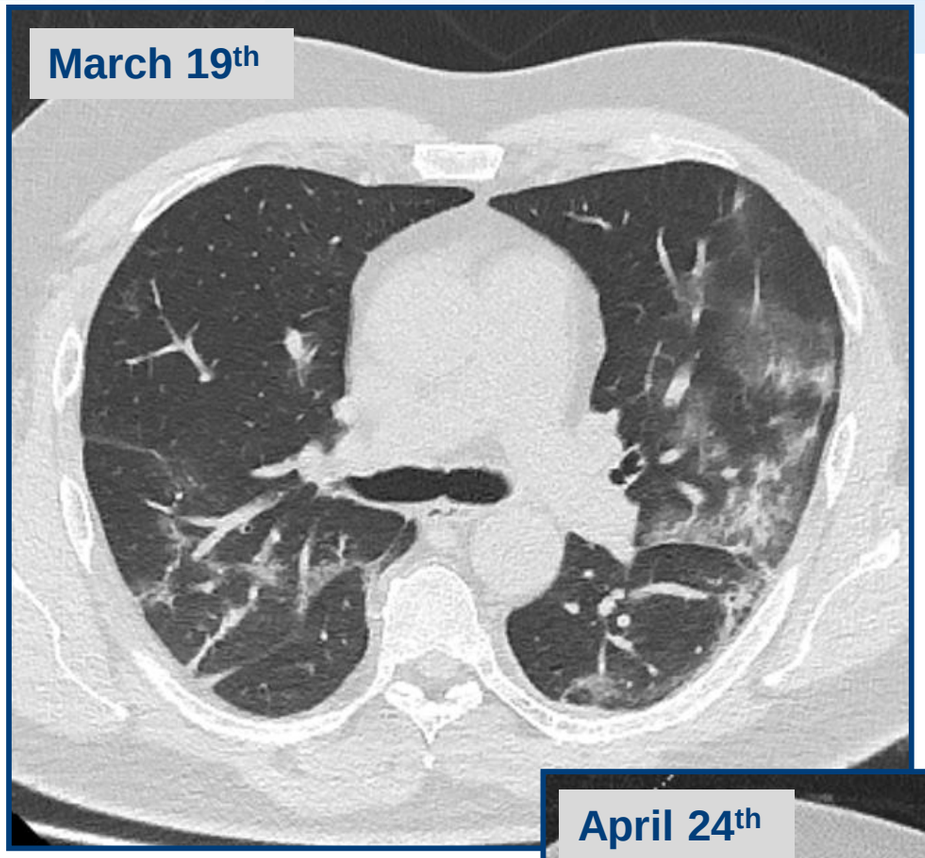
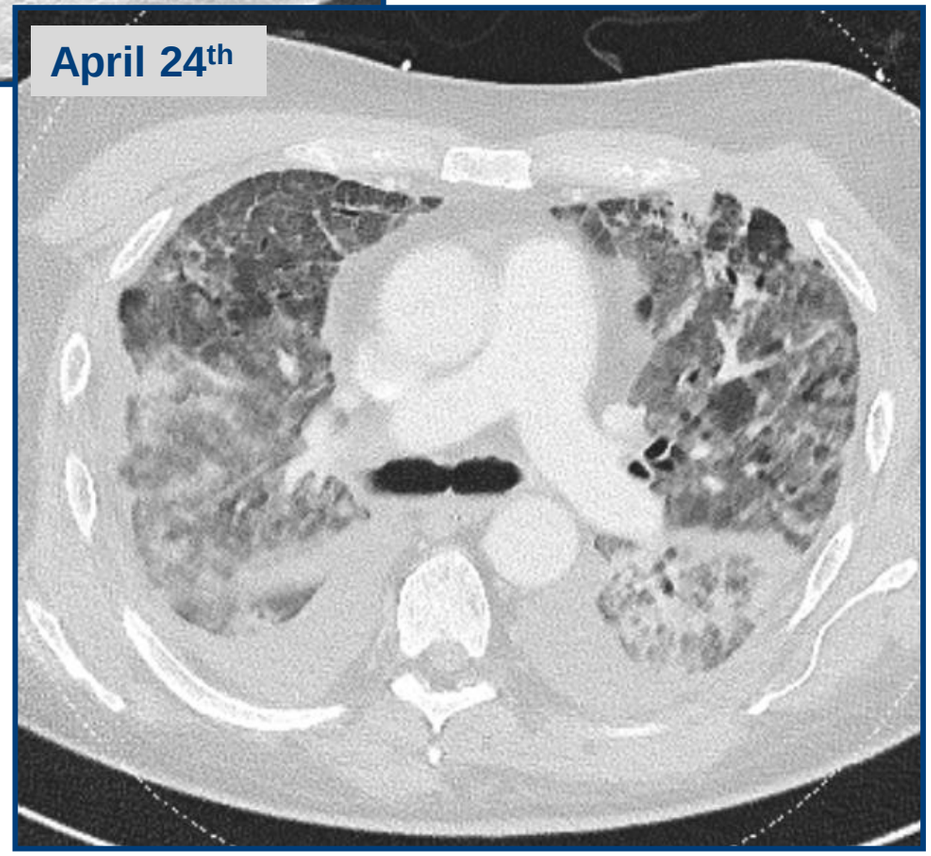
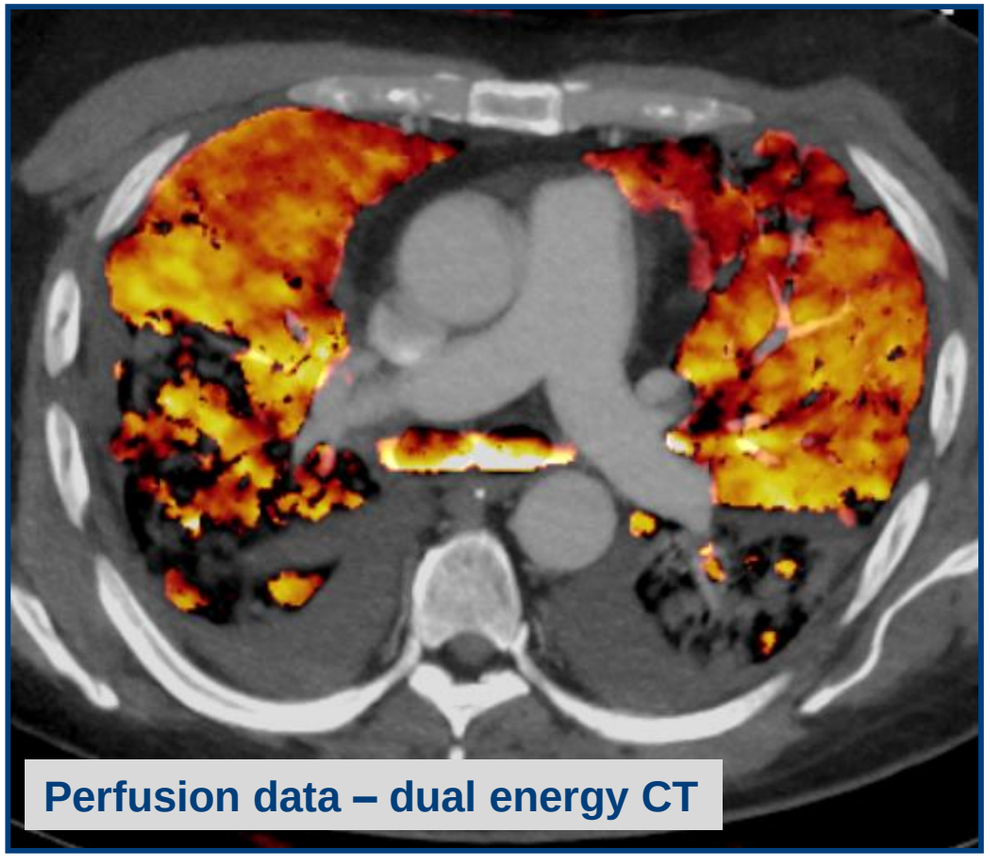
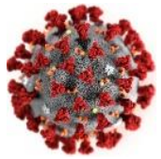


G., J.-L.: 60 years old; art. Hypertension, Obesity

Lab values	23.03.	30.03.	02.05.	
Leukocytes	15.8	24.0	17.8	G/L
Lymphocytes	4	4	3	%
CRP	330	383	20.5	mg/L
IL-6	247.6	12,504*	19.6	pg/mL
Ferritin	n.a.	1005	2176	ng/mL
D-Dimers	2.26	25.21	>33.0	mg/L
PCT	9.31	1.57	0.29	ng/mL
Fibrinogen	800	474	49	mg/dL







* Patient recieved 2 doses of tocilizumab

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ECMO and COVID-19: a bad idea ?

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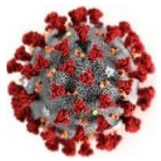
Authors	Age (yrs): [a]	# of patients: n = (# ARDS patients)	Conventional ARDS Therapy: n=	Conventional ARDS Therapy Survivors: n (%)	ECMO: n=	ECMO -Survivors: n (%)
Ruan Q et al. *2020*	Survivors: 67 (15–81) Non-Survivors: 50 (44–81)	150 (62)	55	7 (12.7%)	7	0 (0%)
Wu et al. *2020*	51 (43–60)	210 (84)	83	40 (48.2)	1	0 (%)
Yang X et al. *2020*	59.7 (13.3)	52 (35)	29	9 (31.0%)	6	1 (16.6%)
Zhou F et al. *2020*	56.0 (46.0–67.0)	191 (59)	56	9 (16.1%)	3	0 (0%)

[a] Data presented as mean (SD) or median (IQR). ARDS – Acute Respiratory Distress Syndrome.

