History and development of ARDS (my experience)

CEEA 2015, Kosice

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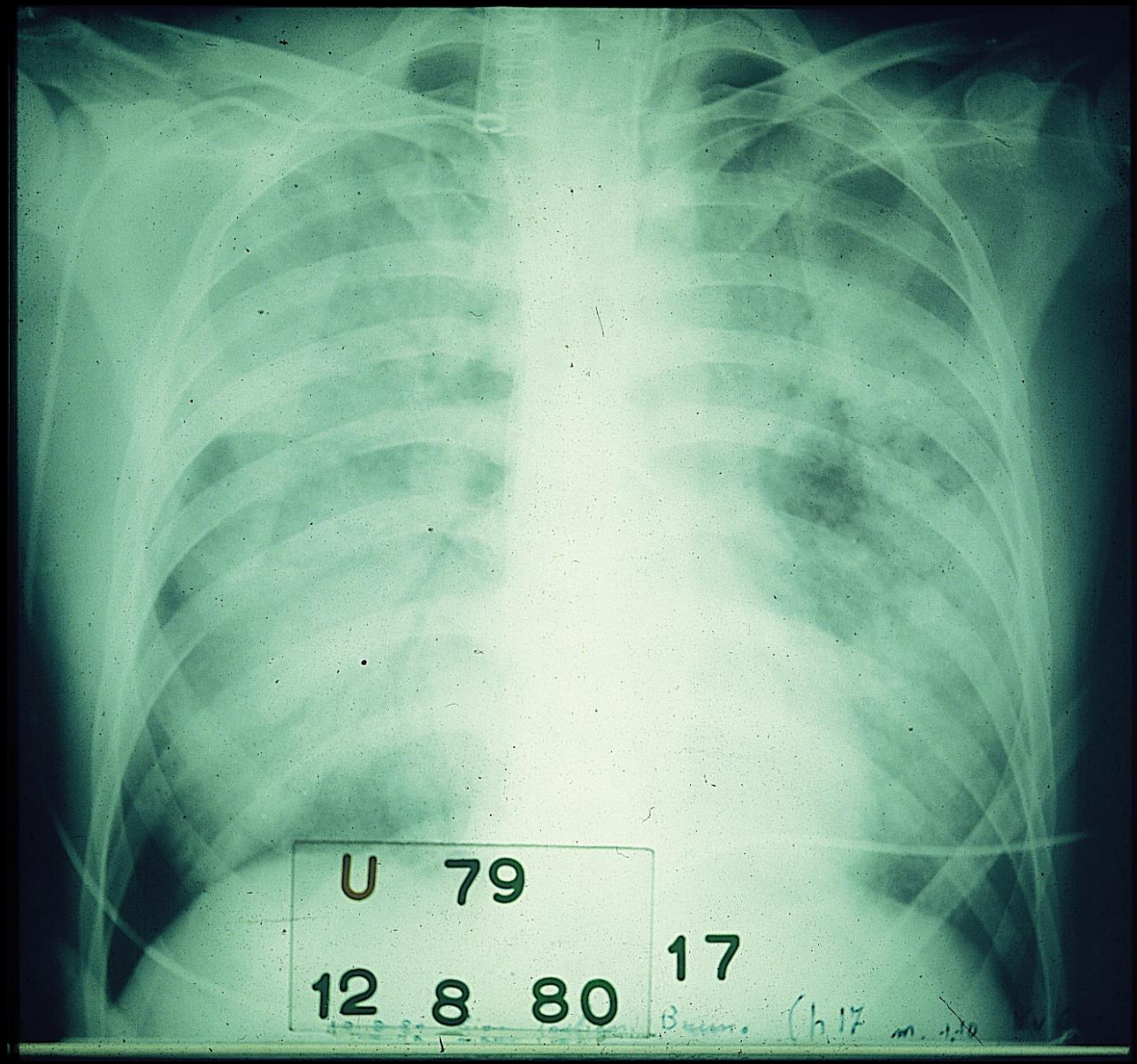
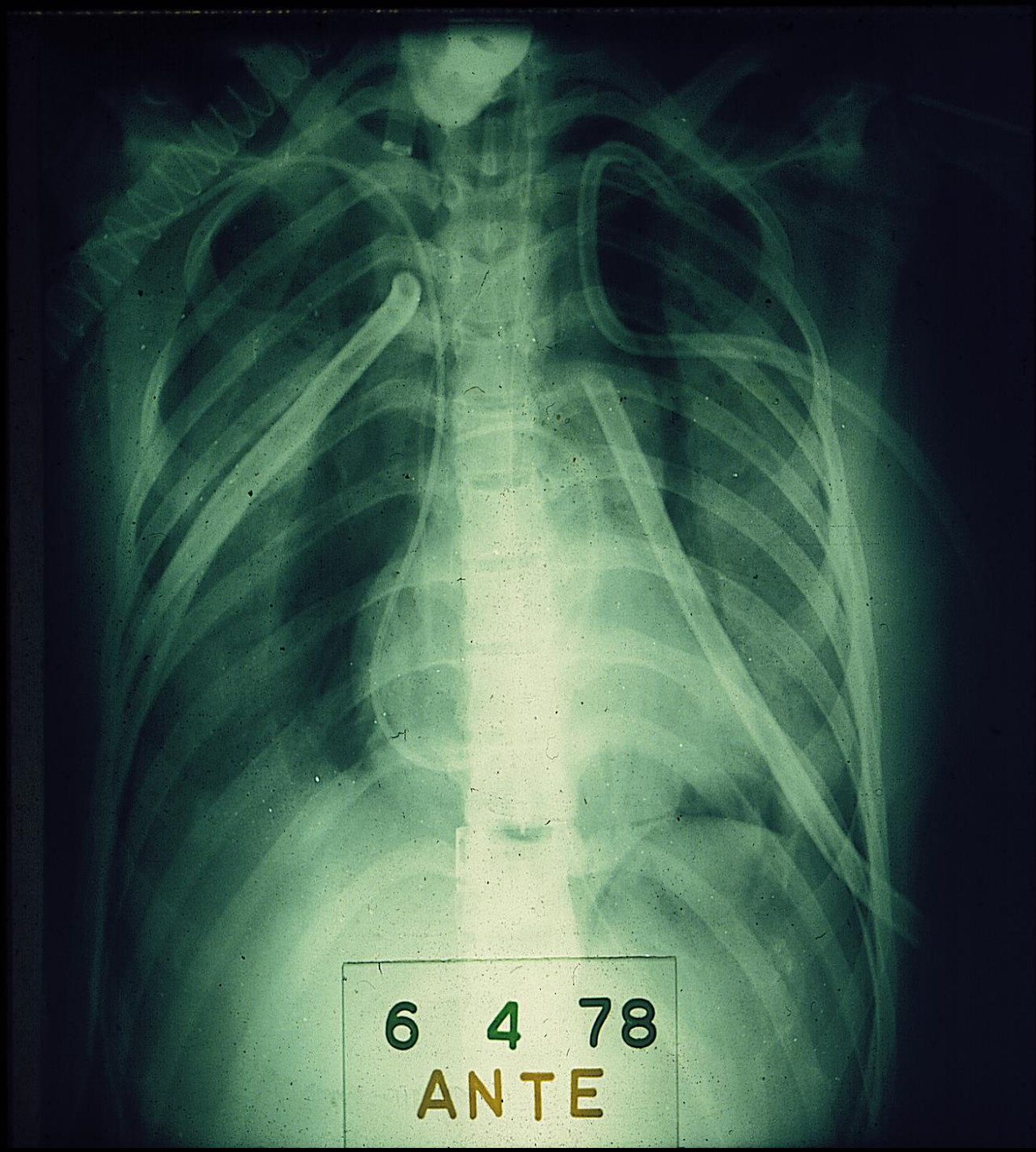

U 79
12 8 80
17

The ’70s mechanical ventilation

12 - 15 ml/kg V_T, 5 - 10 cmH_2O PEEP

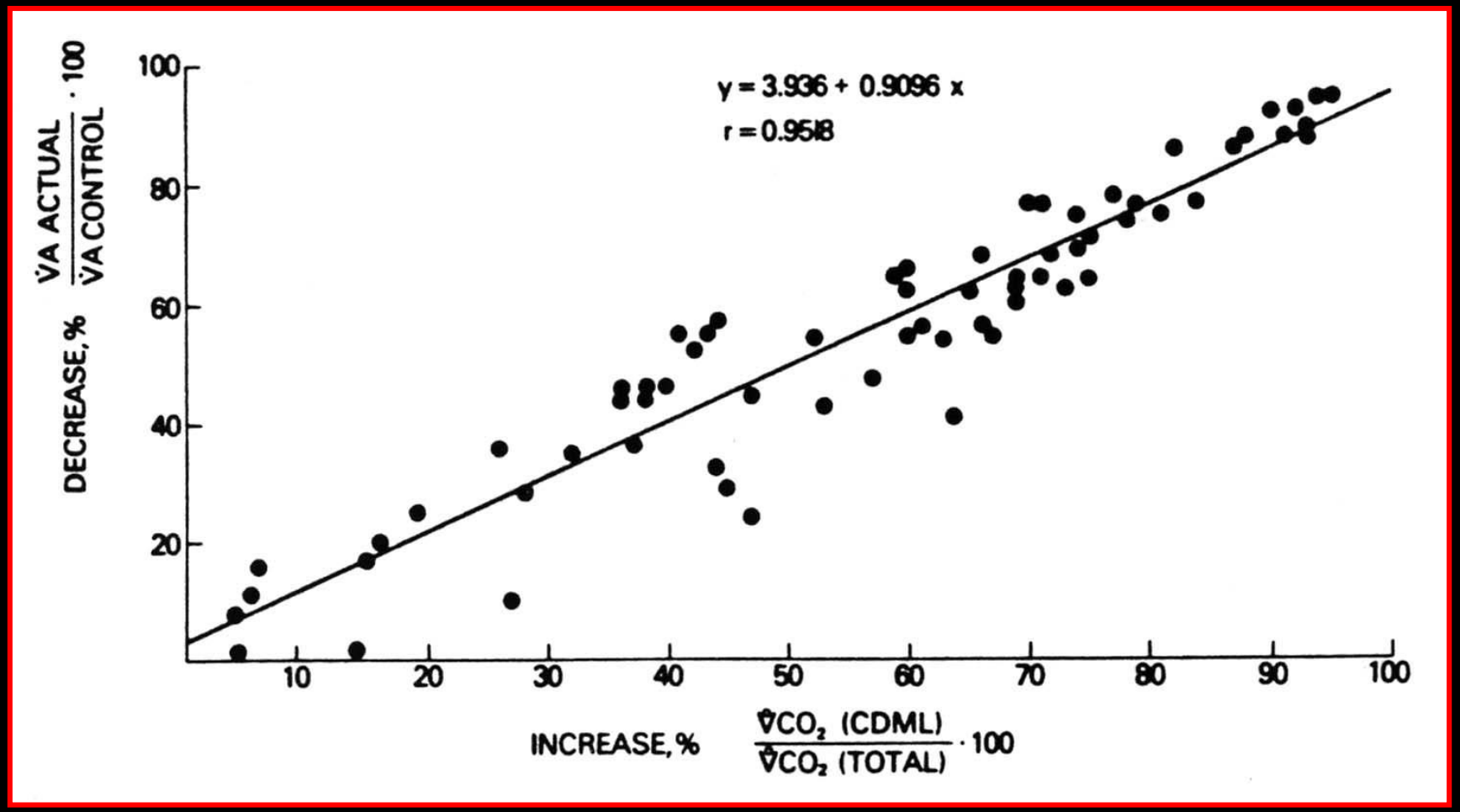
“ We ventilated
thousands of patients in this way,
and the only side effect was hypocapnia”

H. Pontoppidan, *N Engl J Med* 1972


6 4 78
ANTE

The lung rest concept

Control of breathing using an extracorporeal membrane lung



*Kolobow T, Gattinoni et al., Anesthesiology, **1977**; 46: 138-141*

We choose to rest the lung with diffusion oxygenation (3 breaths/min), avoiding possible pulmonary and extrapulmonary complications of CPPV, and removed CO_2 through a membrane lung by low-flow veno-venous bypass to make lung rest feasible.

Gattinoni L. et al. THE LANCET 1980. 292-294

Patients meeting ECMO criteria

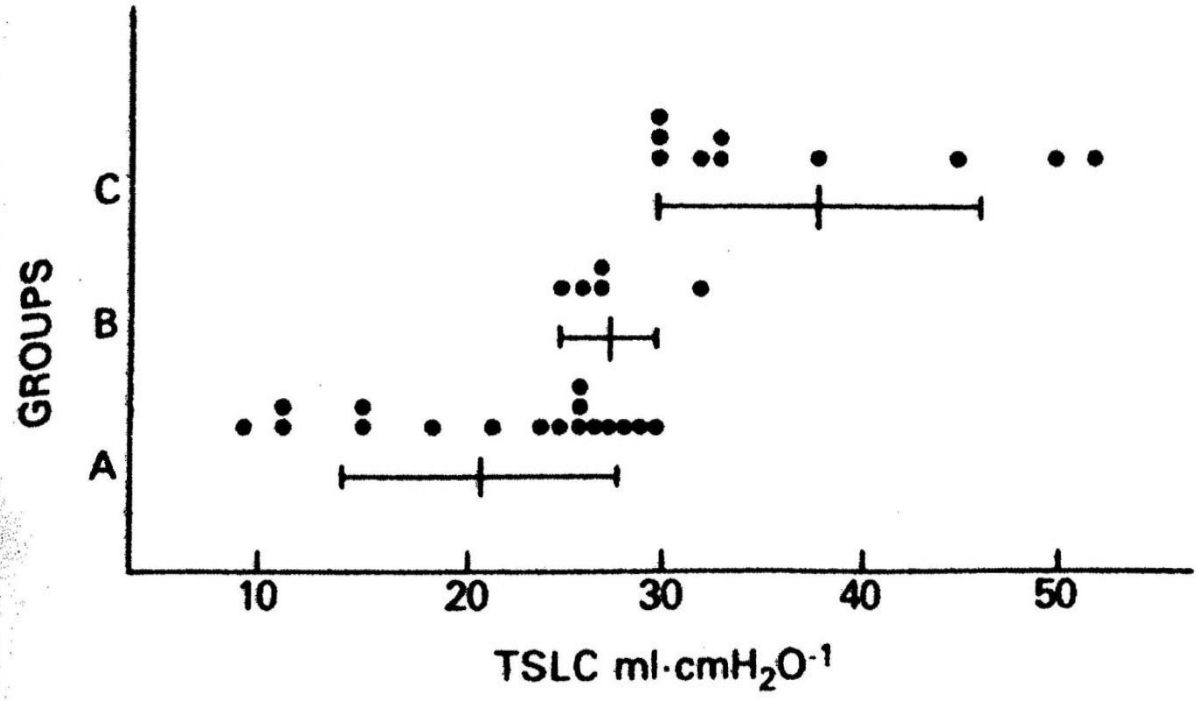
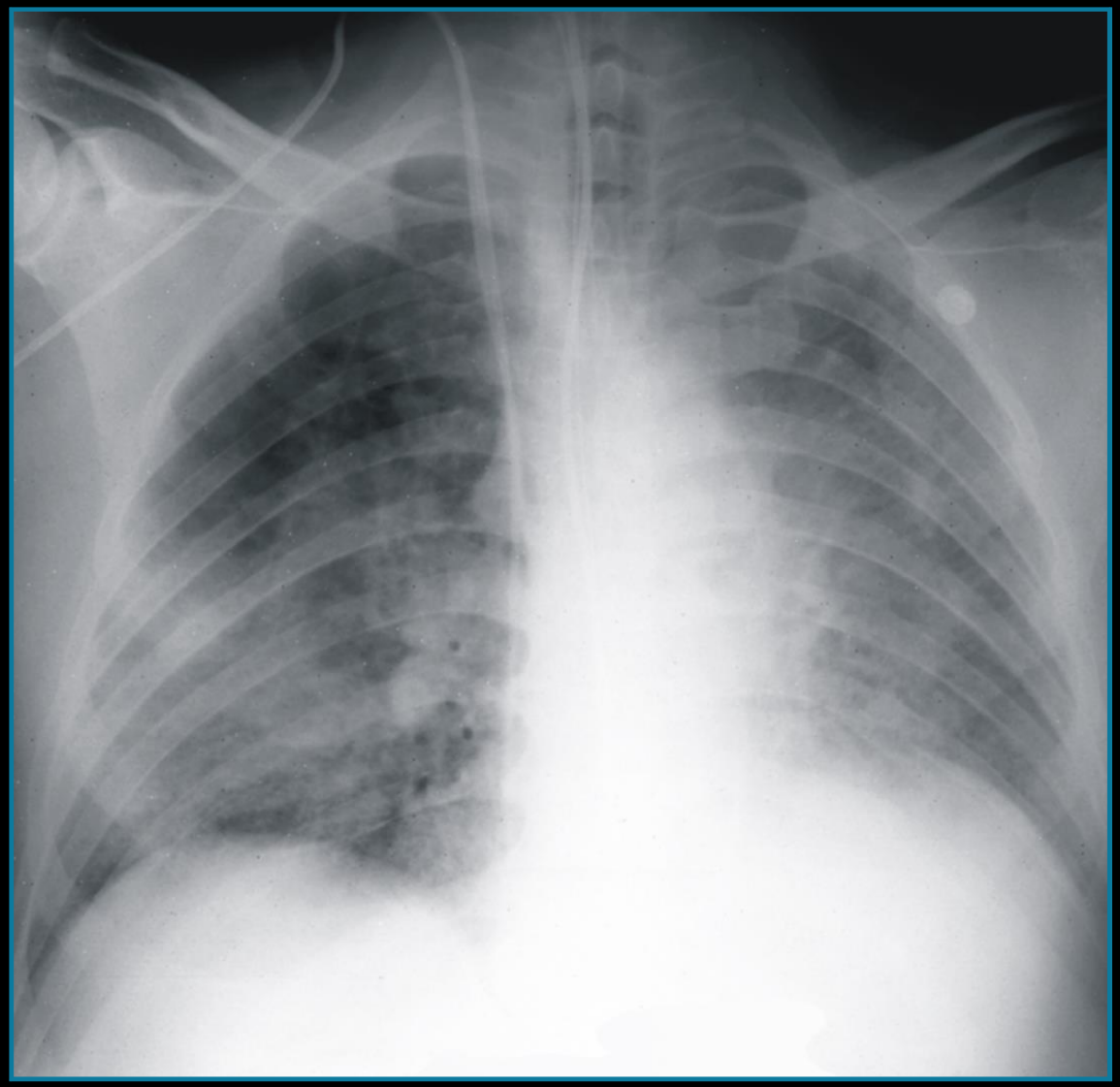
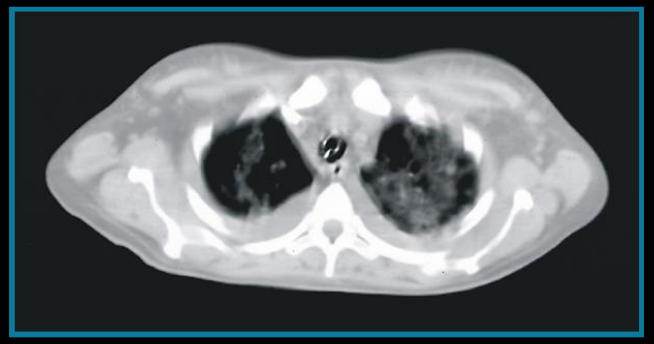
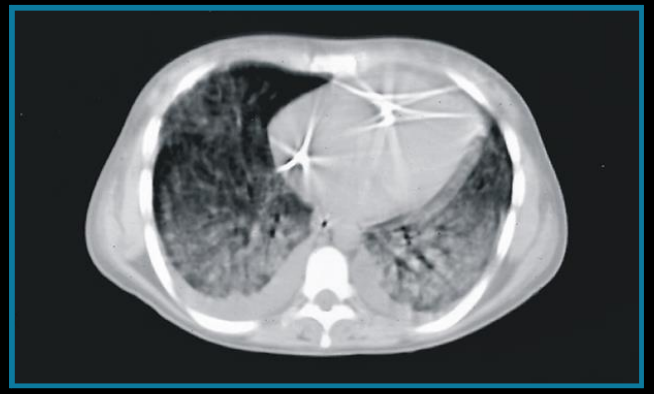


Fig. 2. Baseline total static lung compliance in Groups A, B, and C during conventional continuous positive pressure ventilation

Gattinoni L et al. Int. Care Med. 1984, 10: 121–126

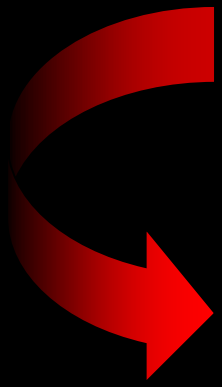






*Gattinoni L et al. Intensive Care Med (**1986**) 12:137-142*

CT “density”

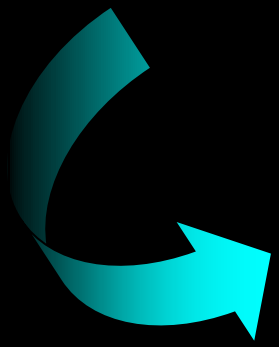


$$\frac{\text{mass}}{\text{volume}}$$

in which

mass

is



original mass of tissue

+

mass of blood

+

mass of edema

+

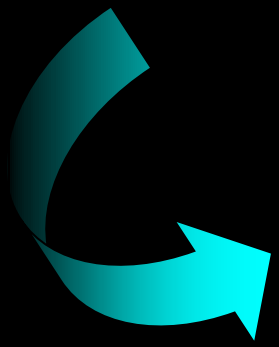
mass of cells, etc.

HU

0

+100

in which
volume
is



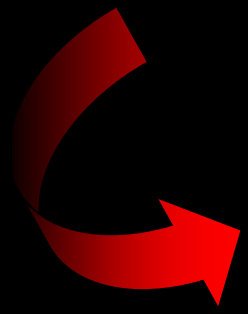
mass of tissue

+

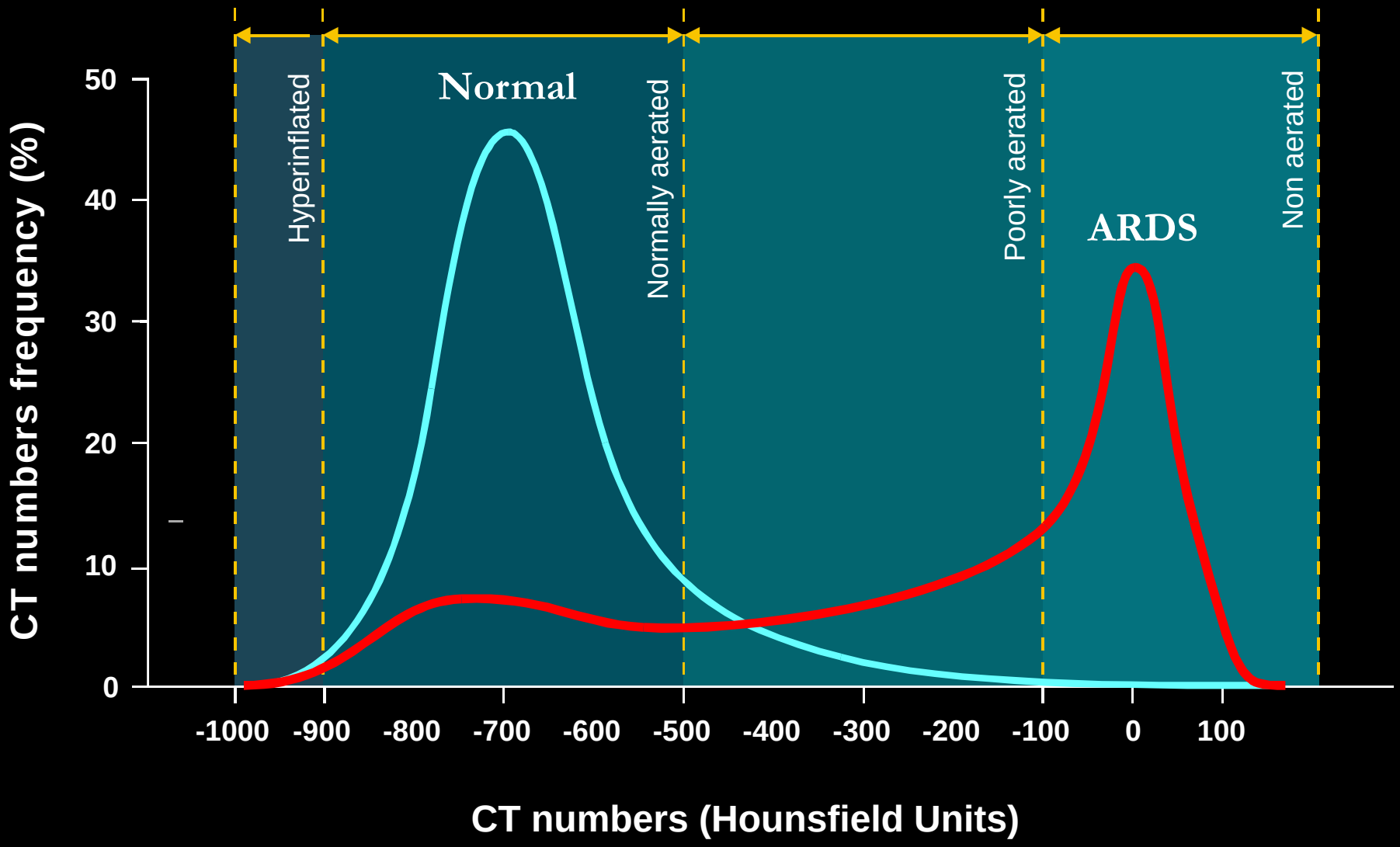
volume of gas

Indeed,

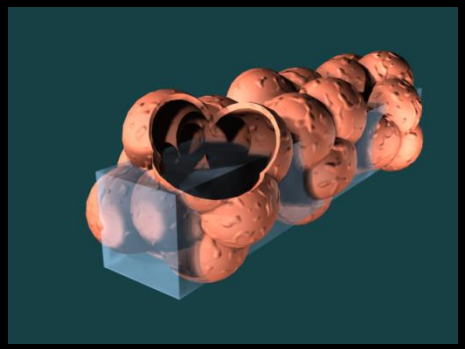
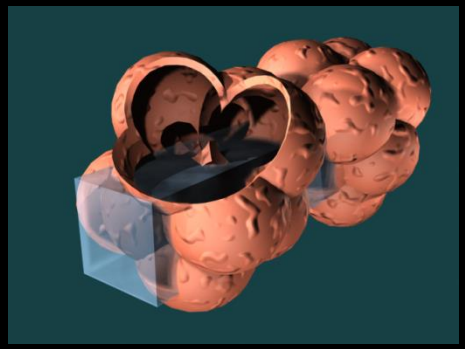
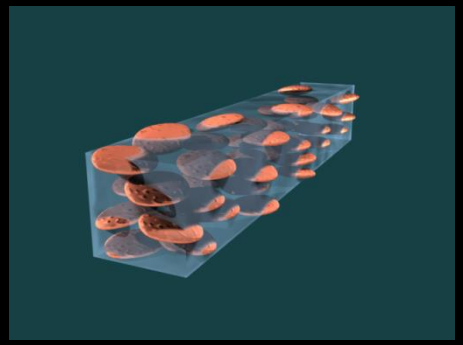
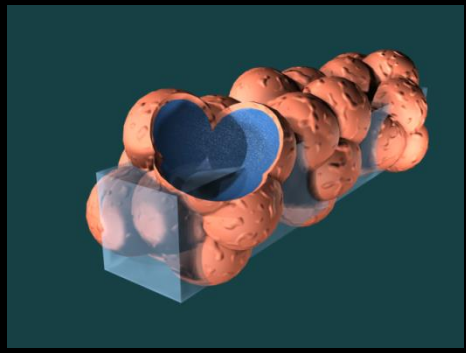
$$\text{CT number} = \frac{\text{mass}}{\text{mass + volume}}$$

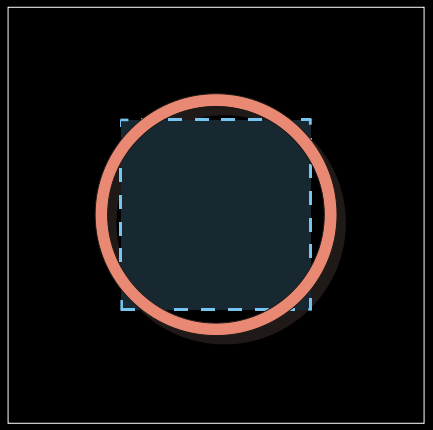
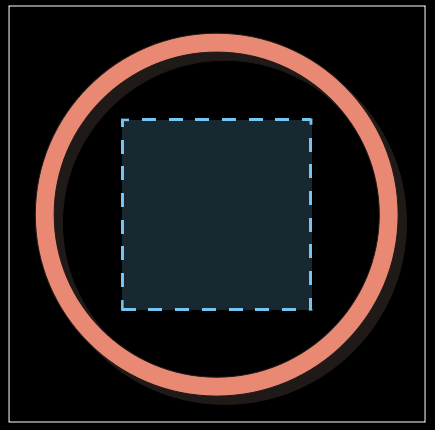
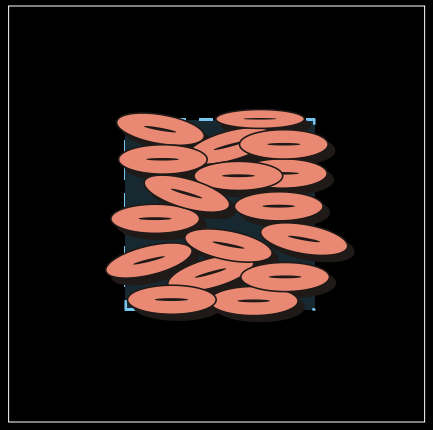
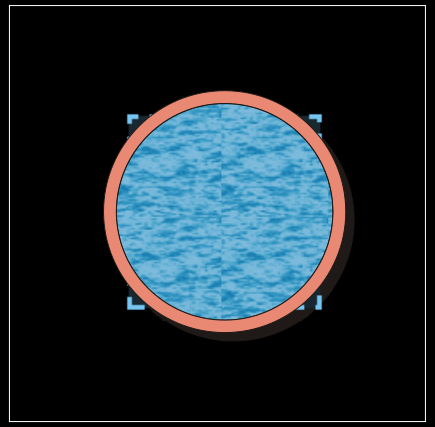


cannot discriminate between tissue mass, blood mass, edema etc.