Conventional ARDS Therapy: n=	Conventional ARDS Therapy Survivors: n (%)	ECMO: n=	ECMO -Survivors: n (%)
55	7 (12.7%)	7	0 (0%)
83	40 (48.2)	1	0 (%)
29	9 (31.0%)	6	1 (16.6%)
56	9 (16.1%)	3	0 (0%)



What might be causes for bad outcome ?

Henry BM et al. J Crit Care 2020

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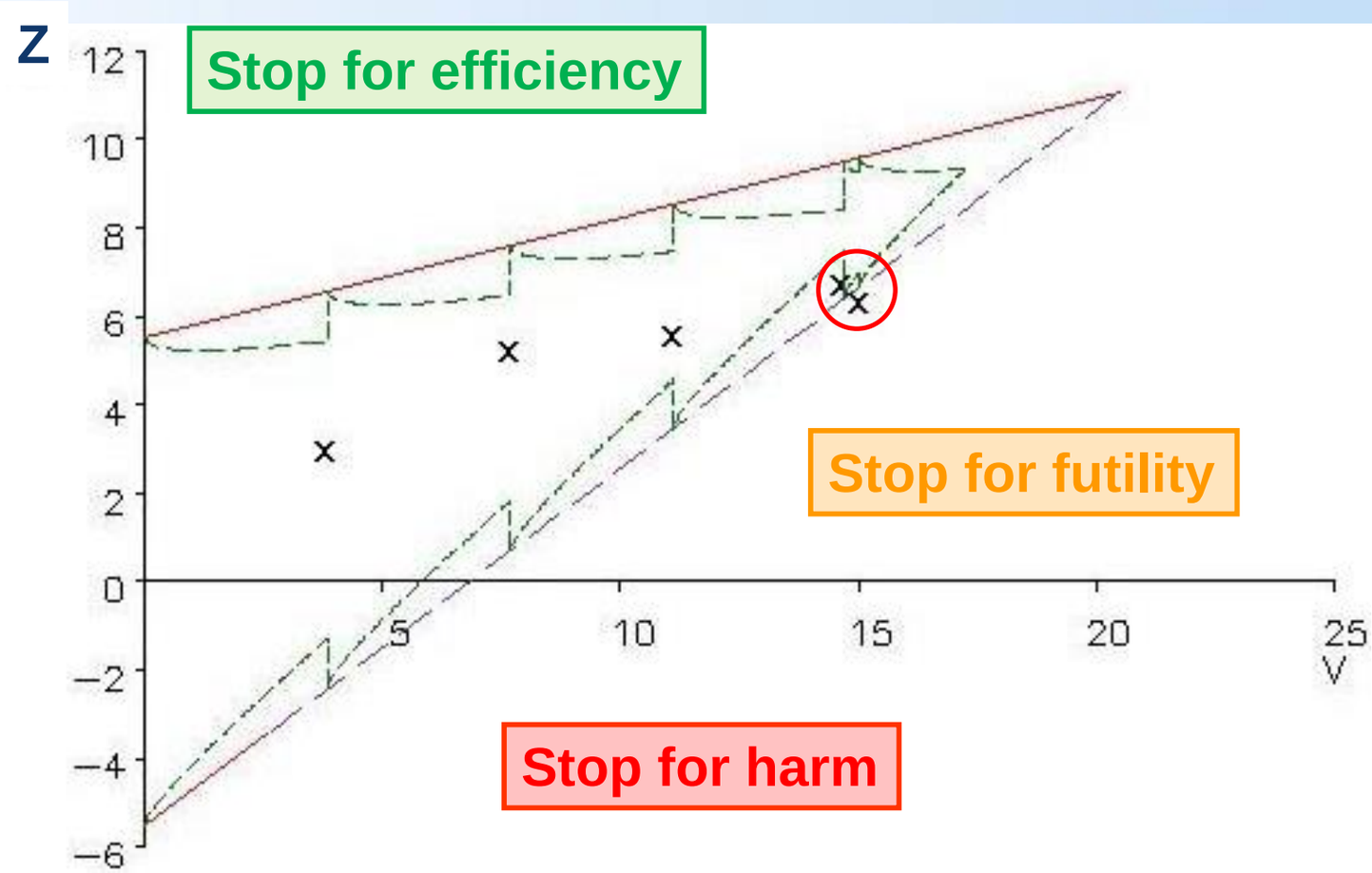
EOLIA: DSMB – safety analysis



- recruitment stopped
- 4th planned interim analysis (each after 60 included patients)
  - 240 patients
  - till April 2017
- lower boundary of "stopping-rule triangle" crossed
  - difference between groups unlikely

Combes A at al. NEJM 2018

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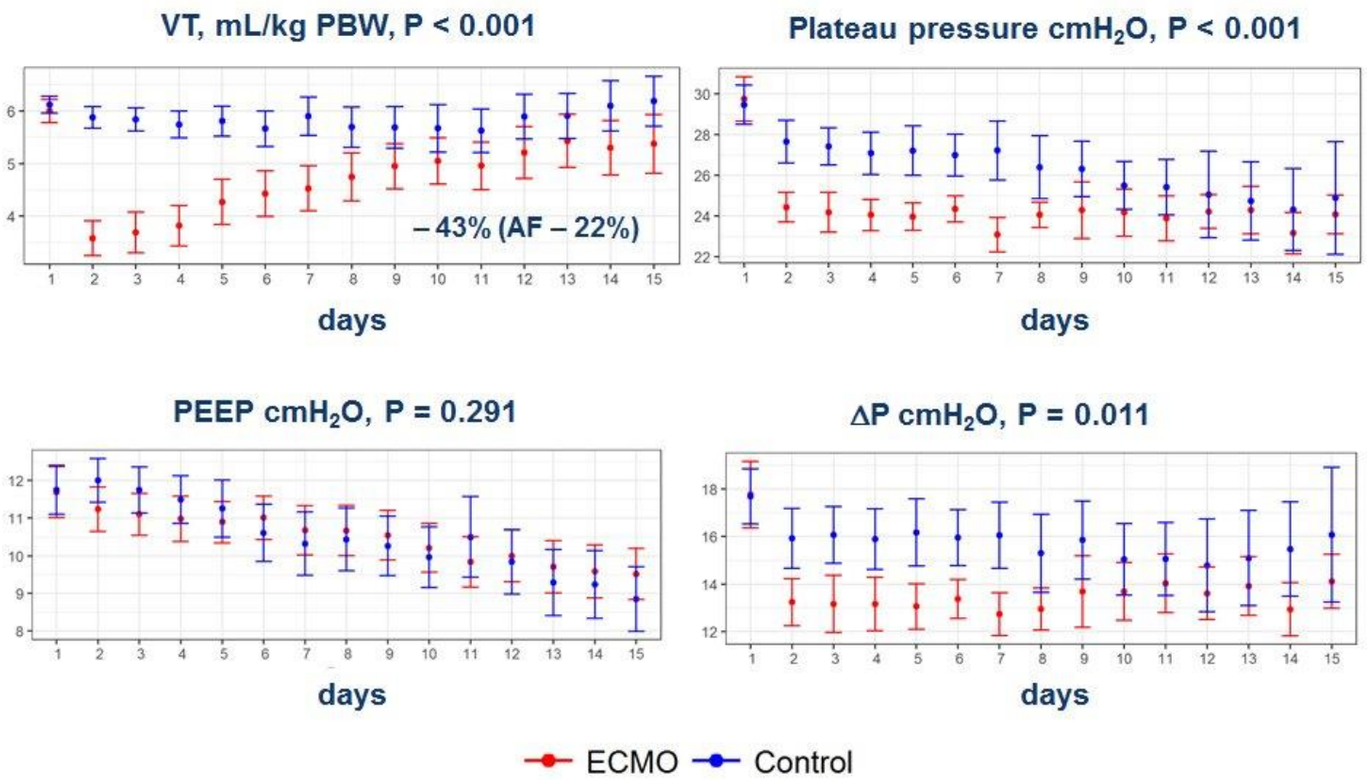
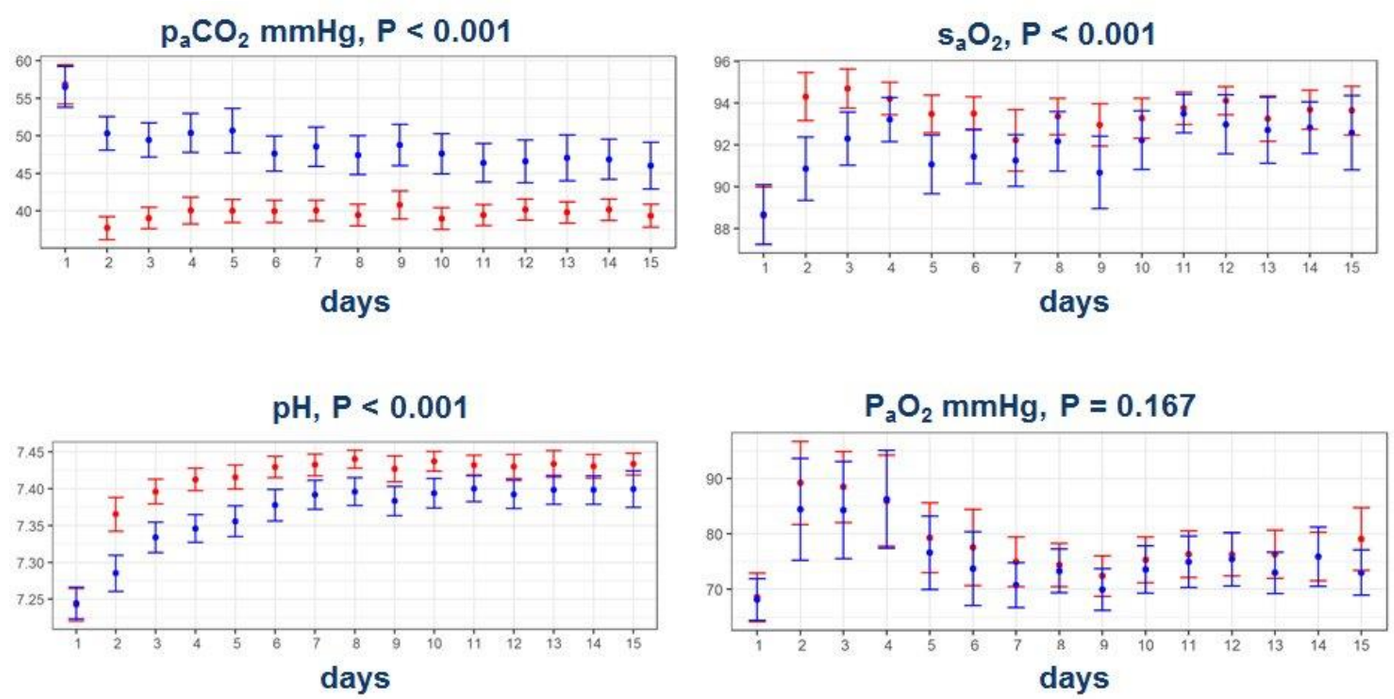
EOLIA: comparison between groups