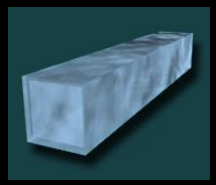

Hyperinflated
Normal
Normally aerated
Poorly aerated
ARDS
Non aerated
CT numbers frequency (%)
50
40
30
20
10
0
-1000
-900
-800
-700
-600
-500
-400
-300
-200
-100
0
100
CT numbers (Hounsfield Units)

FRC TLC Collapse Edema

Voxel:



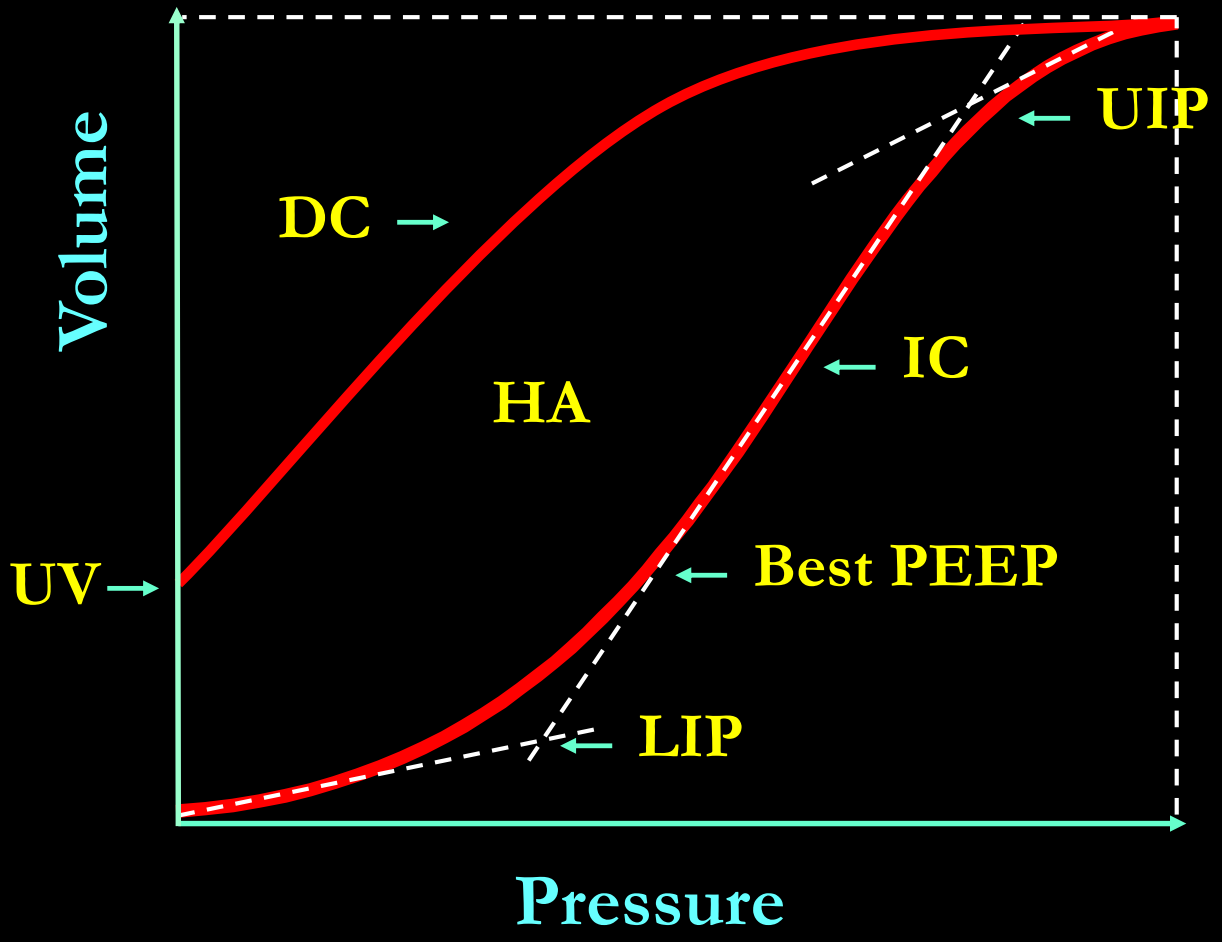
1.5 x 1.5 x 10 mm = 22.5 mm^3

Each voxel,
the "CT pulmonary unit"
is a black box

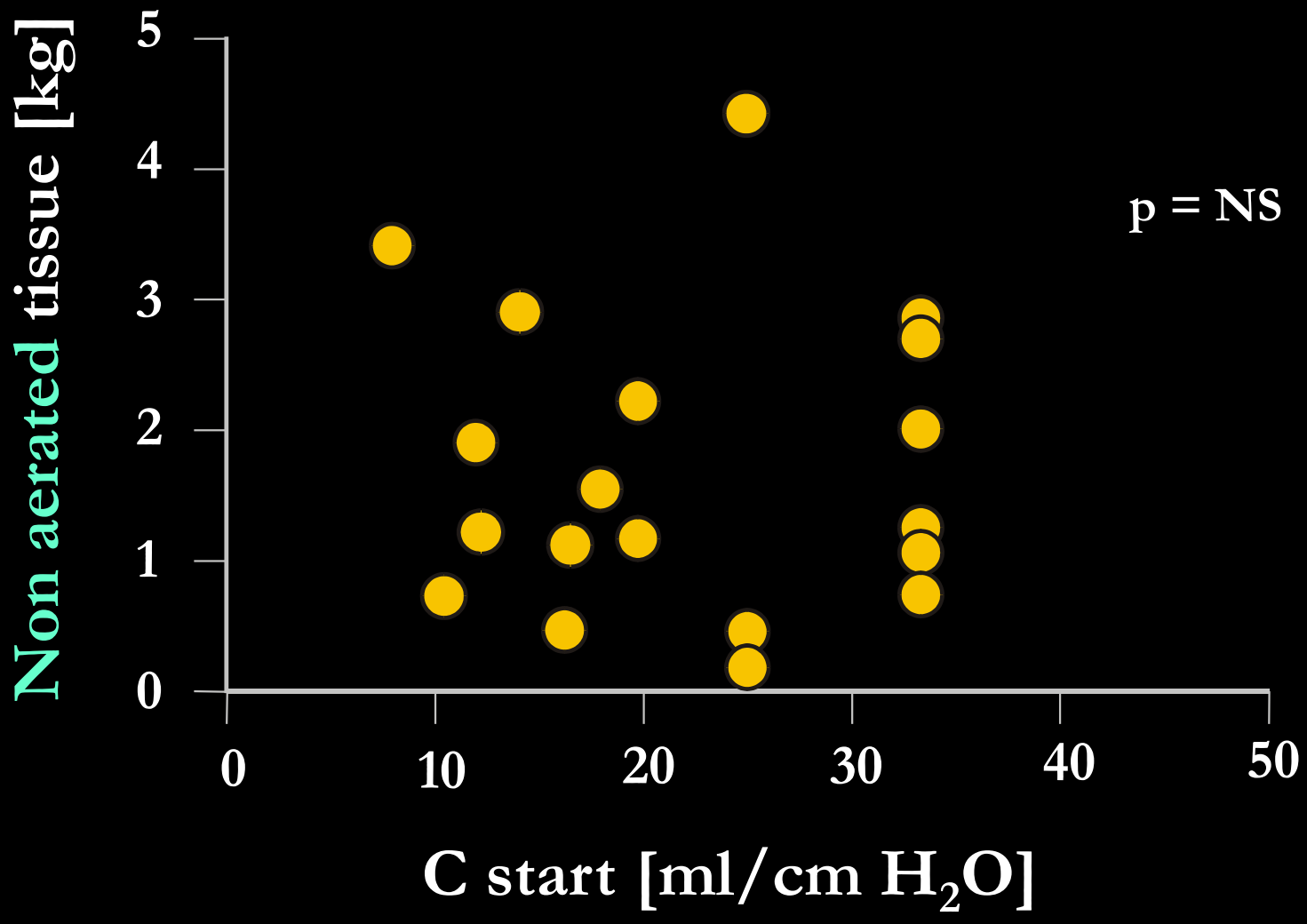
where

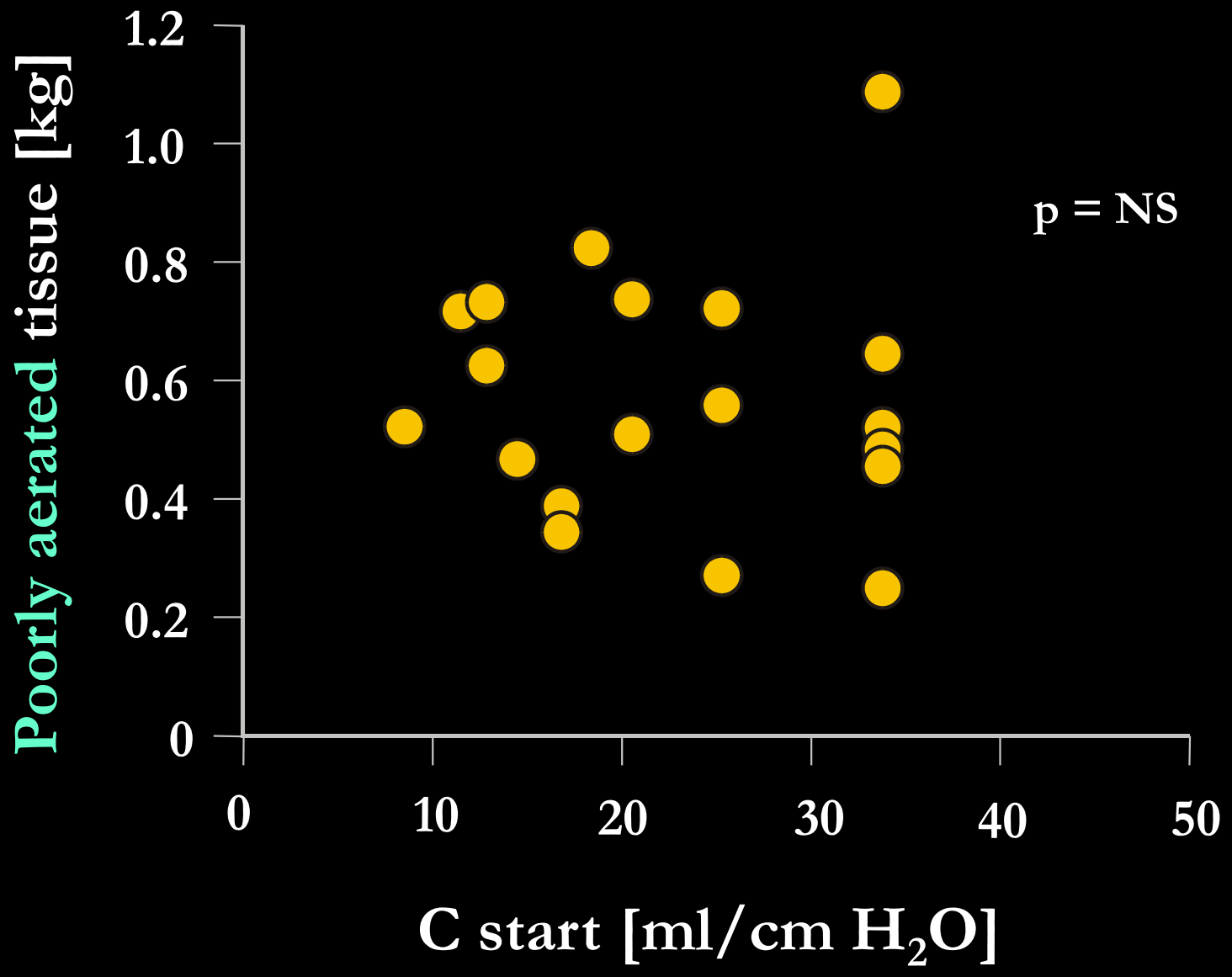
it is impossible to discriminate directly
the nature of the density

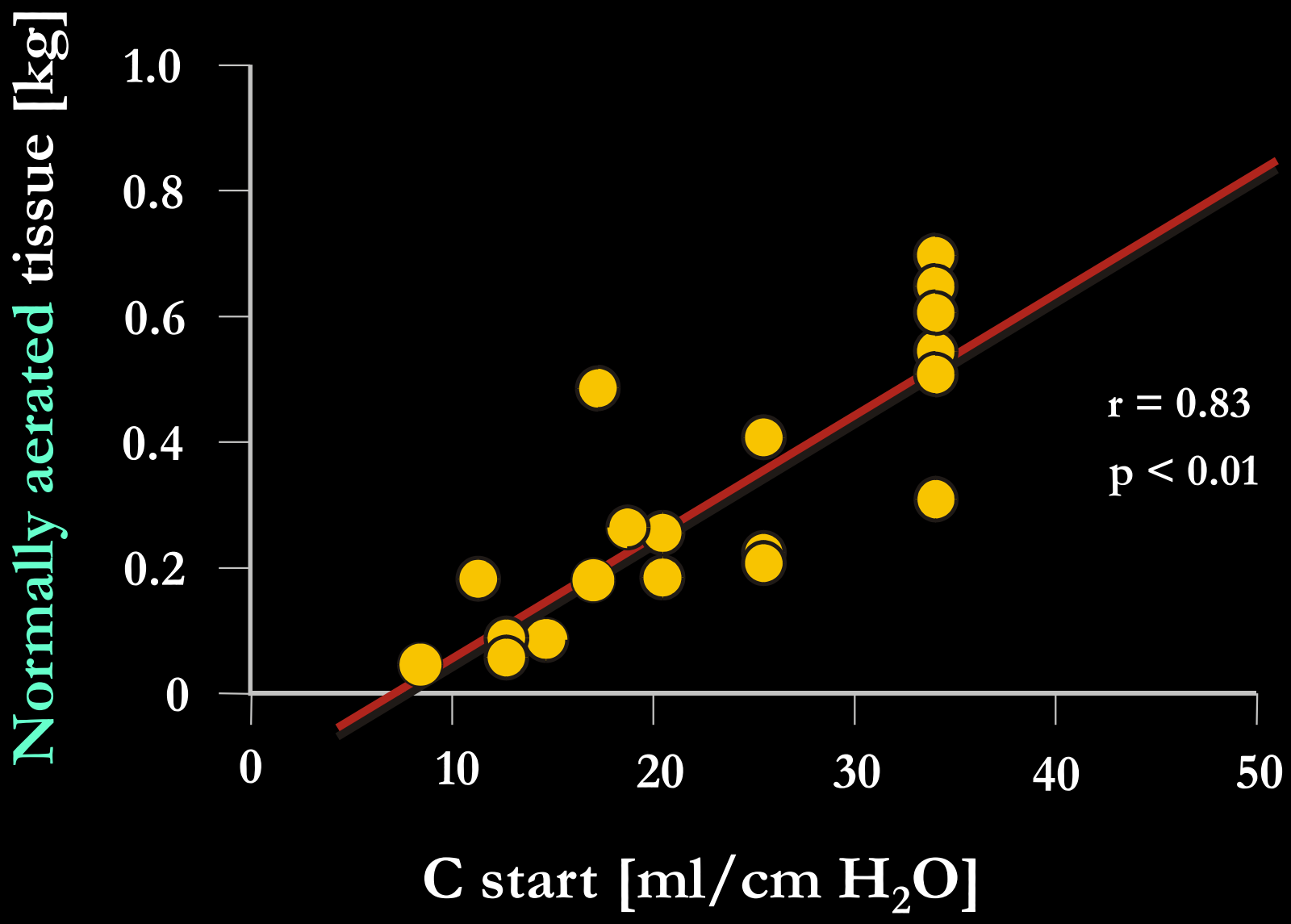
Volume-Pressure curve



Gattinoni et al. *Am Rev Respir Dis* 1987;136:730-736


Non aerated tissue [kg]
5
4
3
2
1
0
0
10
20
30
40
50
C start [ml/cm H2O]
p = NS


Poorly aerated tissue [kg]
1.2
1.0
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
C start [ml/cm H2O]
p = NS


Normally aerated tissue [kg]
1.0
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
C start [ml/cm H2O]
r = 0.83
p < 0.01

The ARDS lung is small and not stiff

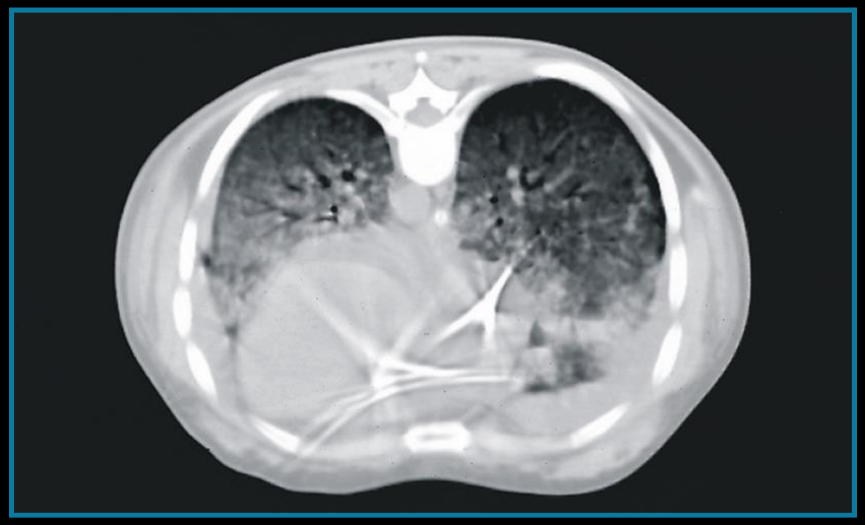
Normal → $\frac{V_T}{FRC} = \frac{500\ ml}{2500\ ml} = 0.2$

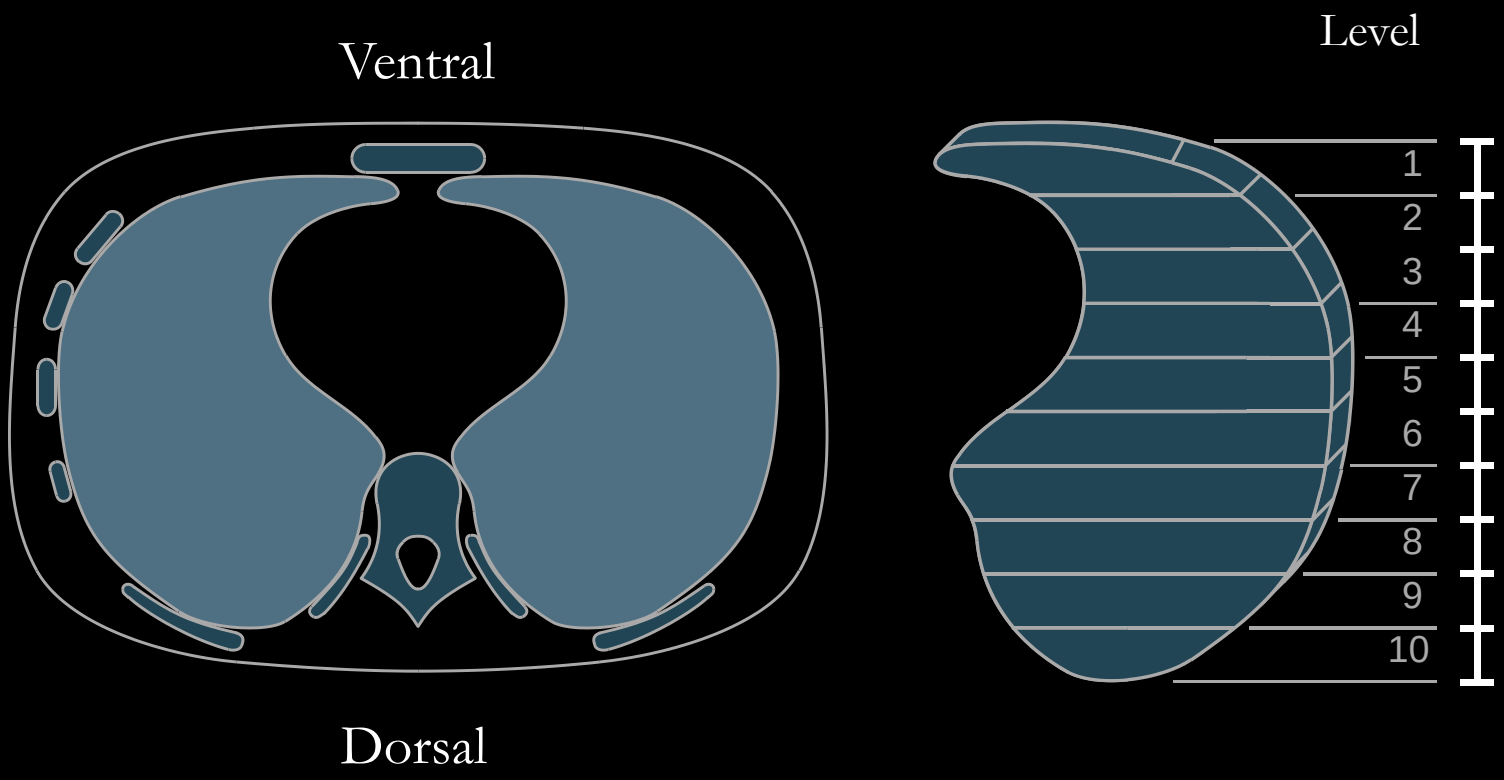
ARDS → $\frac{V_T}{FRC} = \frac{500\ ml}{500\ ml} = 1$