ECMO works with regard to certain technical parameters

Combes A at al. NEJM 2018

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EOLIA: Results per protocol

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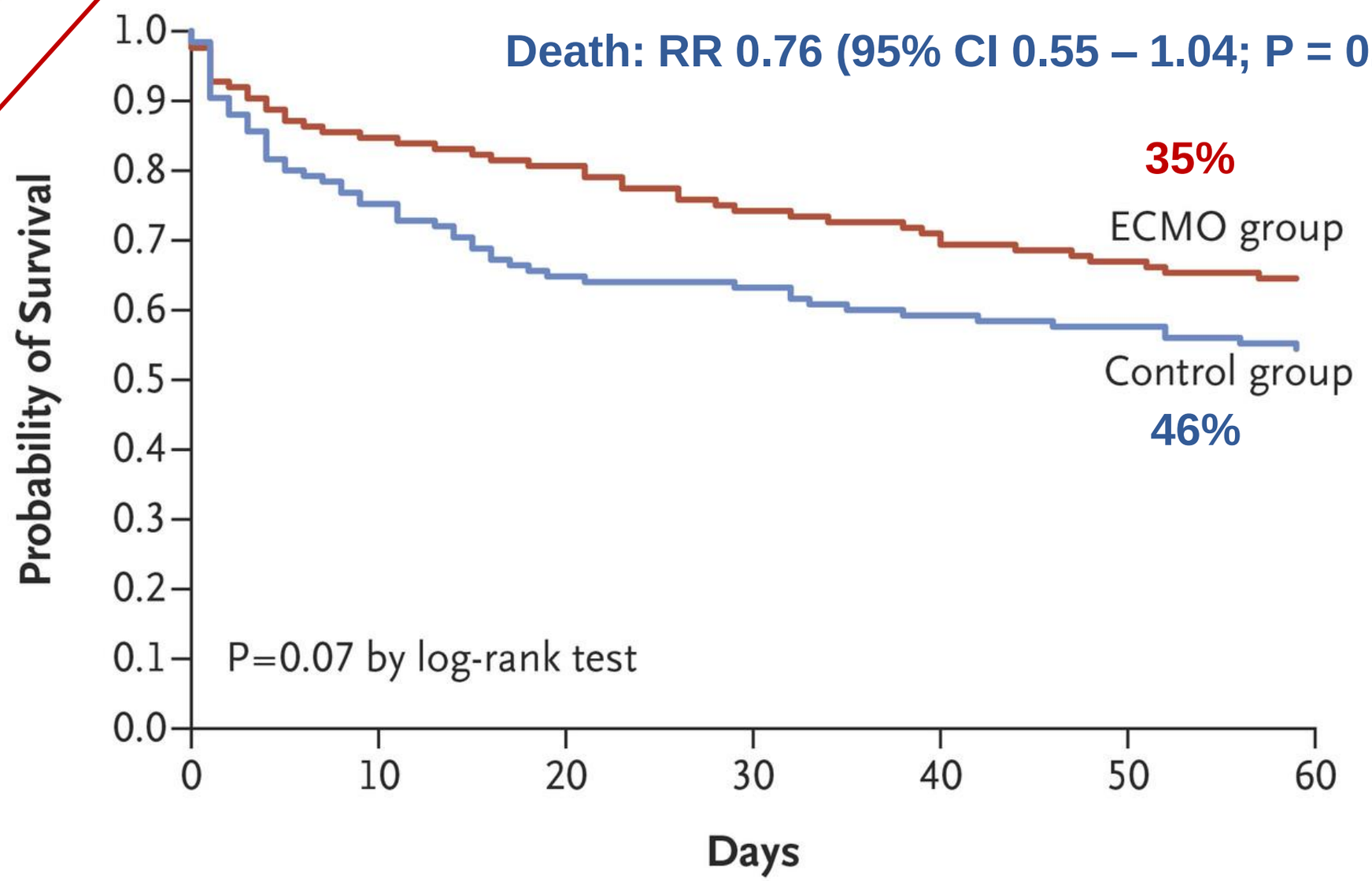
11% absolute reduction in mortality

Death: RR 0.76 (95% CI 0.55 – 1.04; P = 0.07)



No. at Risk							
ECMO	124	105	100	92	88	83	80
Control	125	94	81	79	74	72	69

Combes A at al. NEJM 2018

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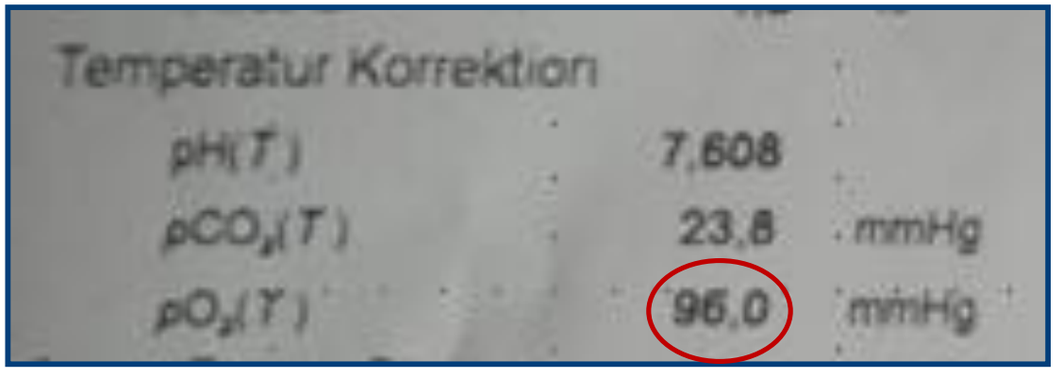
COVID-19: alveolar gas equation



$$P_AO_2 = (F_iO_2 \times [P_{atm} - P_{H2O}]) - (p_aCO_2/R)$$

We may suppose that R = 0.80; alveolar-arterial O2 difference:

$$P_AO_2 = (F_iO_2 \times [P_{atm} - P_{H2O}]) - 24/0.8$$
$$P_AO_2 = (0.21 \times [760 - 47]) - 30$$
$$P_AO_2 = (0.21 \times 713) - 30$$
$$P_AO_2 = 120 \text{ mmHg}$$

A-a difference = 120 - 96

The alveolar-arterial O2 difference is 24 mmHg
→ thus, there is *ventilation-perfusion inequality* (to some extent)…

The lung does not determine the amount of oxygen transferred, the amount of oxygen transferred is determined by the peripheral tissues.

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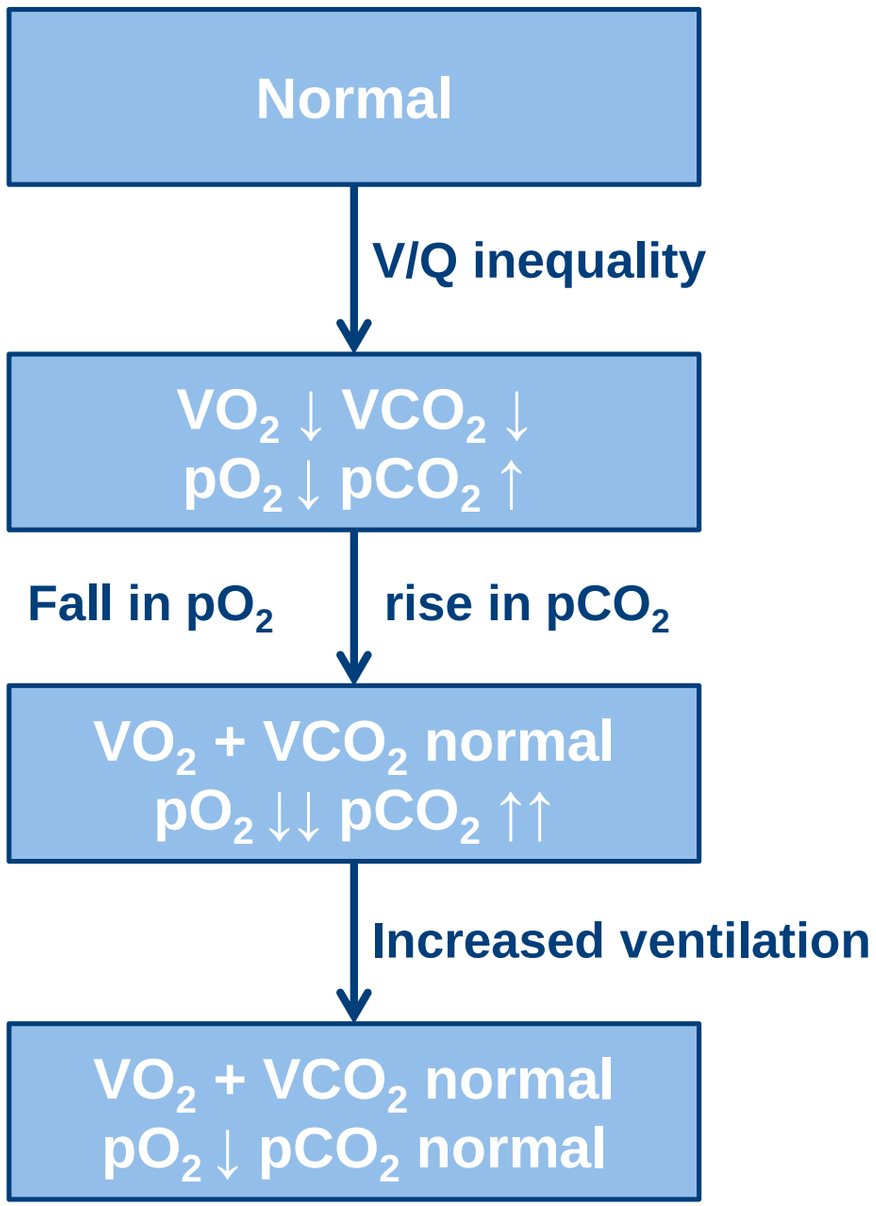
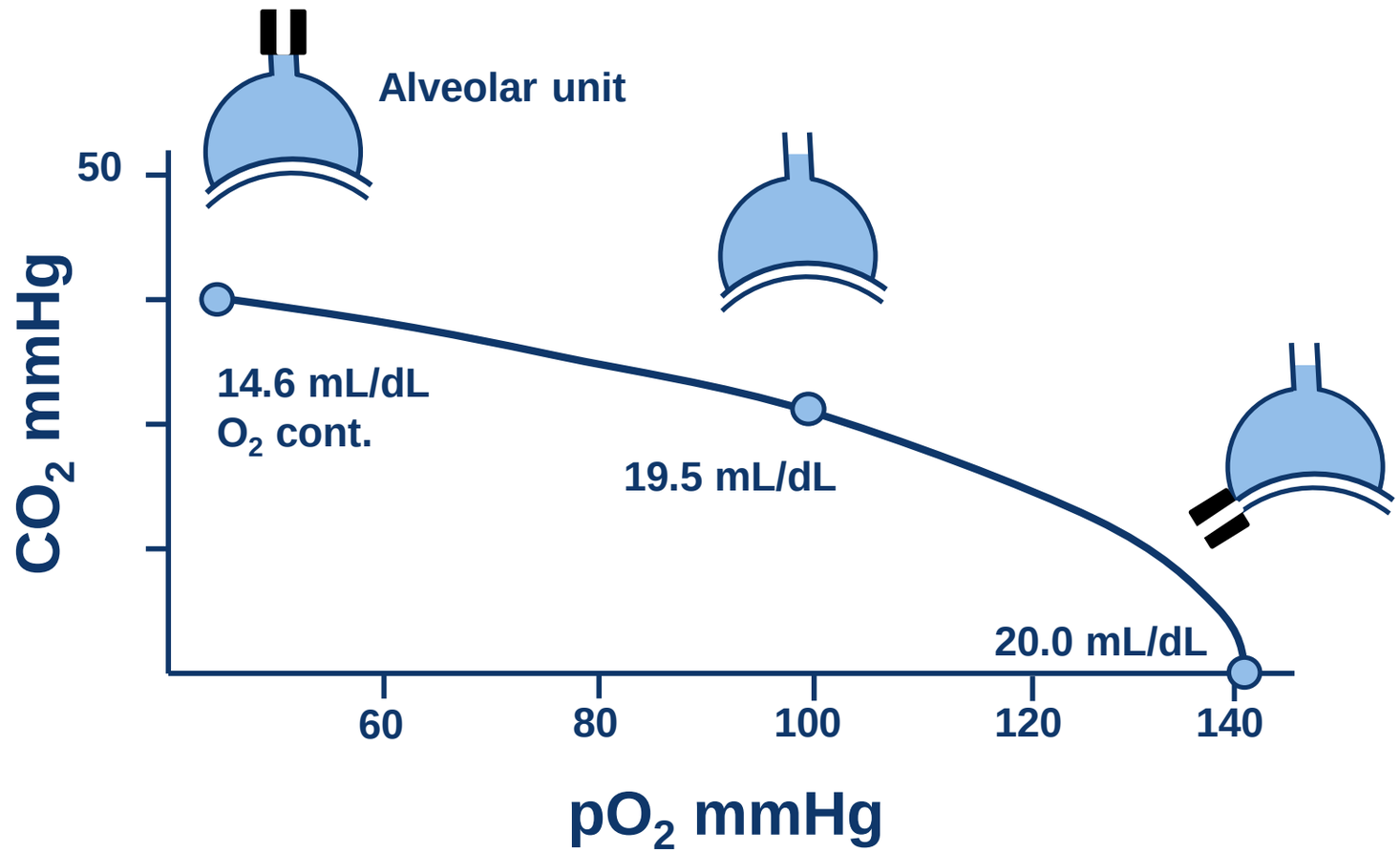
COVID-19: V/Q inequality

- **Ventilation-perfusion inequality must cause hypoxemia**





- **Hyperventilation can bring pCO_2 back to normal, but can never resolve hypoxemia**

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COVID-19: V/Q inequality

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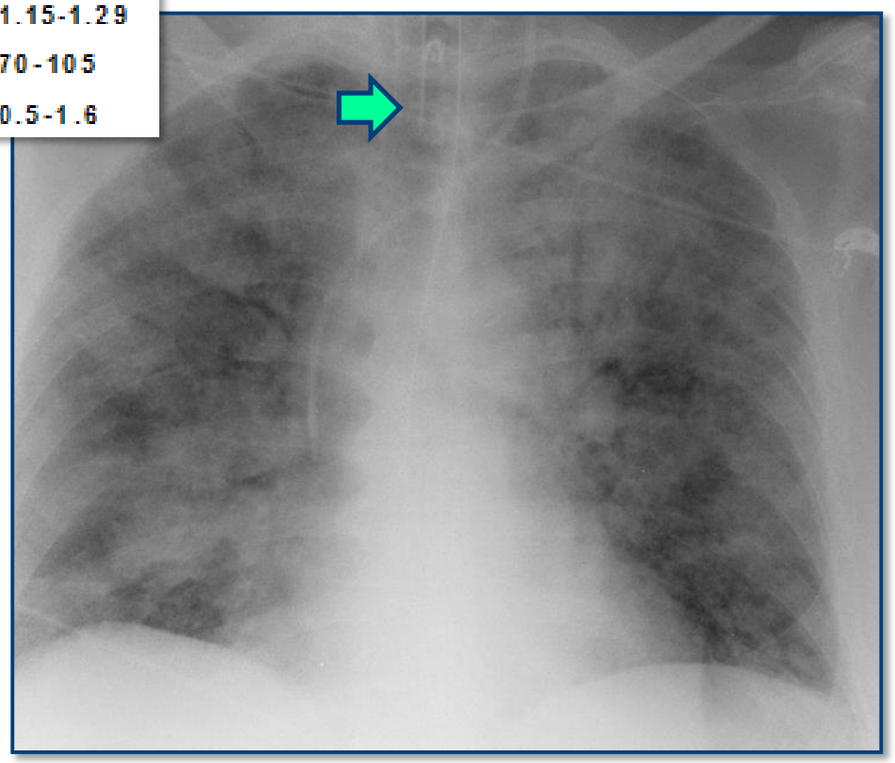
Sample type	Arteriell	
pH(T)	7.299/L	7.35-7.45
pCO2(T)	57.1/H	35-48
pO2(T)	58.6/L	83-108
tHb	10.0/L	13.5-17.5
sO2	88.1/L	95-99
O2Hb	87.0/L	94-98
COHb	1.1	0.5-1.5
MetHb	0.1	<1.5
HCO3-	28.0/H	22-27
Na+	142	136-146
K+	5.1/H	3.5-4.5
Ca++	1.14/L	1.15-1.29
Glu(BG)	124/H	70-105
Lac	2.2/H	0.5-1.6

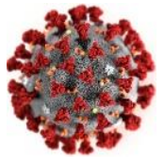
FiO2	100%
pO_2	59 mmHg
pCO_2	57 mmHg
PEEP	10 mbar
P_{insp}	26 mbar
TV	880 mL

1. Severe V/Q inequality;
2. Preserved compliance
3. Increased dead space
4. Impaired HPV (see below)



- DO_2 relatively preserved
- pH not (yet) an issue
- $s_{cv}O_2$ 55% → Inotrope ?