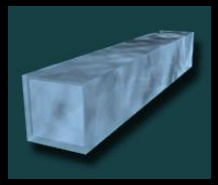
End Expiration

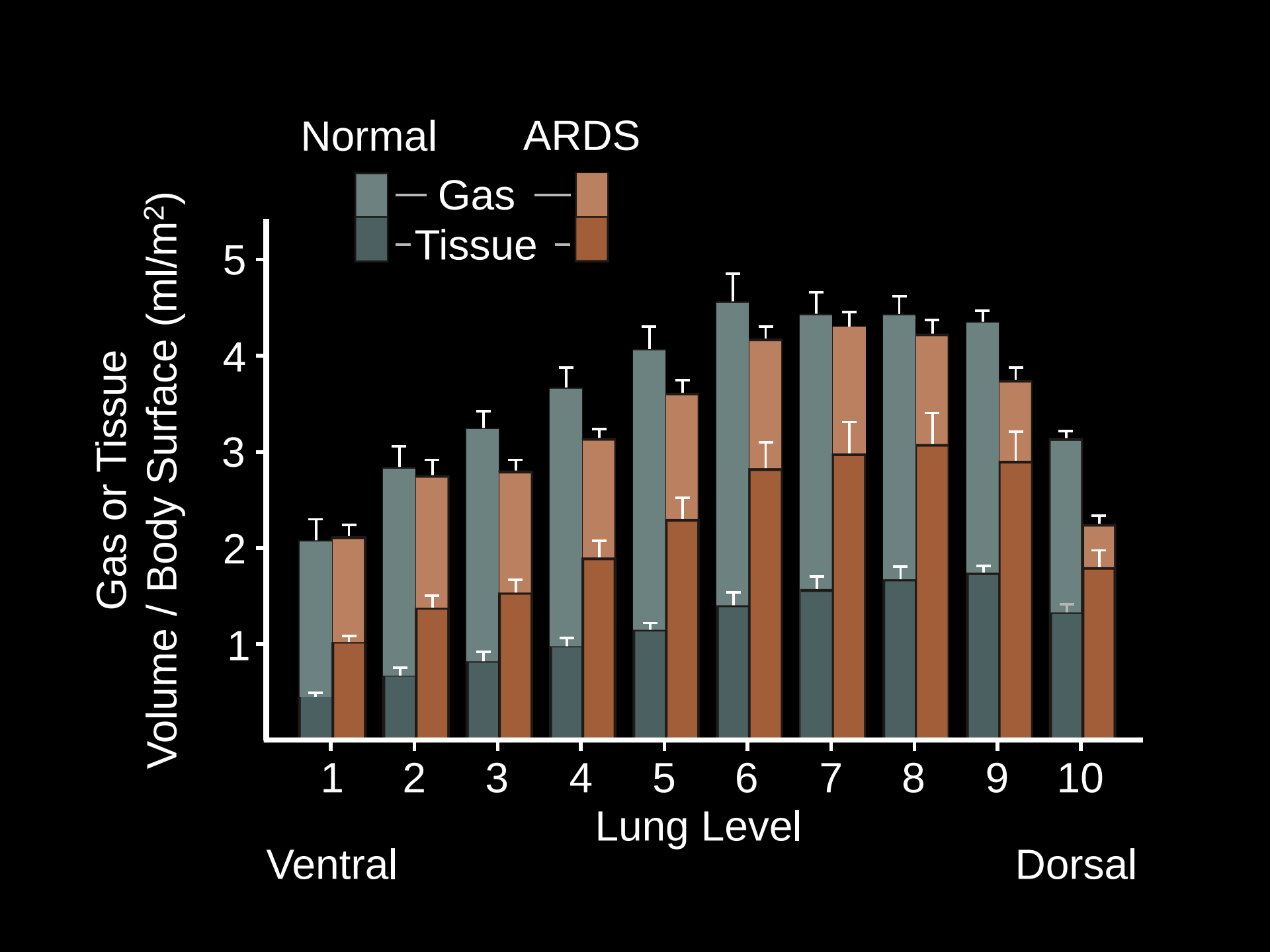
Supine

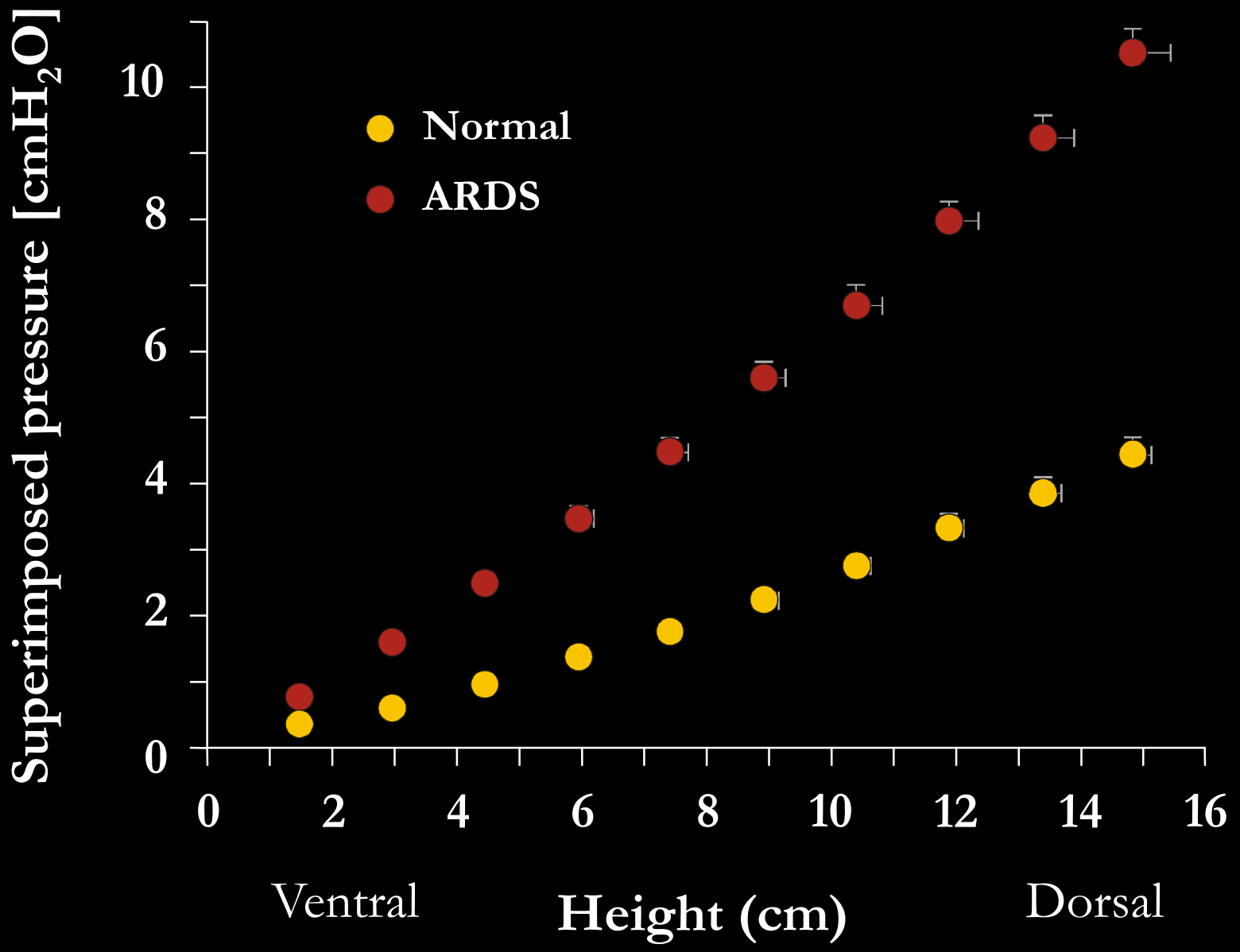
Prone

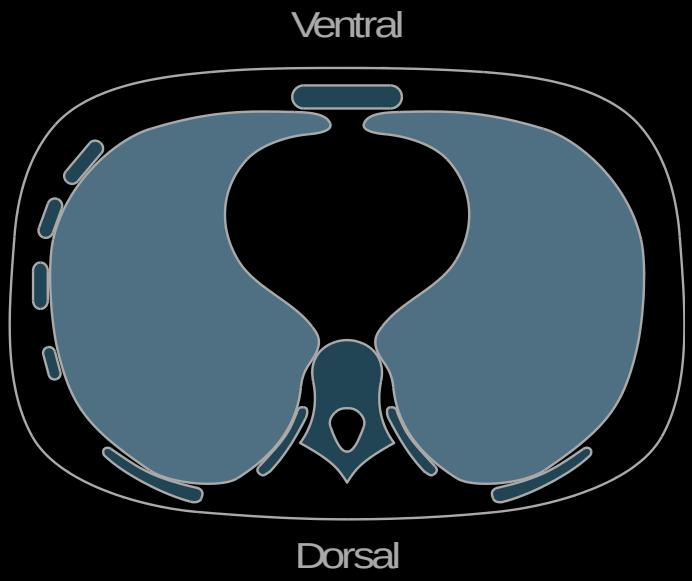


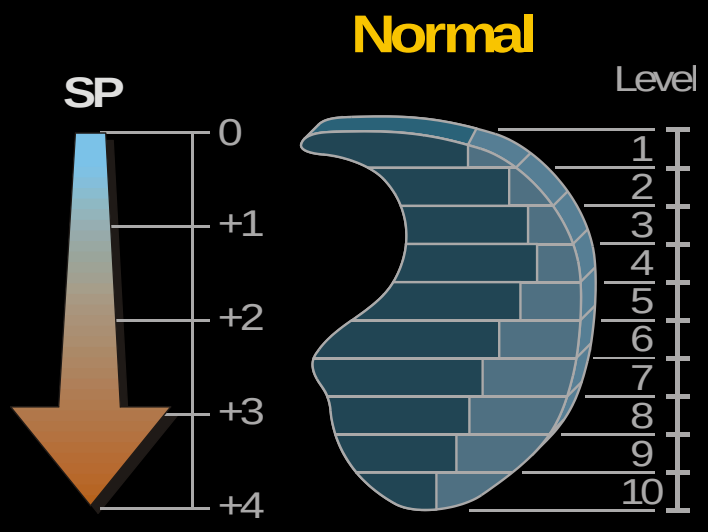


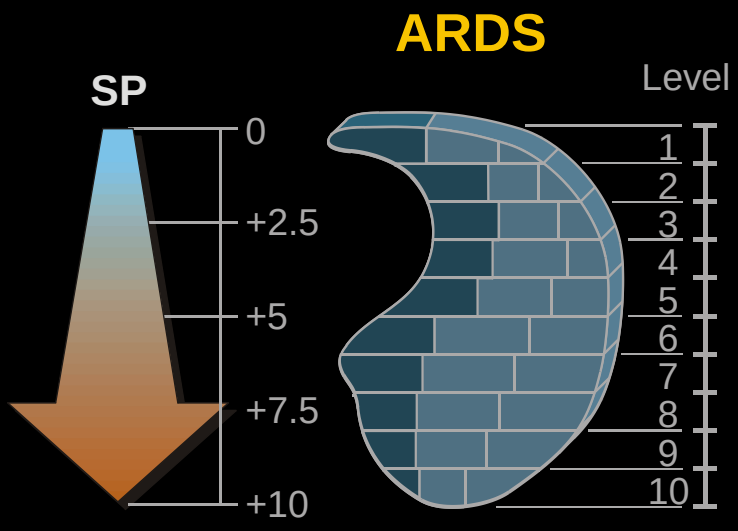
Voxel:  1.5 x 1.5 x 10 mm = 22.5 mm^3


Normal
ARDS
Gas
Tissue
Gas or Tissue
Volume / Body Surface (ml/m²)
5
4
3
2
1
1
2
3
4
5
6
7
8
9
10
Lung Level
Ventral
Dorsal

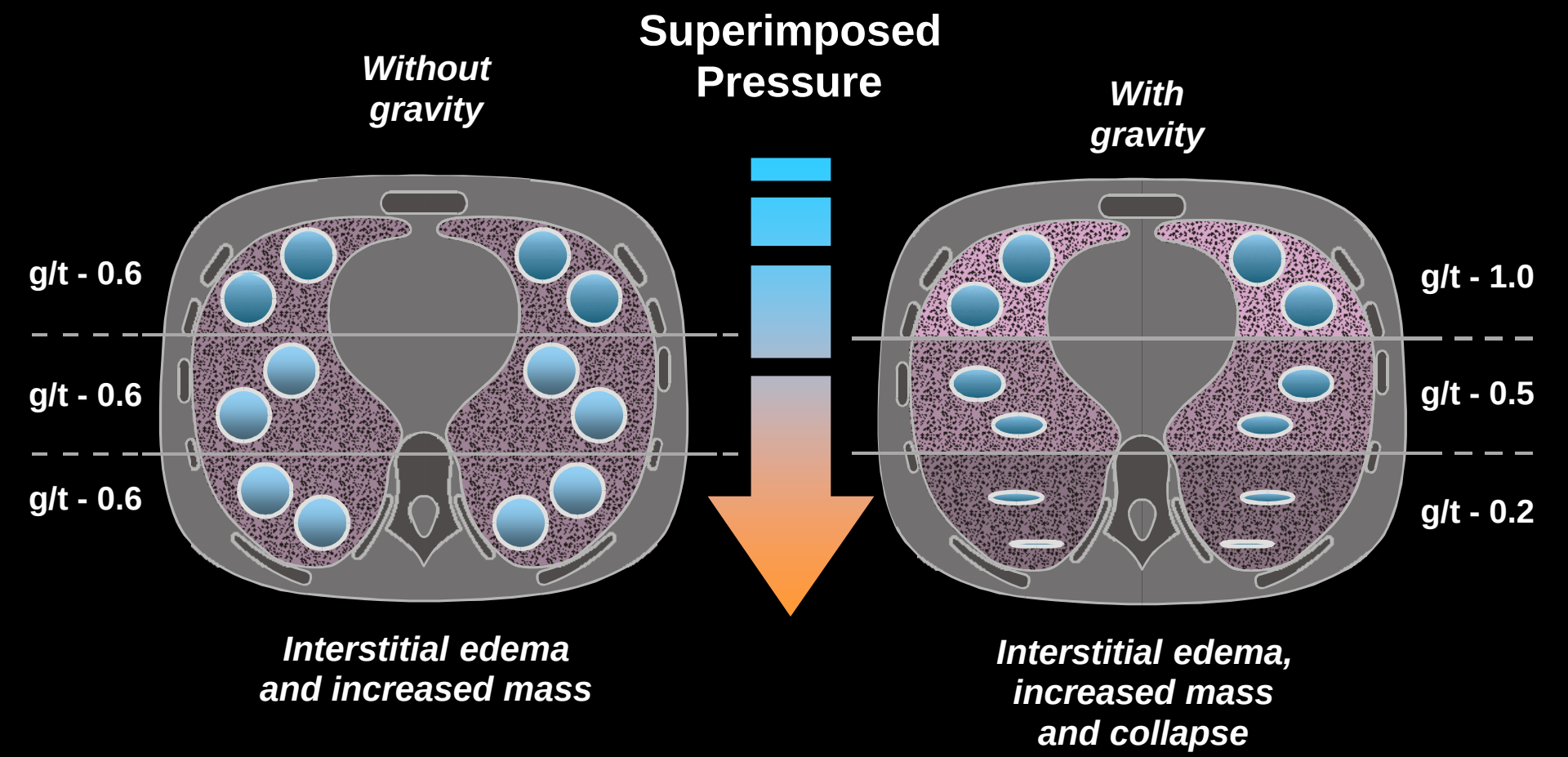

Superimposed pressure [cmH2O]
0
2
4
6
8
10
Normal
ARDS
0
2
4
6
8
10
12
14
16
Ventral
Height (cm)
Dorsal

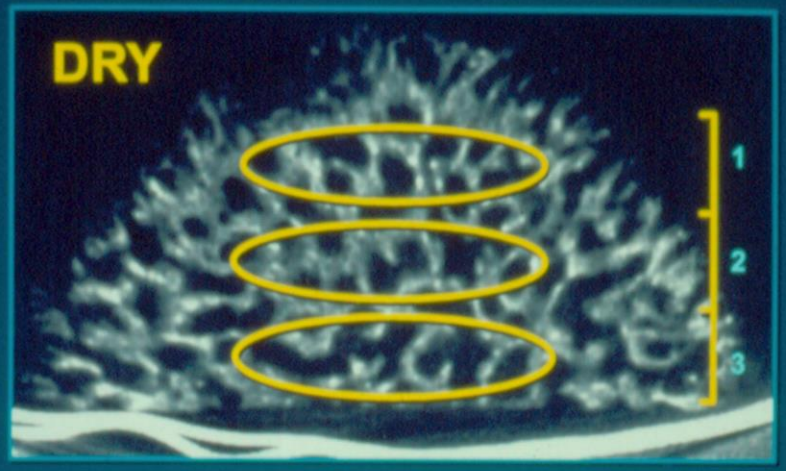

Ventral
Dorsal


Normal
SP
Level
0
+1
+2
+3
+4
1
2
3
4
5
6
7
8
9
10

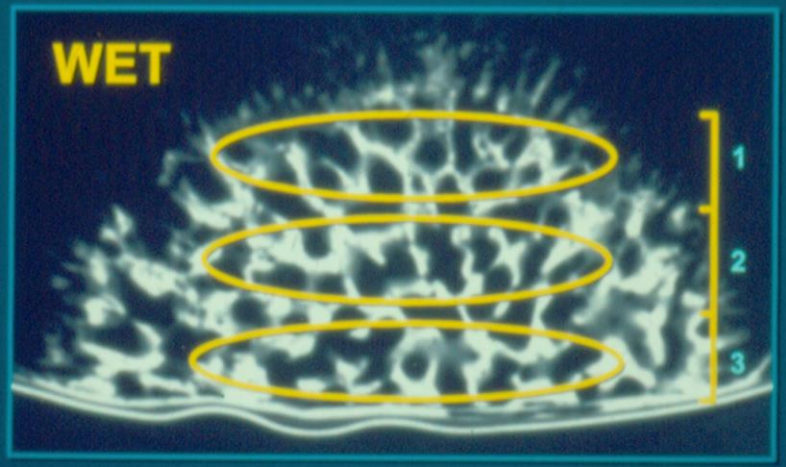

ARDS
SP
Level
0
+2.5
+5
+7.5
+10
1
2
3
4
5
6
7
8
9
10

The Sponge Model



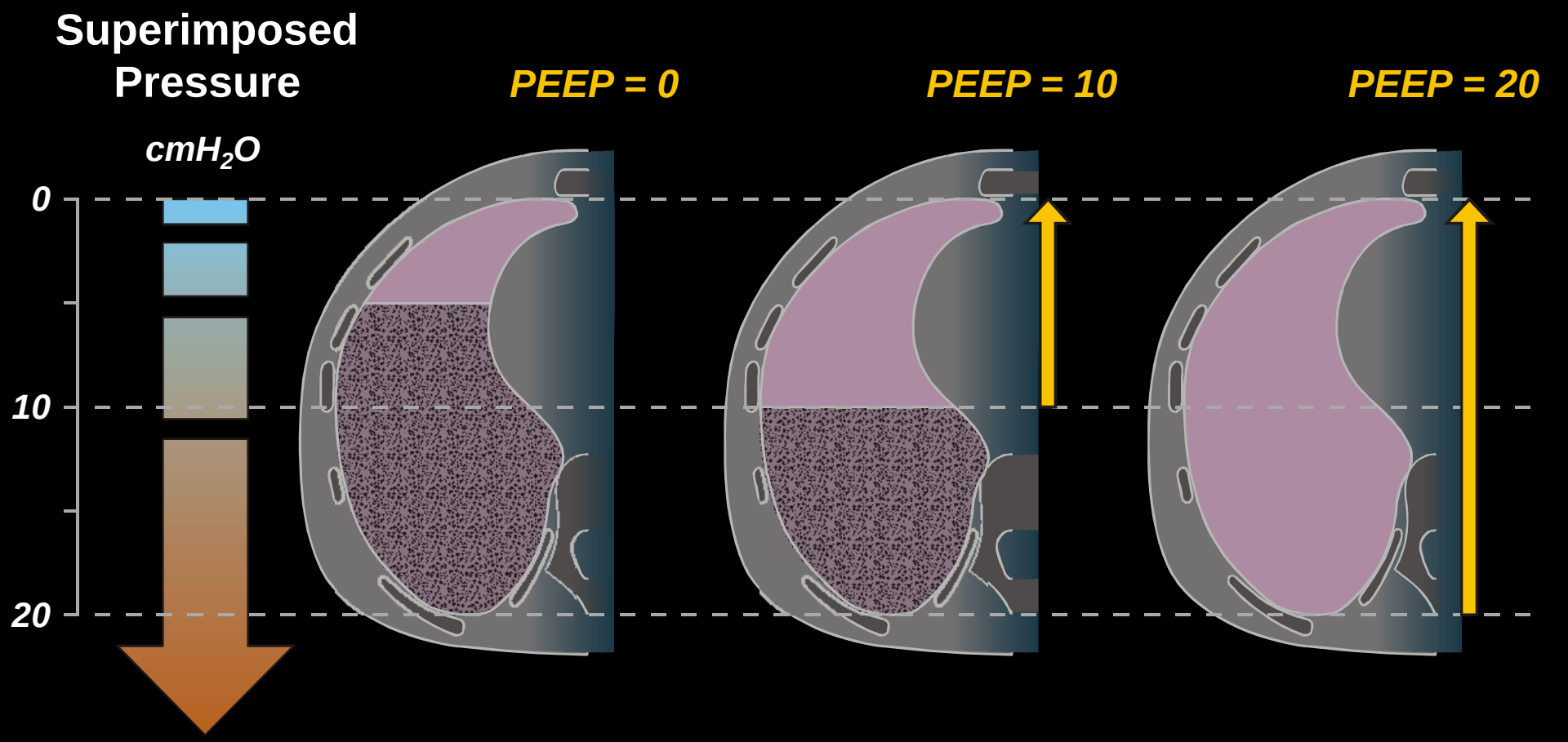


1. mean CT = -965.9 ± 21.2
2. mean CT = -966.5 ± 19.4
3. mean CT = -968.1 ± 20.6

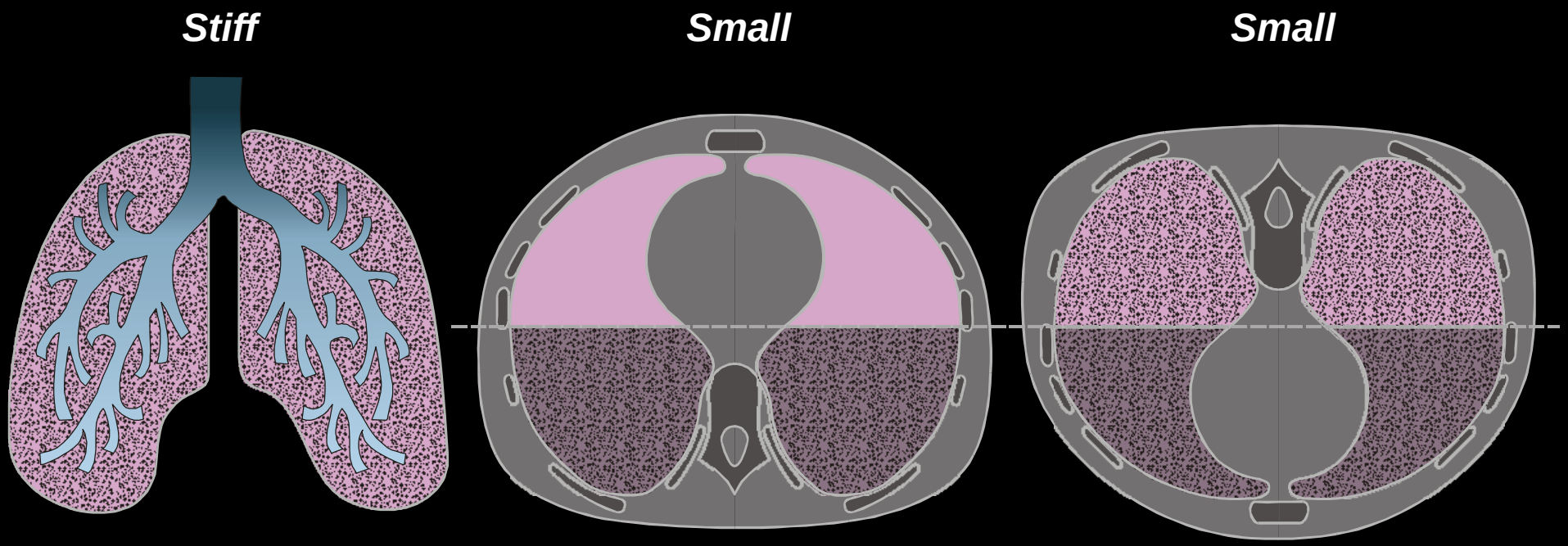


1. mean CT = -668.2 ± 295.0
2. mean CT = -594.4 ± 341.8
3. mean CT = -572.6 ± 354.2