- Hemodynamics
  - sPAP 32 mmHg
  - dPAP 20 mmHg
  - PCWP 15 mmHg
  - CO 7.8 L/min
  - CI 3.9 L/min/m²
  - PVR 91 dyn · s · cm^{-5}
  - SVR 792 dyn · s · cm^{-5}
  - EF 55%



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COVID-19 (and ECMO): the UKS experience

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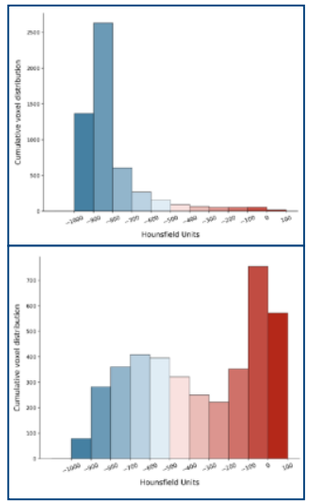
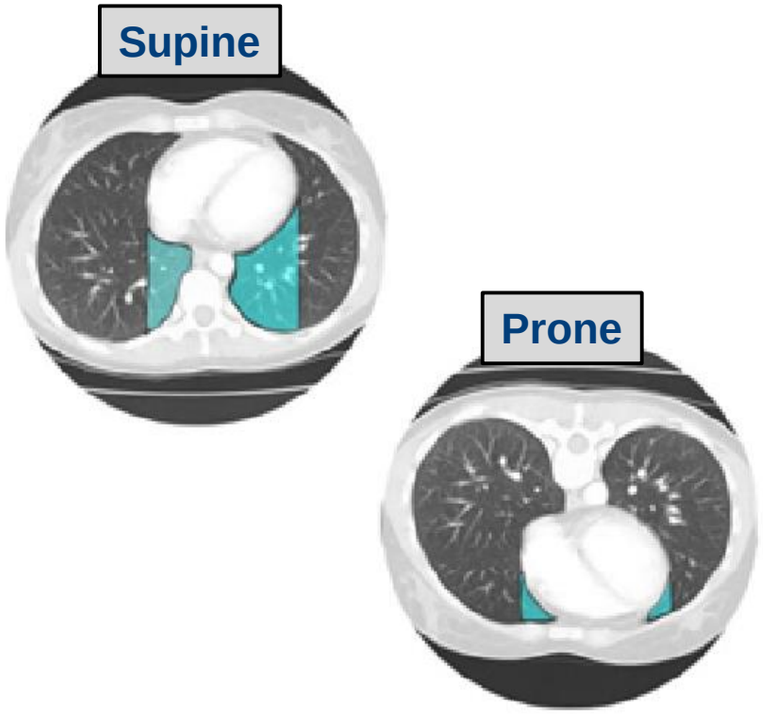
*Prone position and higher PEEP

- may work or may not work
- both are meant to alter V/Q





Keep your standards

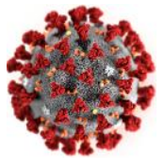
- Things work best if you do them as always

Cannulation should follow patient needs

- Patients will mainly need vvECMO
- Some might need va- or vvaECMO e.g. in pulmonary embolism

UKS Standard vvECMO cannulation is

- drainage VF and return VJI
- UKS max. patients on ECMO at a time: 8



***related to COVID-19**

Gattinoni L et al. ICM 2020

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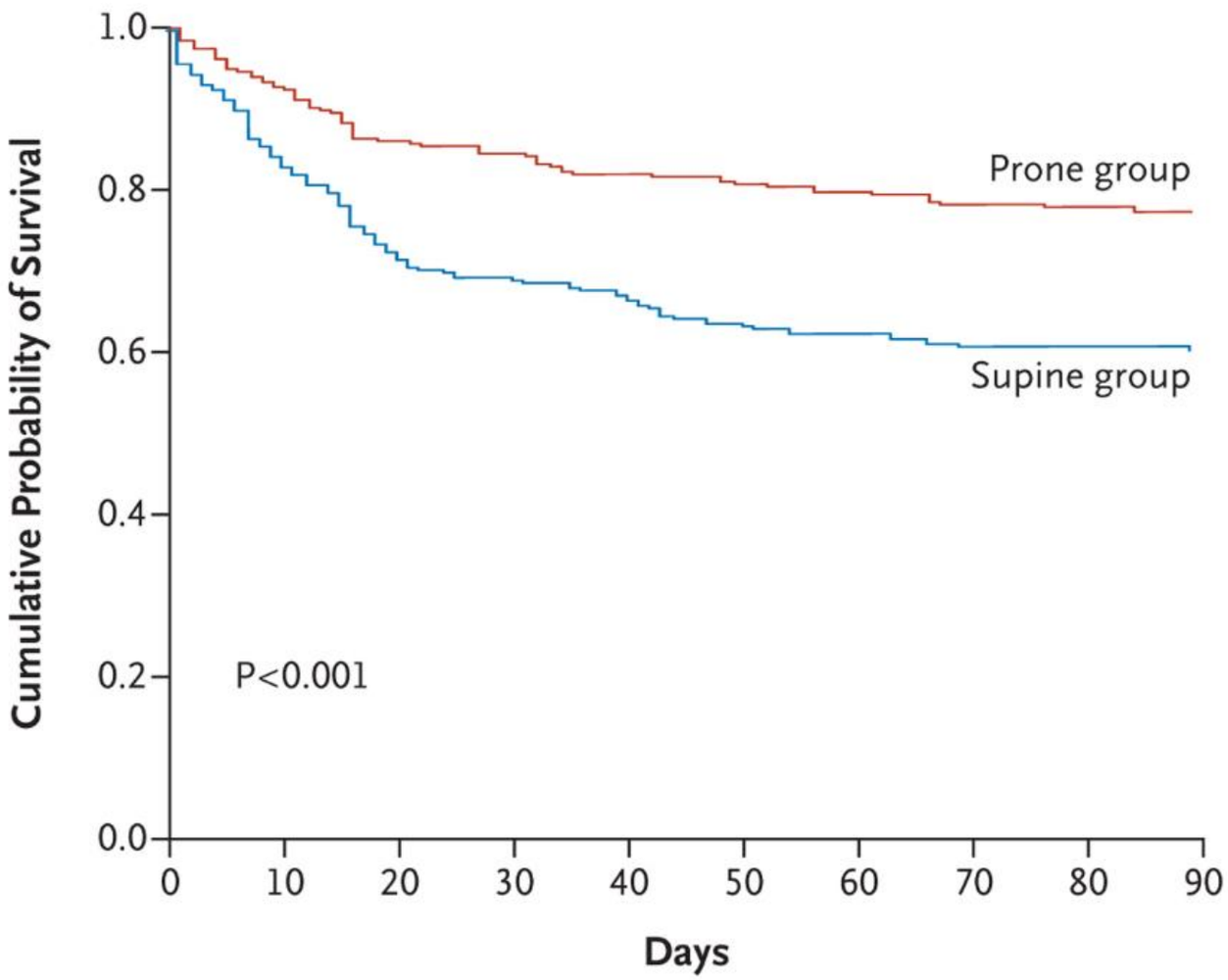
Prone Position in ARDS



No. at Risk					
Prone group	237	202	191	186	182
Supine group	229	163	150	139	136

474 patients randomized; prone position for ~16 h (up to 4 x)
Kaplan-Meier Estimates 90 d survival
[82% recieved NMBA; 40% recieved steroids]