PEEP mechanism



ALI / ARDS modeling (early phase)



The uniform lung

The baby lung

The sponge lung

Early vs late ARDS

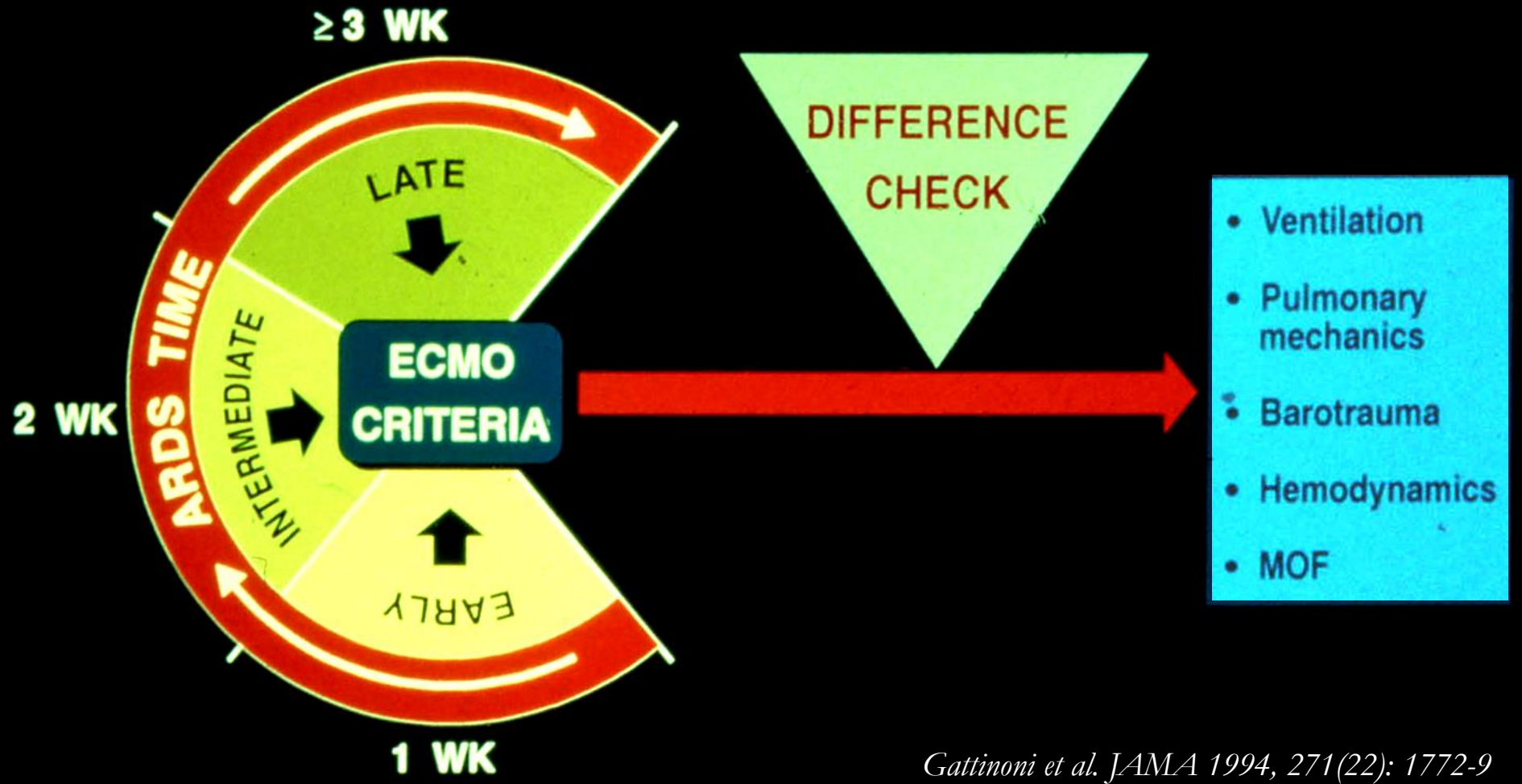
N° PATIENTS

EARLY ARDS = 37

INTERMEDIATE ARDS = 24

LATE ARDS = 23

Early vs late ARDS



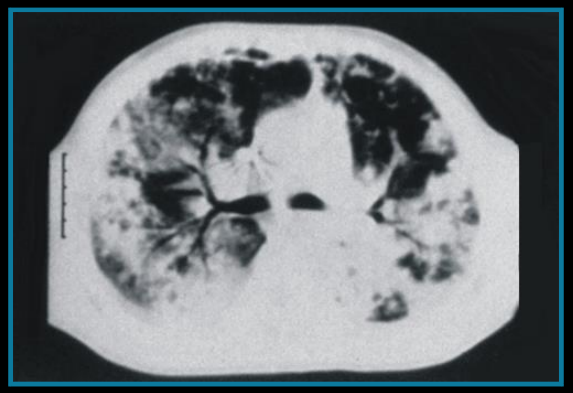
Gattinoni et al. JAMA 1994, 271(22): 1772-9

Early ARDS

(week 1)

Intermediate ARDS

(week 2)



Late ARDS

(week ≤ 3)

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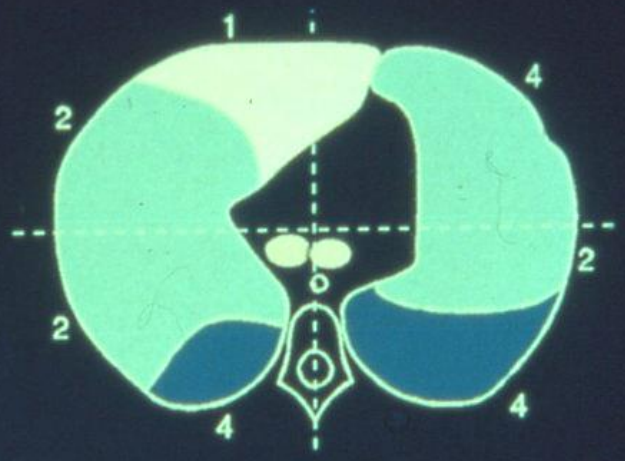
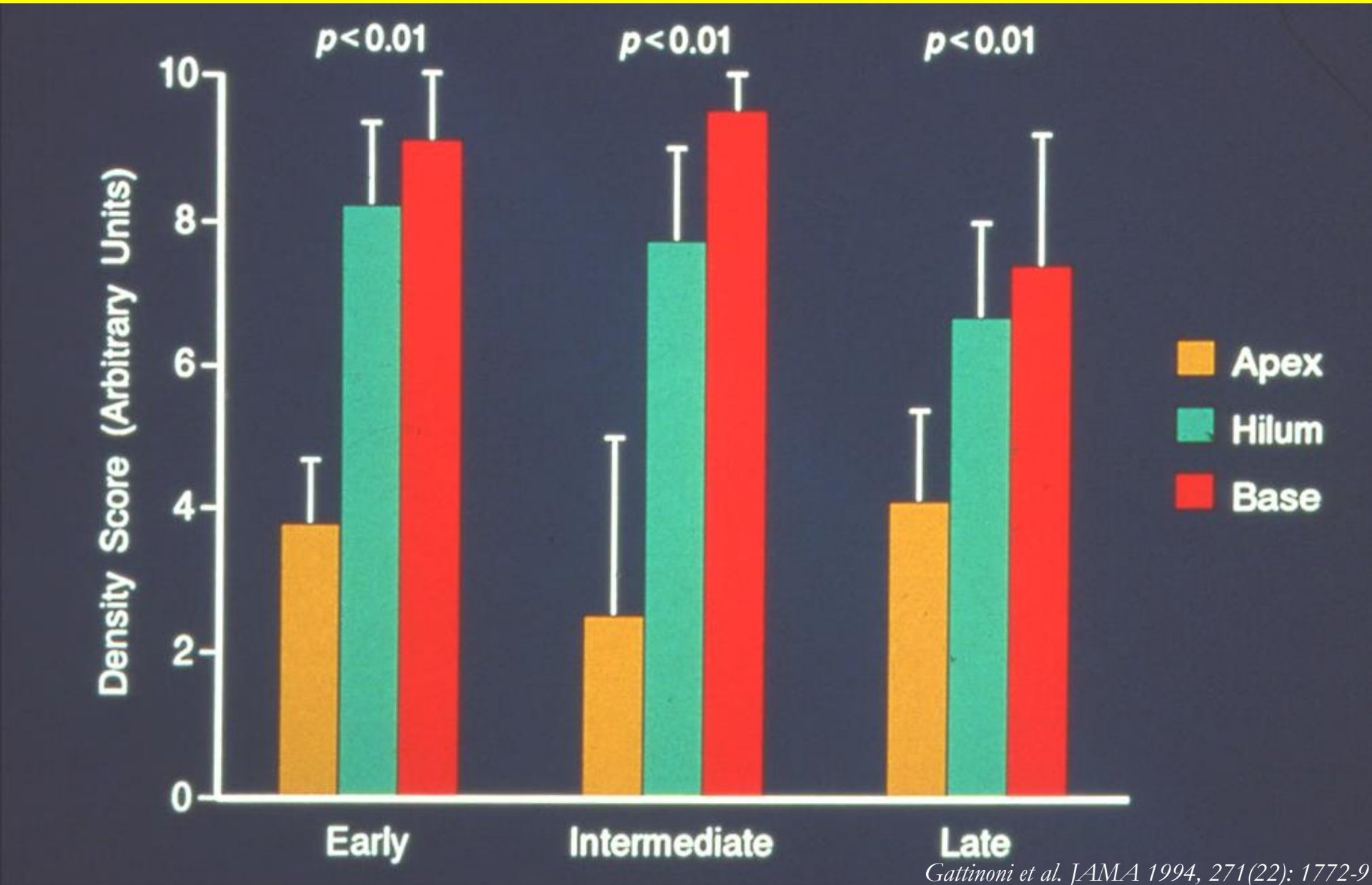
Early vs late ARDS



hazy (1-2) patchy (2-4) compact (4-8)

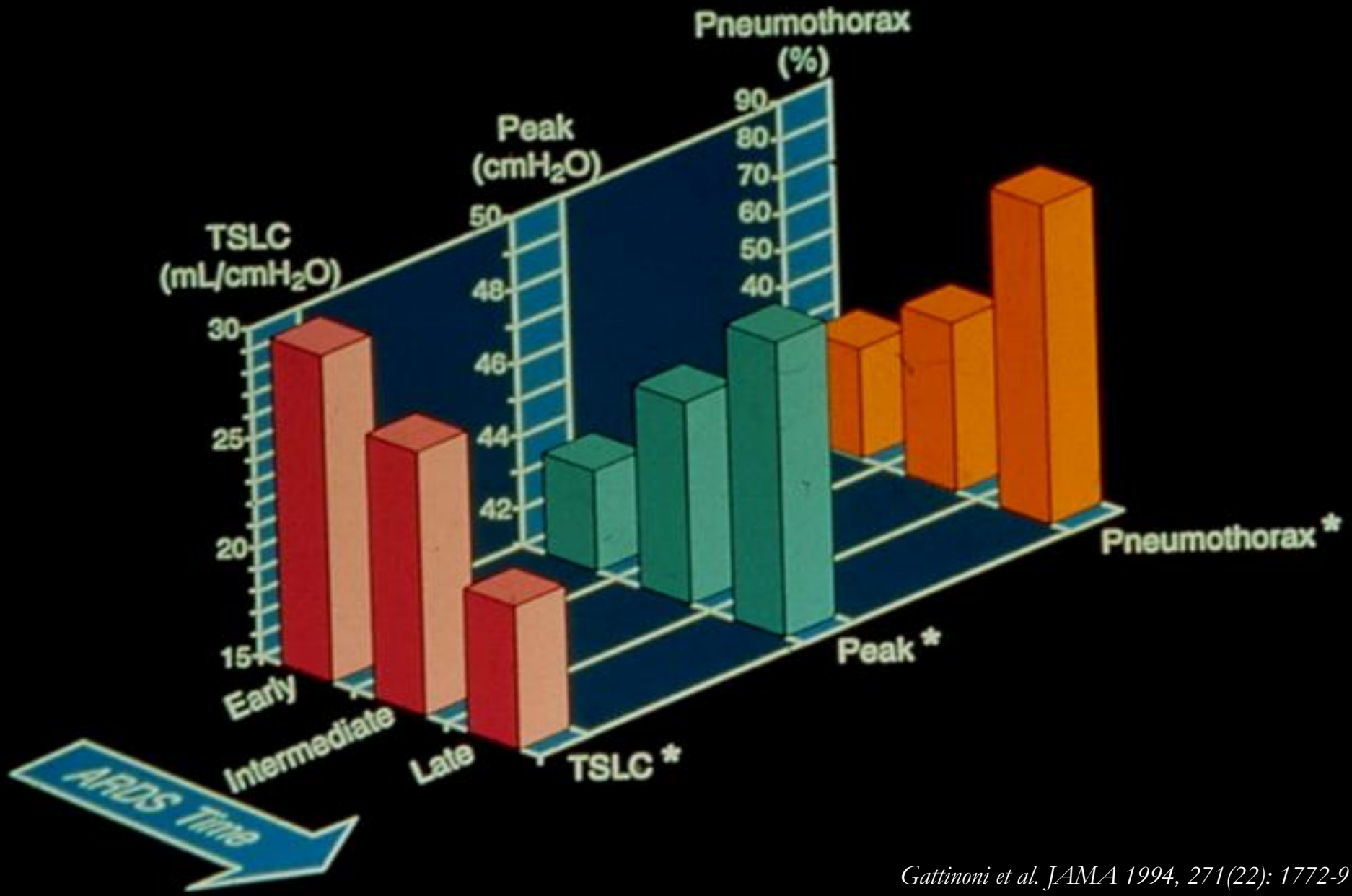
Gattinoni et al. JAMA 1994, 271(22): 1772-9