Guerin C et al. for the PROSEVA Study Group; N Engl J Med 2013

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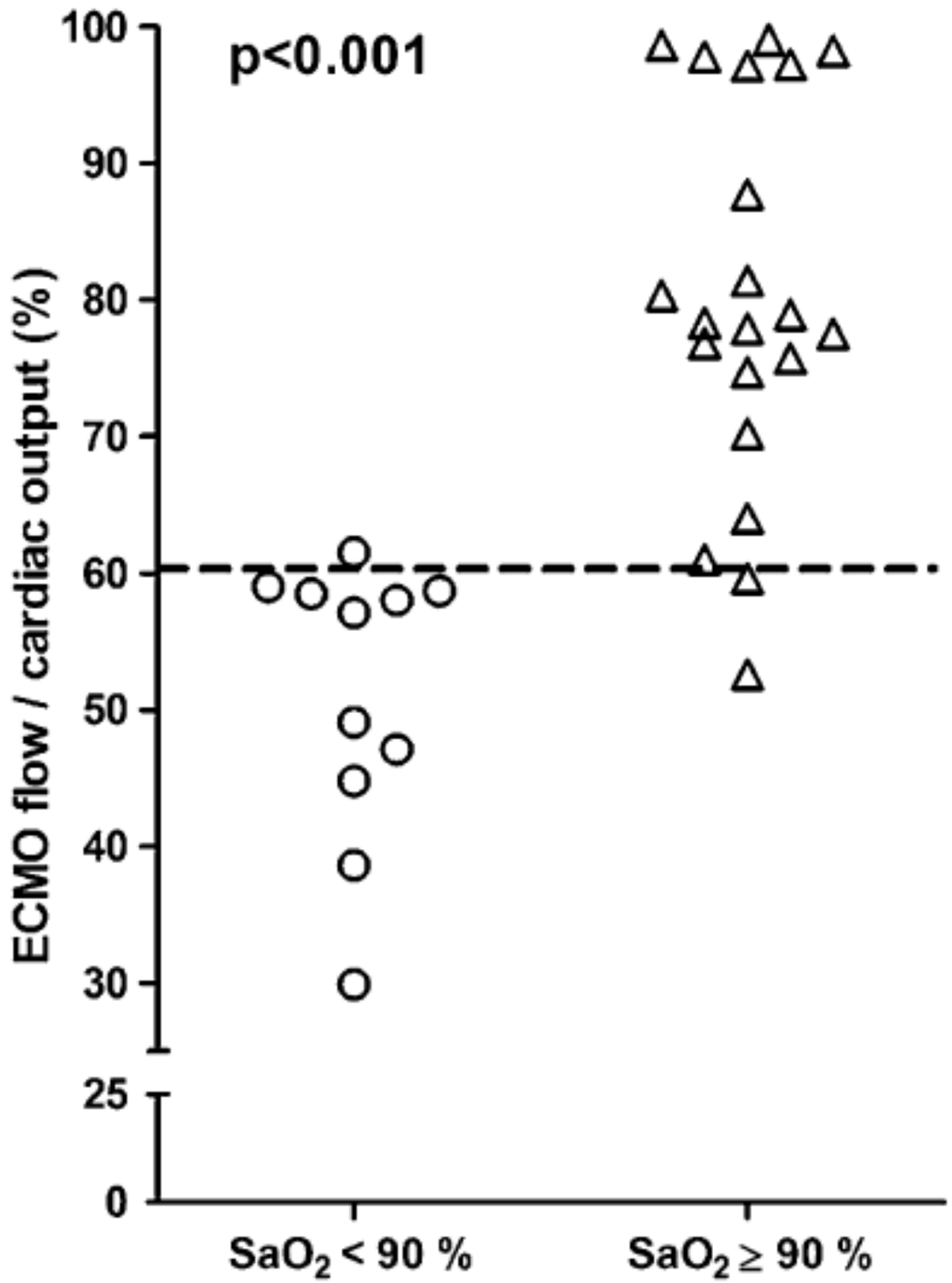
Reminder: venovenous ECMO



ECMO blood flow ~ 60% of CO to achieve $S_aO_2 \geq 90\%$

⇒ high ECMO flow in hyperdynamic states

Schmidt M et al. (2013) ICM 39:838

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COVID-19 and ECMO: what is different ?

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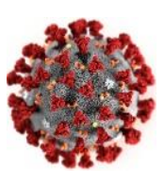
- **Sedation**
  - Patients might need more sedatives than we are used to
  - Consider also volatile anaesthetics
  - Fever and awake states increase CO_2 production
  - Consider NMBA and aggressive temperature treatment
- **Is it still COVID-19 or bacterial or fungal superinfection or „autoimmune“?**
  - regular microbiological sampling necessary
  - COVID-19 hygiene does not prevent „other outbreaks“
  - Consider steroids if ifection is controlled and GGO does not resolve
- **High ECMO flows might be necessary, even if C is preserved**
  - Recirculation will possibly increase
  - Monitor DO_2
  - What is acceptable within physiologic boundaries ?



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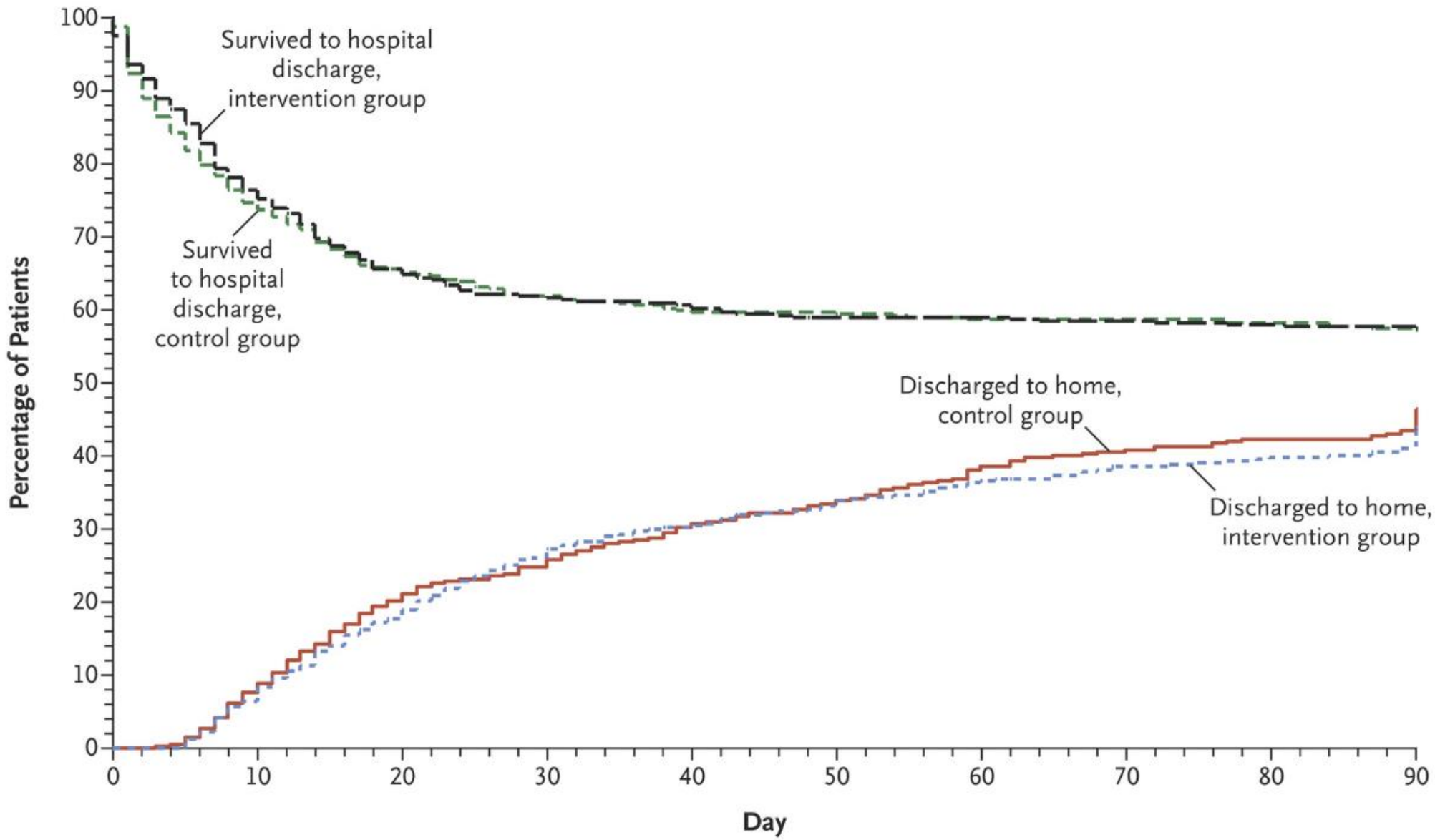
NMBA in early ARDS - ROSE



1006 randomized patients; Cisatracurium for 48 h within the first 48 h after ARDS onset
Kaplan-Meier Estimates 90 d survival

The National Heart, Lung, and Blood Institute PETAL Clinical Trials Network; N Engl J Med 2019

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COVID-19 and ECMO: what is different ?

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- **Coagulation**
  - **COVID-19 is disturbing coagulation**
  - **DIC-like phenomena likely**
  - **Anticoagulation with Heparin (PTT 45 – 55 s)**
  - **high rate of positive HIT ELISAs;**

HIT 4-T Score			folgt *	4 H
HIT Typ-II (E				positiv A
HIPA-Test				negativ
Therapieangab	Heparin, unfra		agatroban	

- **Critical evaluation of concepts**
  - **no bridge to nowhere**
  - **consider palliative care for patients that have no recovery (but be patient)**

ECMOing

After considering that, all we can do ~~ventilating~~ these patients is “buying time” with minimum additional damage: the lowest possible PEEP and gentle ventilation. We need to be patient.