Early vs late ARDS



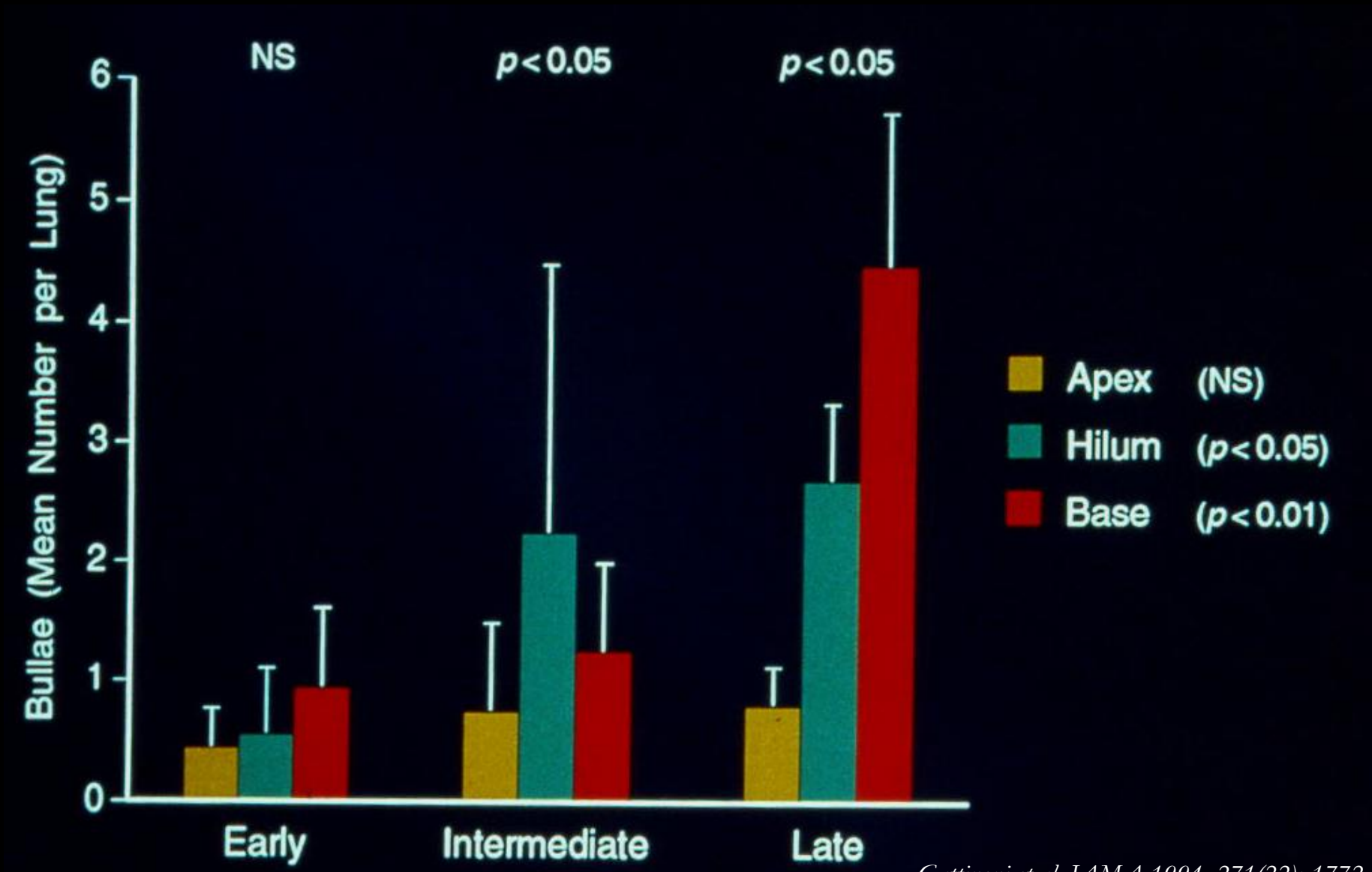
Gattinoni et al. JAMA 1994, 271(22): 1772-9

Early vs late ARDS



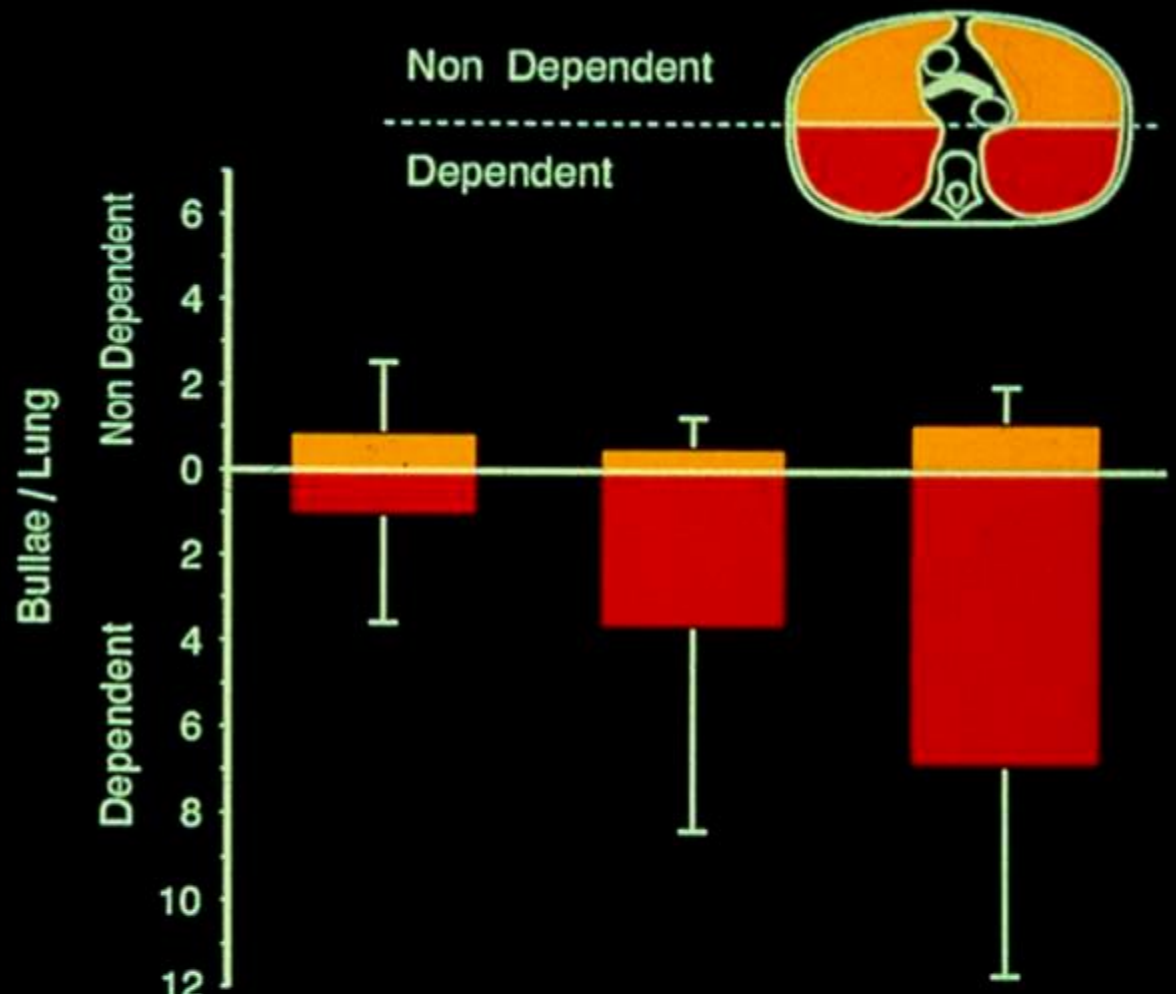
Gattinoni et al. JAMA 1994, 271(22): 1772-9

Early vs late ARDS



Gattinoni et al. JAMA 1994, 271(22): 1772-9

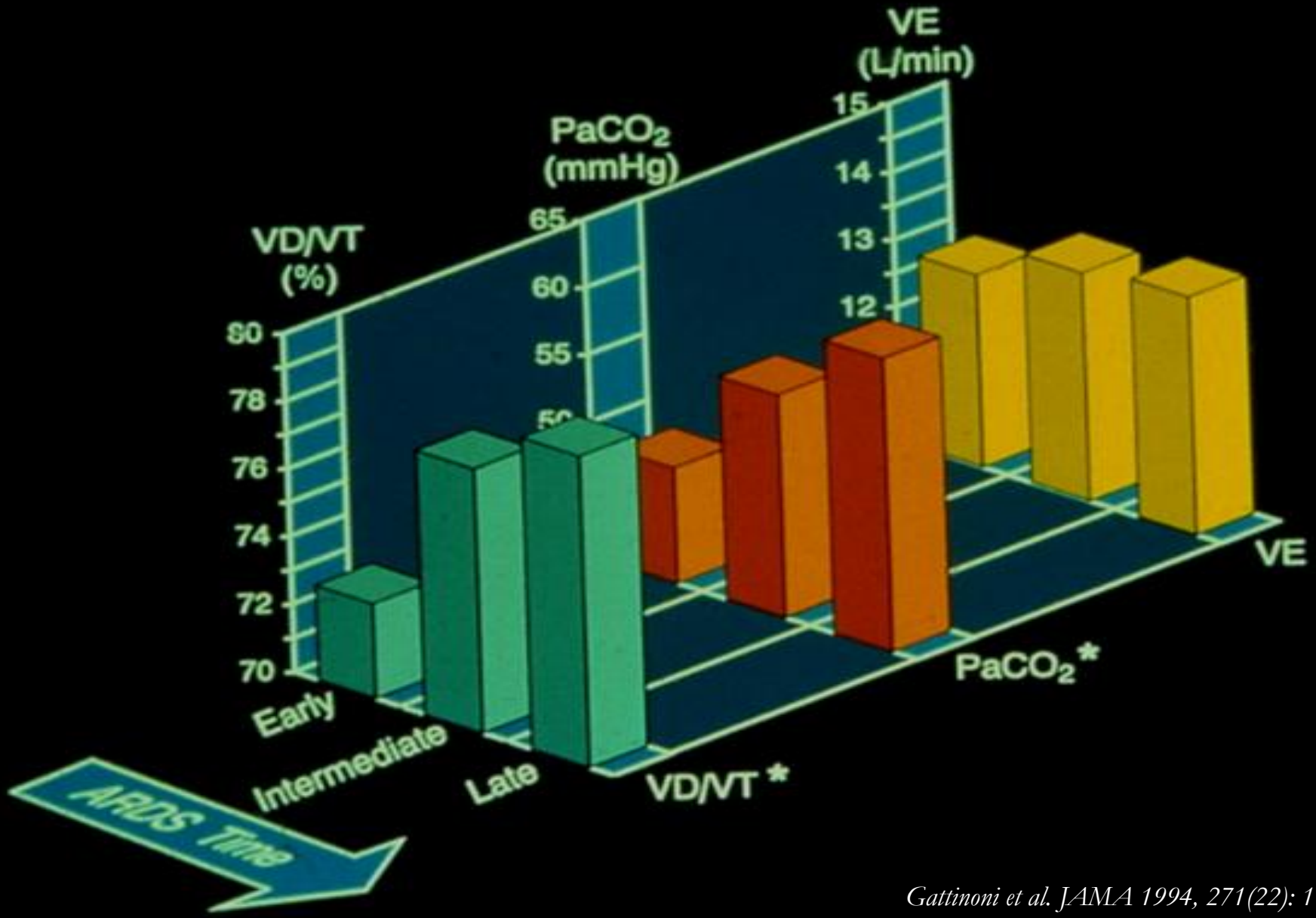
Early vs late ARDS



	Early	Intermediate	Late
Total bullae	35	16	81
Pts with bullae	4/9	2/2	5/5

Gattinoni et al. JAMA 1994, 271(22): 1772-9

Early vs late ARDS



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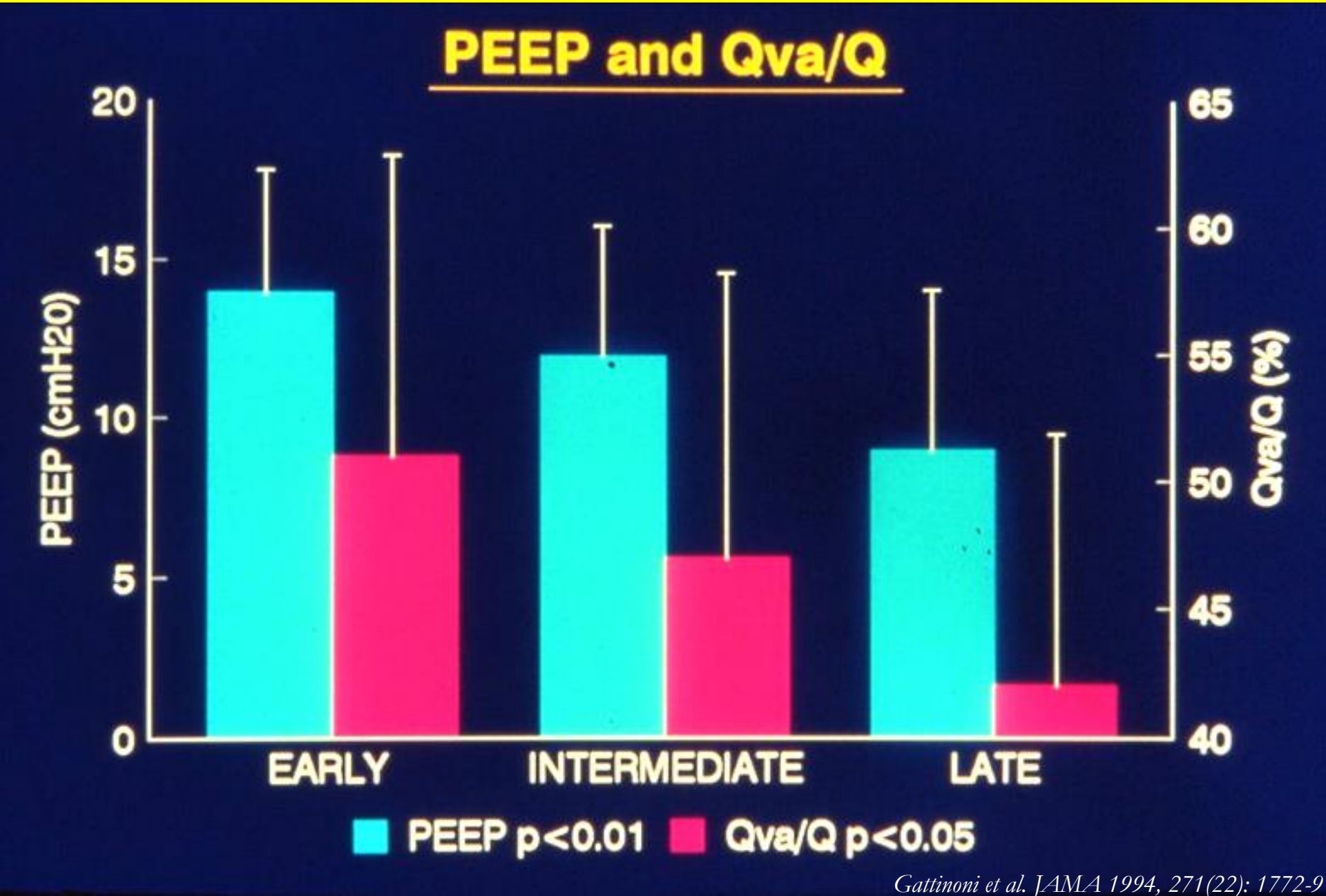
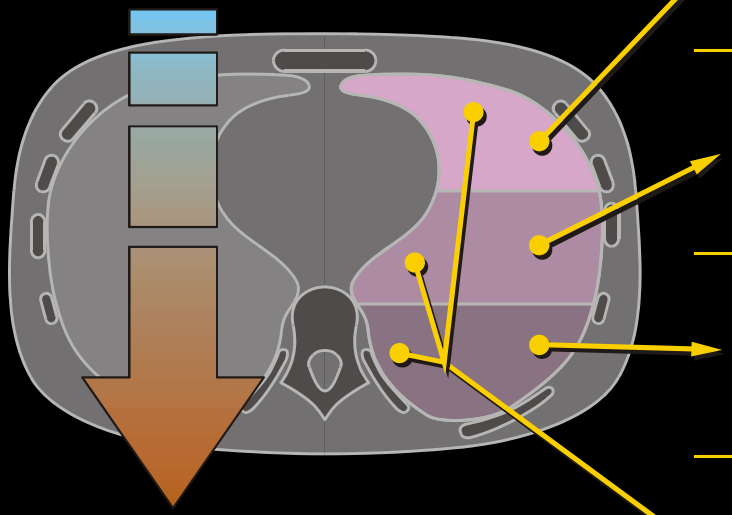
Early vs late ARDS