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COVID-19: Case III

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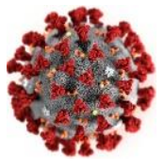
D-Dimers	**2.26**	**25.21**	**>33.0**	**mg/L**
PCT	9.31	1.57	0.29	ng/mL
Fibrinogen	**800**	**474**	**49**	**mg/dL**

It might be difficult to differentiate between patient and circuit problems:

- **Monitor circuit and changes in the circuit**
- **In the example above we assumed a circuit problem, rather than a COVID-19-related coagulation problem as fibrinogen dropped rather fast**



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Ventilation on ECMO – objectives

COVID-19

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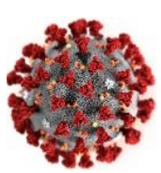
Objectives	Means
Limit „alveolar strain“	Allow „lung rest“ or „ultraprotective“ ventilation ~~Low tidals < 4 mL/kg PBW~~ Accept higher tidals Peak pressure ~~20 –~~ 25 cmH2O Limit respiratory rate
Limit „atelectrauma“	Maintain PEEP ≥ 8 cmH_2O Reduce SILI
Limit „reabsorbtion atelectasis“	Decrease ventilator F_iO_2 ~~Maintain adequate level of PEEP~~
Avoid overdistension	If possible: monitor transpulmonary pressure

Acute respiratory failure treated with ECMO



Schmidt M et al. Crit Care 2014

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Mechanical ventilation **during ECMO**

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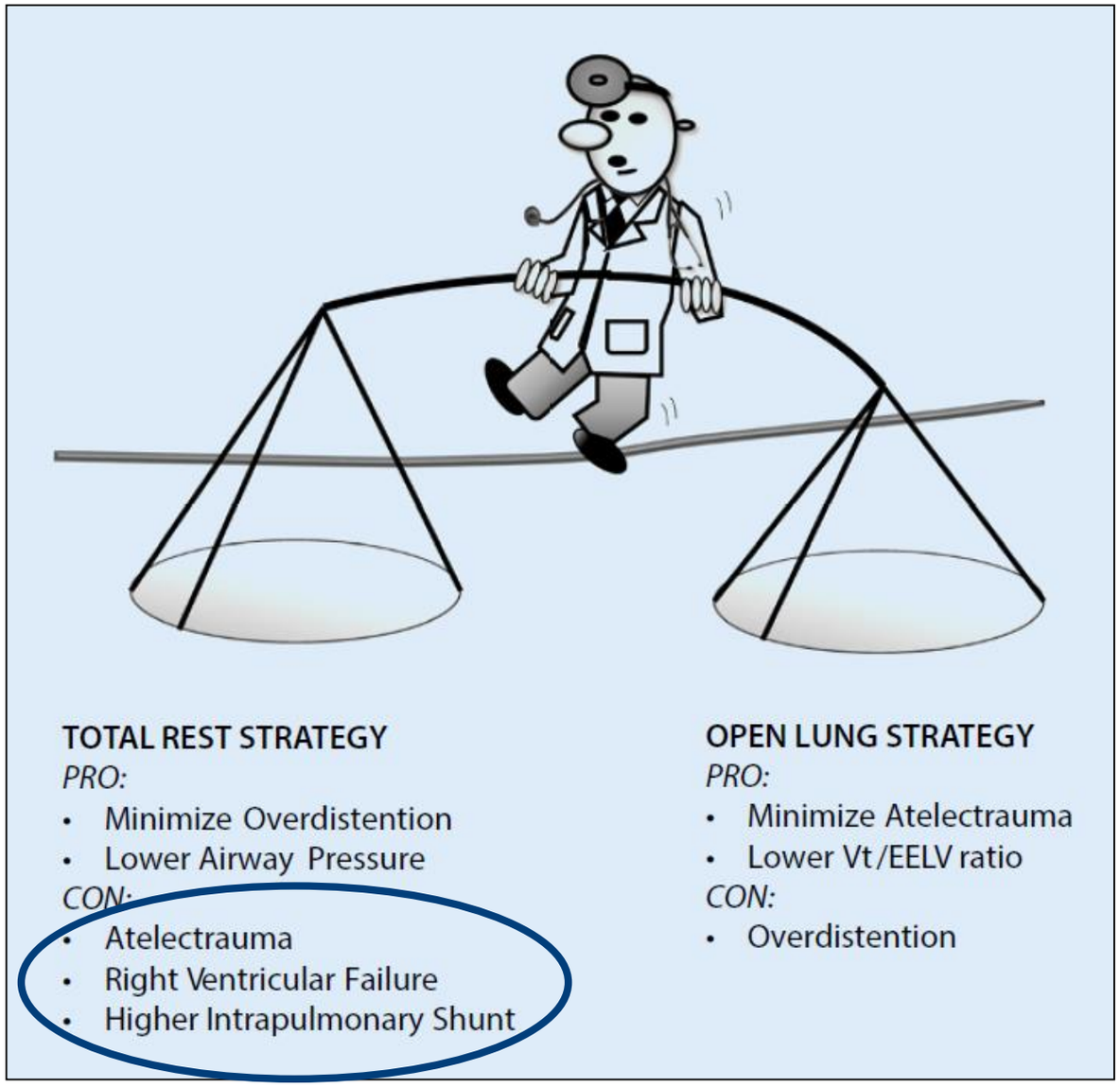
complete lung rest



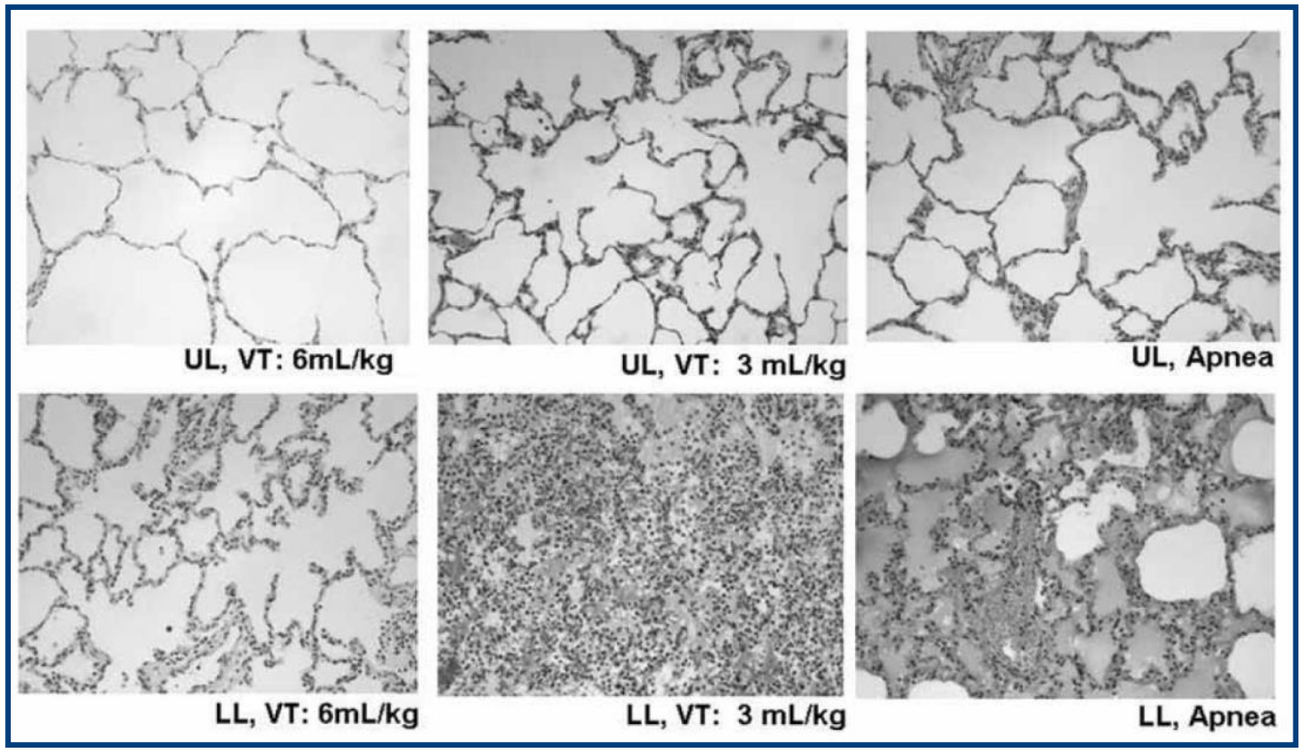
Pesenti A et al. 2018

Apnoeic ventilation + ECMO ($ECCO_2R$)

J Thorac Cardiovasc Surg. 1978 Feb;75(2):261-6.

An alternative to breathing. ?

Kolobow T, Gattinoni L, Tomlinson T, Pierce JE.