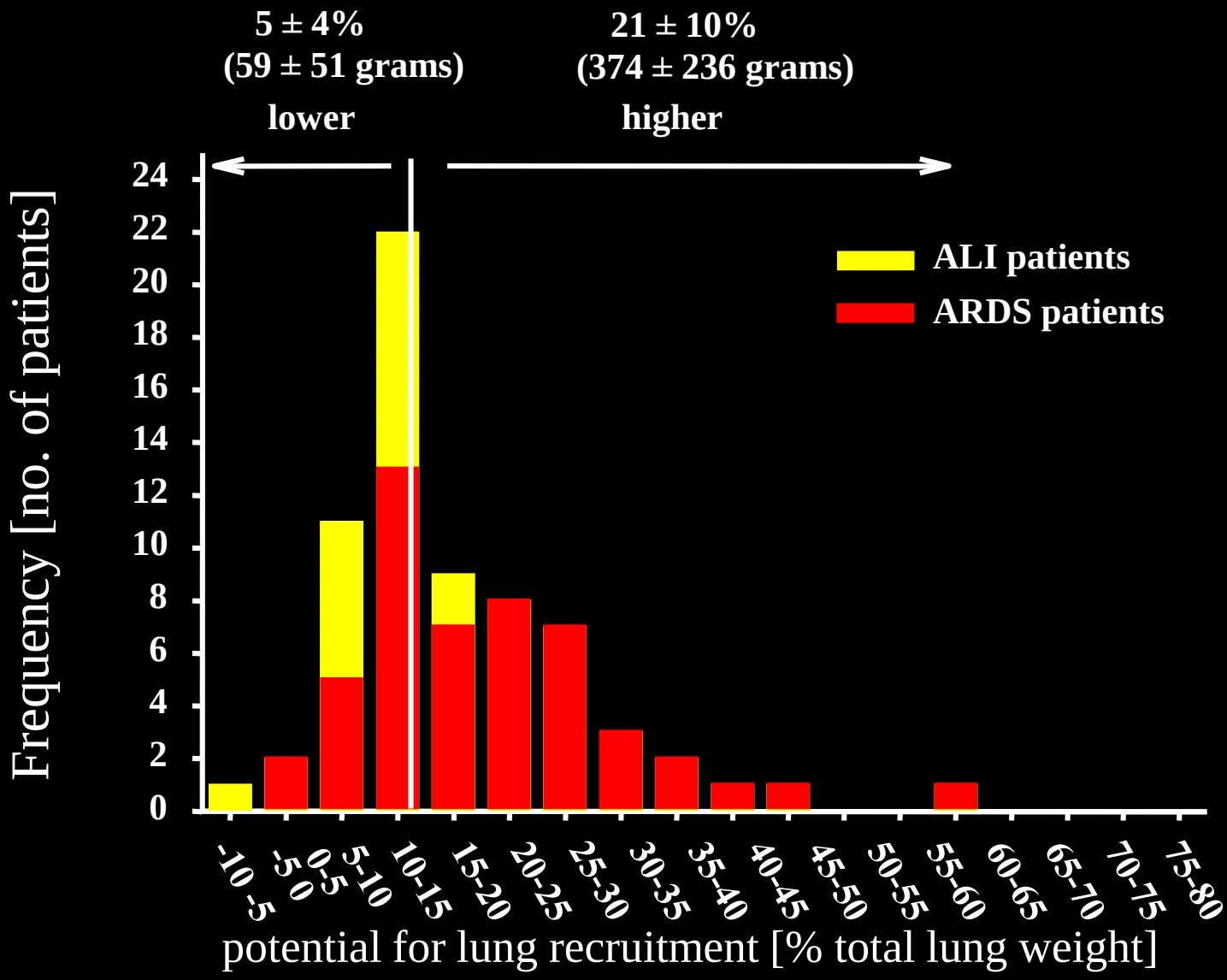


Gattinoni et al. JAMA 1994, 271(22): 1772-9

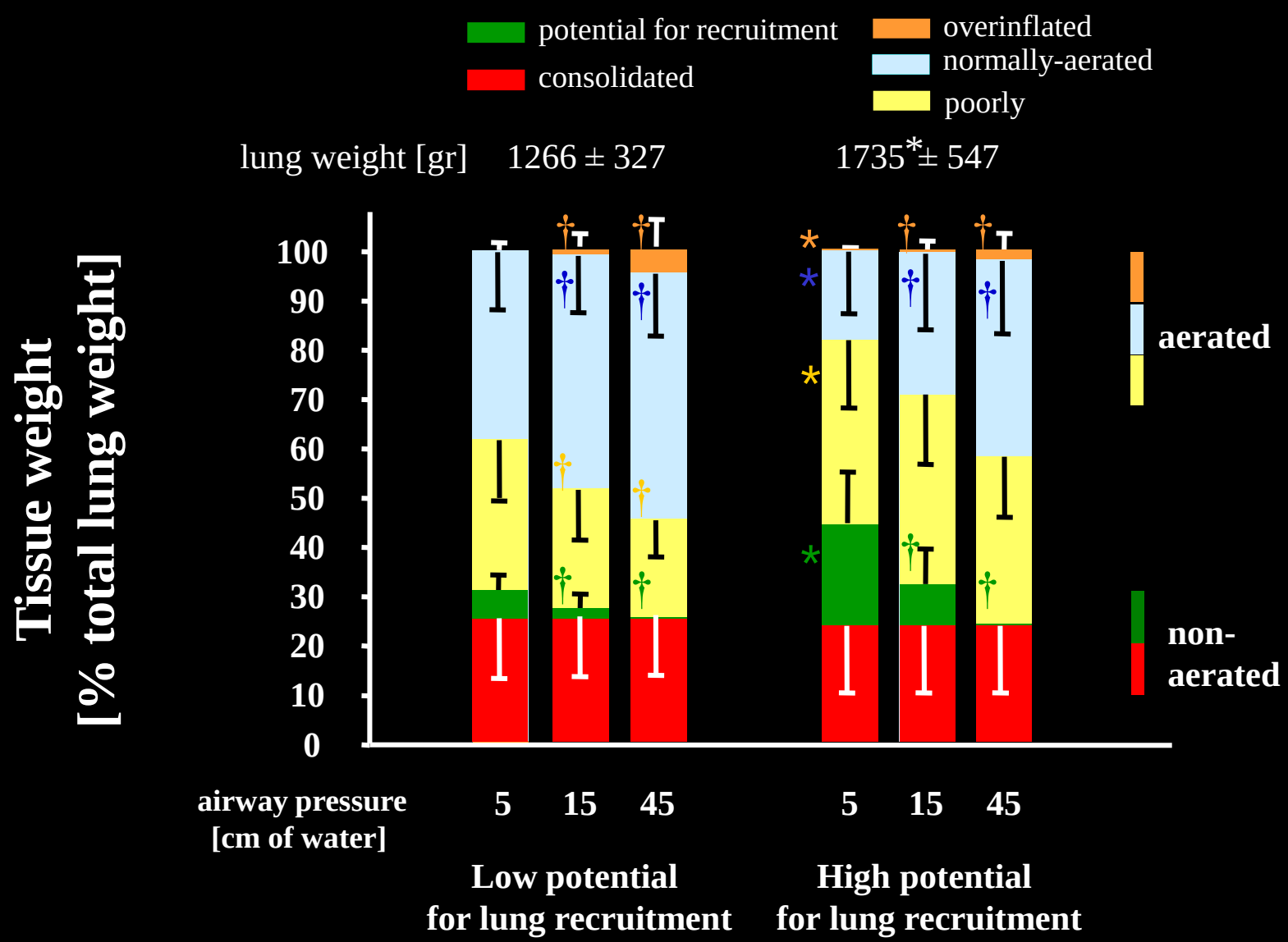


	Opening Pressure
Normal	0
Small Airway Collapse	10-20 cmH_2O
Alveolar Collapse (Reabsorption)	20-30 cmH_2O
Consolidation	∞

Potential for lung recruitment



Gattinoni L, Caironi P, Cressoni M, Chiumello D, Ranieri VM, Quintel M, Russo S, Cornejo R, Bugedo G, NEJM 2006, 354(17):1775-86



*P<0.01 vs. patients with a low potential for lung recruitment,
†P<0.01 vs. 5 cm of water of PEEP within the same group.

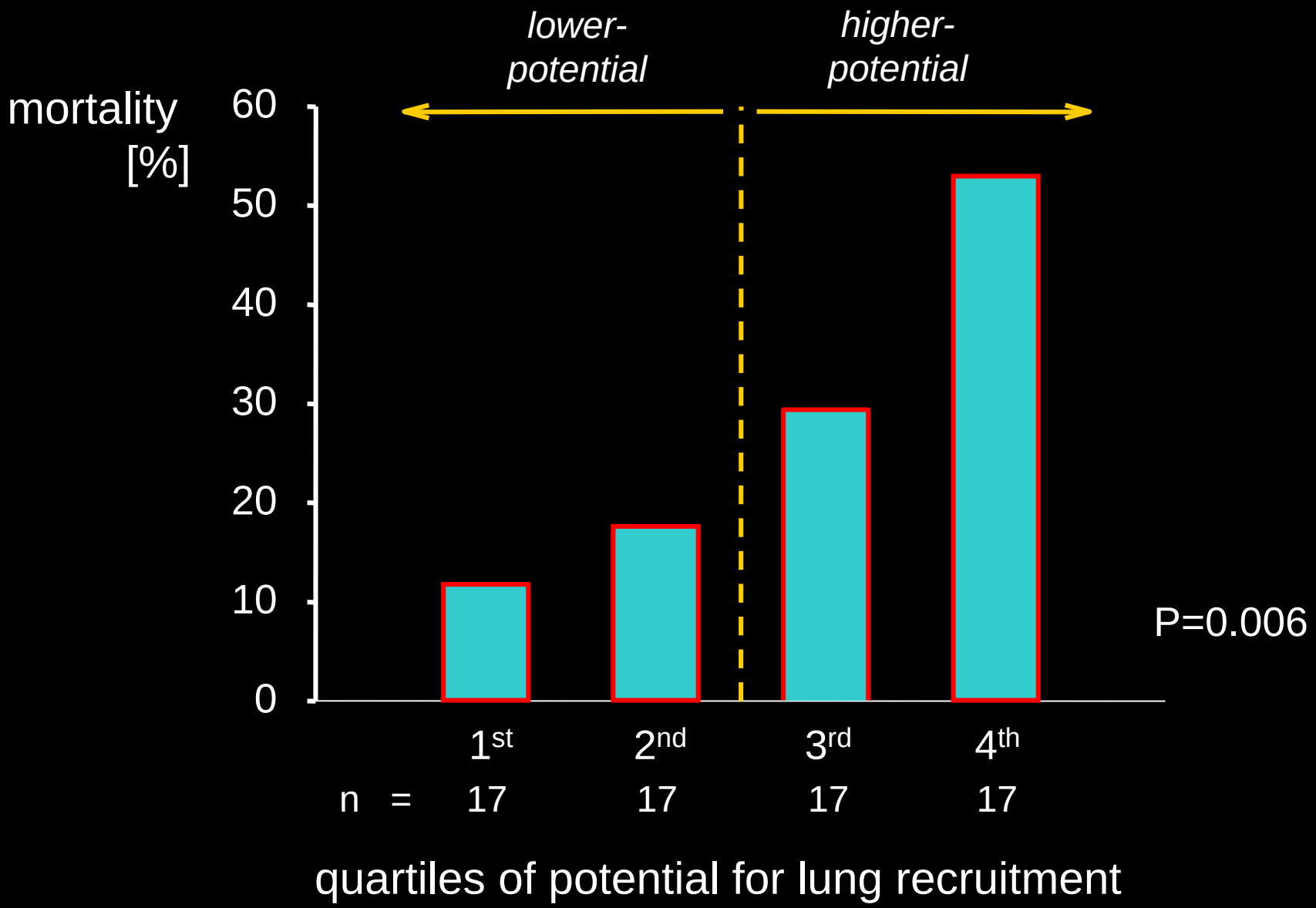
Gattinoni L, Caironi P, Cressoni M, Chiumello D, Ranieri VM, Quintel M, Russo S, Cornejo R, Bugedo G, NEJM 2006, 354(17):1775-86

ALI/ARDS lung composition

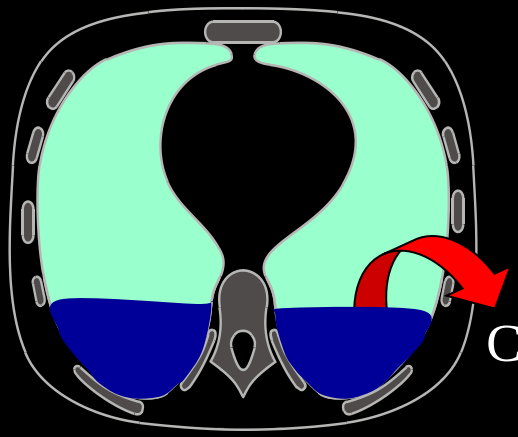
	Lower potential for recruitment (34 pts)	Higher potential for recruitment (34 pts)	P
Lung weight	1266±327	1735±547	0.0001
% Open	70±12	56±17	<0.0001
% openable at 45cmH_2O	5±4	21±10	<0.0001
% always closed	25±12	24±14	0.69

Gattinoni L, Caironi P, Cressoni M, Chiumello D, Ranieri VM, Quintel M, Russo S, Cornejo R, Bugedo G, NEJM 2006, 354(17):1775-86

Mortality at ICU-discharge



Possible model

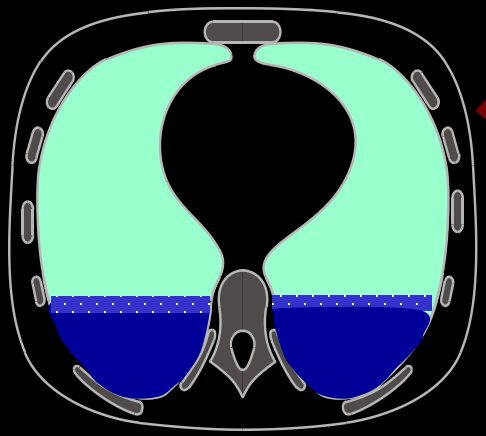


Core disease
24%

Inflammation spreading

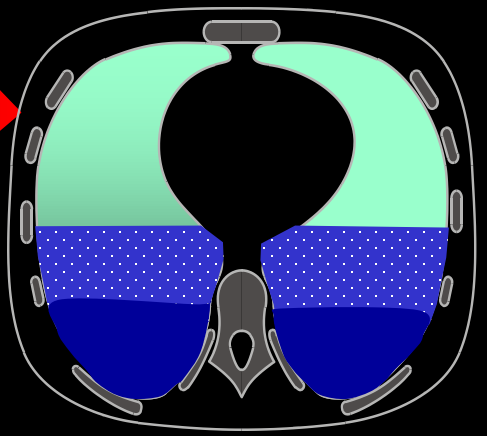
Lower

Higher



71%
5%
24%

55%
21%
24%



Lower severity and mortality

Higher severity and mortality

Conclusion

- Early ARDS is characterized by edema and intact lung structure (baby lung)
- Recruitability is function of the extent of edema
- With time lung structure is altered associated with increased dead space and PCO_2

Thank you

Grazie