Johannes A et al. 2014

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Mechanical ventilation **during ECMO**

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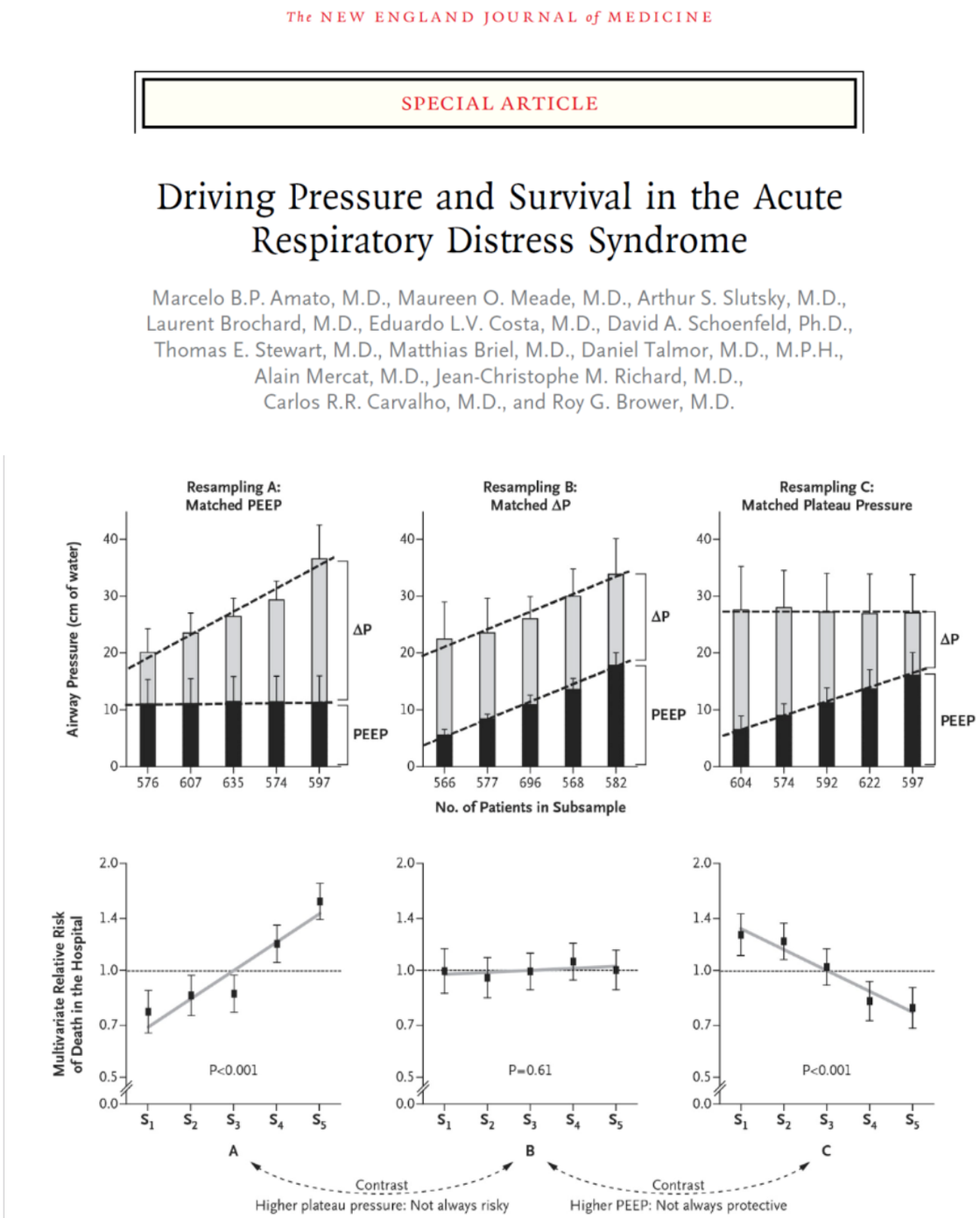
driving pressure
…in ARDS

Lachmann ICM 1992:

“Maintain optimal gas exchange at the smallest possible pressure amplitude”

Decreases in ΔP owing to changes in ventilator settings were strongly associated with increased survival.

Survival benefit if ΔP < 15 cmH_2O


The NEW ENGLAND JOURNAL of MEDICINE

SPECIAL ARTICLE

Driving Pressure and Survival in the Acute Respiratory Distress Syndrome

Marcelo B.P. Amato, M.D., Maureen O. Meade, M.D., Arthur S. Slutsky, M.D., Laurent Brochard, M.D., Eduardo L.V. Costa, M.D., David A. Schoenfeld, Ph.D., Thomas E. Stewart, M.D., Matthias Briel, M.D., Daniel Talmor, M.D., M.P.H., Alain Mercat, M.D., Jean-Christophe M. Richard, M.D., Carlos R.R. Carvalho, M.D., and Roy G. Brower, M.D.

Amato M et al. The New England Journal of Medicine 2015

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The concept of driving pressure

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driving pressure
… during ECMO

	All ($n = 545$)	Survivors ($n = 353$)	Non-survivors ($n = 192$)	p value[a]
Ventilatory parameters				
Tidal volume, ml/kg PBW	4.0 ± 1.7	4.0 ± 1.6	4.0 ± 1.9	0.934
Tidal volume, ml/kg ABW	3.2 ± 1.6	3.1 ± 1.5	3.4 ± 1.8	0.075
PEEP, cmH_2O	12.9 ± 3.4	13.0 ± 3.3	12.5 ± 3.7	0.125
FiO_2	0.69 ± 0.24	0.67 ± 0.23	0.74 ± 0.23	0.005
Plateau pressure, cmH_2O	26.2 ± 4.6	26.0 ± 4.3	26.7 ± 5.1	0.205
Driving pressure, cmH_2O	13.7 ± 5.3	13.3 ± 4.8	14.5 ± 6.2	0.048
Respiratory rate, bpm	17.8 ± 8.0	17.4 ± 7.7	18.7 ± 8.7	0.105

Design:

individual patient data metaanalysis (9 studies, n=545)

Results:

- driving pressure is the only parameter independently associated with the primary endpoint (in-hospital mortality)
- High PEEP is not associated with increased survival

Limitation:
unclear clinical relevance
(Δ driving pressure 1.2 cmH_2O, HR 1.06!)

	HR (95 %CI), p
Age, years	1.01 (1.00–1.02), 0.006
Gender, male	1.63 (1.21–2.21), 0.001
BMI, kg/m^2	0.95 (0.93–0.97), <0.001
Risk of death, %[a]	1.01 (0.99–1.01), 0.063
SOFA	1.03 (0.98–1.07), 0.252
Time between MV-ECMO	
≤24 h	1.00 (Reference)
24–72 h	0.70 (0.45–1.09), 0.112
>72 h	0.78 (0.58–1.05), 0.103
Indication of ECMO	
Hypoxemia	0.96 (0.34–2.70), 0.935
Hypercapnia	1 (Reference)
Ventilatory parameters	
PEEP, cmH_2O	–
FiO_2, %	0.96 (0.40–2.30), 0.924
Driving pressure, cmH_2O	1.06 (1.03–1.10), <0.001
Respiratory rate, bpm	–
Laboratory parameters	
PaO_2/FiO_2, mmHg	1.00 (0.99–1.00), 0.431
$PaCO_2$, mmHg	0.99 (0.99–1.01), 0.891
Lactate, mg/dL	1.00 (1.00–1.01), 0.005
Hemodynamics (pre-ECMO)	
Norepinephrine, µg/kg/min[b]	1.07 (0.88–1.29), 0.518

Neto AS et al. Intensive Care Med 2016

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Mechanical ventilation **during ECMO**

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Source	Recommendations for Ventilator Settings for MV on ECMO
ELSO guidelines	▪ **decelerate flow** ▪ **modest PEEP** ▪ **low inflation pressure** ▪ **respiratory rate 4 - 5**
European Network of Mechanical Ventilation	▪ **PEEP ≥ 10** ▪ **plateau pressure ≤ 20 - 25** ▪ **respiratory rate 6 – 20** ▪ **F_iO_2 30% - 50%**
CESAR trial	▪ **peak inspiratory pressure 20 -25** ▪ **PEEP 10 -15** ▪ **respiratory rate 10** ▪ **F_iO_2 30%**
EOLIA trial	▪ **PEEP ≥ 10** ▪ **Reduced tidal volume → $P_{plateau}$ ≤ 20** ▪ **respiratory rate 10 – 30**

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ECMO and COVID-19

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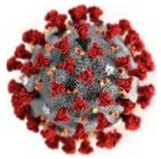
Recommendations….easily achivable during ECMO
(not COVID-19 specific)

- **Reduce respiratory rate to < 12/min**
- **Reduce patients breathing efforts**
- **Increase T_{insp} to increase mean airway pressure**
- **Reduce F_iO_2 to 0.6 or less; maintain SpO_2 > 88% ($\dot{D}O_2$)**
- **Play with PEEP and monitor for right heart failure**
- **Reduce P_{plat} to reduce ΔP to <14 (10)**
- **Consider prone position on ECMO**

- **Wean the patient of ECMO as fast as possible**



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Conclusion

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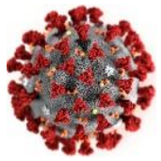
- **ECMO might be a very good idea in COVID-19**
- **As always, ECMO can facilitate an „ultraprotective“ ventilation in patients with severe ARDS – especially by reducing the need for ventilation**
- **The advantage of *„facilitated ventilation“* must be protected against adverse effects ECMO might have (thrombosis, bleeding etc.)**
- **COVID-19 seems to be a slowly resolving problem**

- **Don‘t start an ECMO program with COVID-19 patients**



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Thank you for your attention

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EDUCATION
for Anesthesia and Respiratory Care

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