EVANGELISCHES KRANKENHAUS GÖTTINGEN-WEENDE

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Hochfrequenzbeatmung beim ARDS

Peter Neumann, Abteilung für Anästhesie und Operative Intensivmedizin

Kassel, 10. Intensivpflegetag, 05.04.2014

Sekundäre Lungenschäden unter Beatmung

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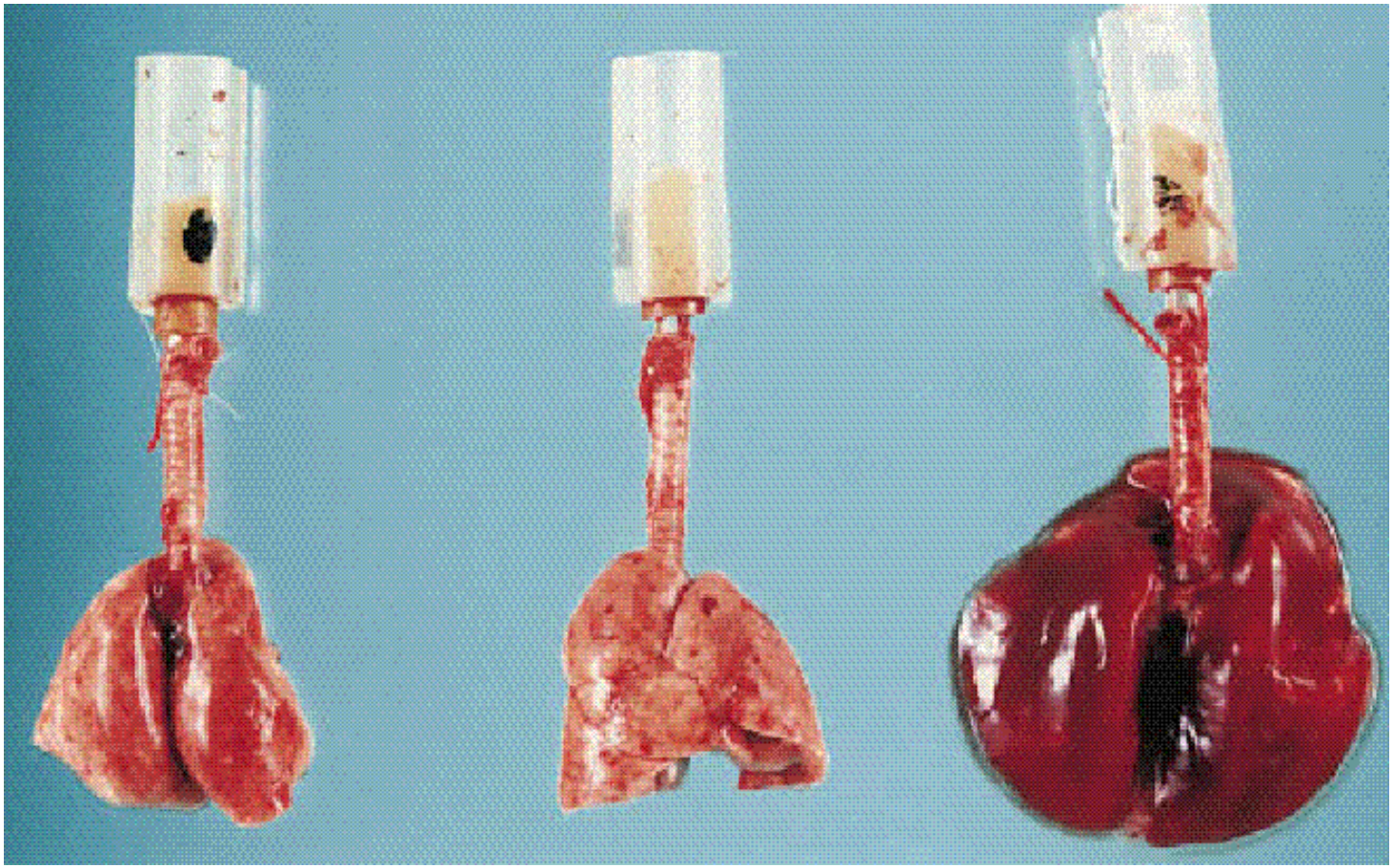
Normal 5 ' 45 cm H_20 20 ' 45 cm H_2O

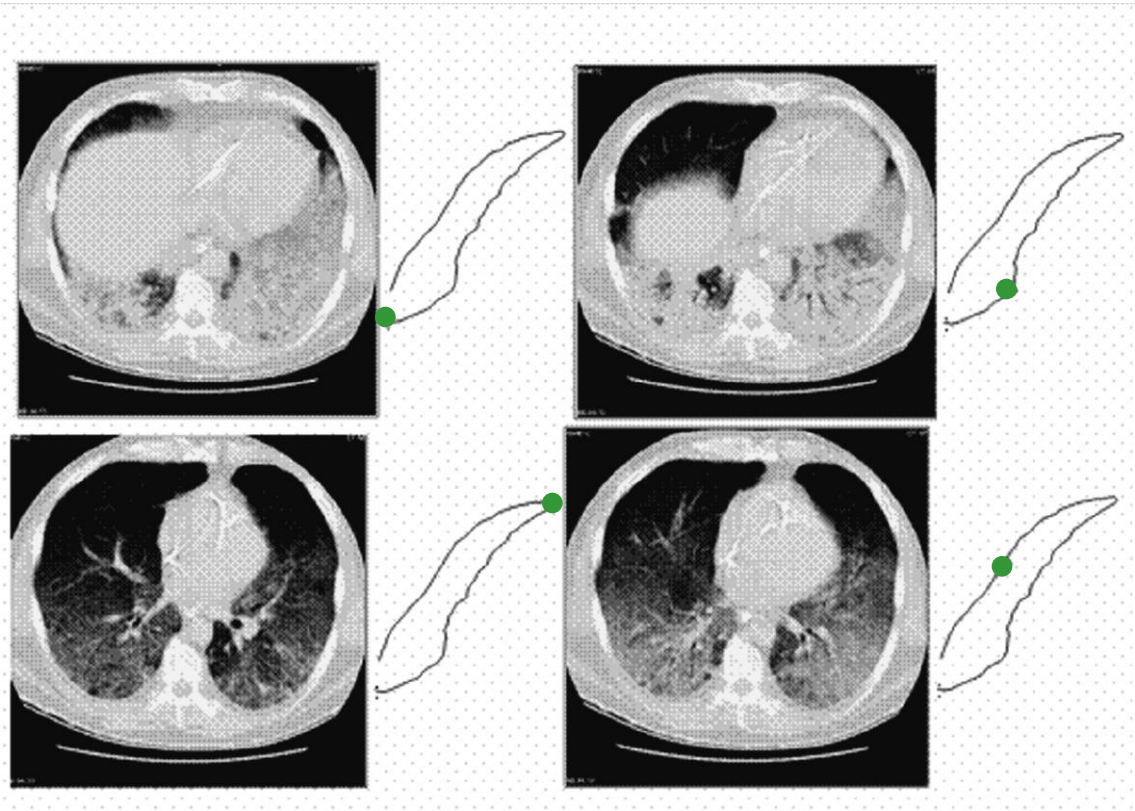


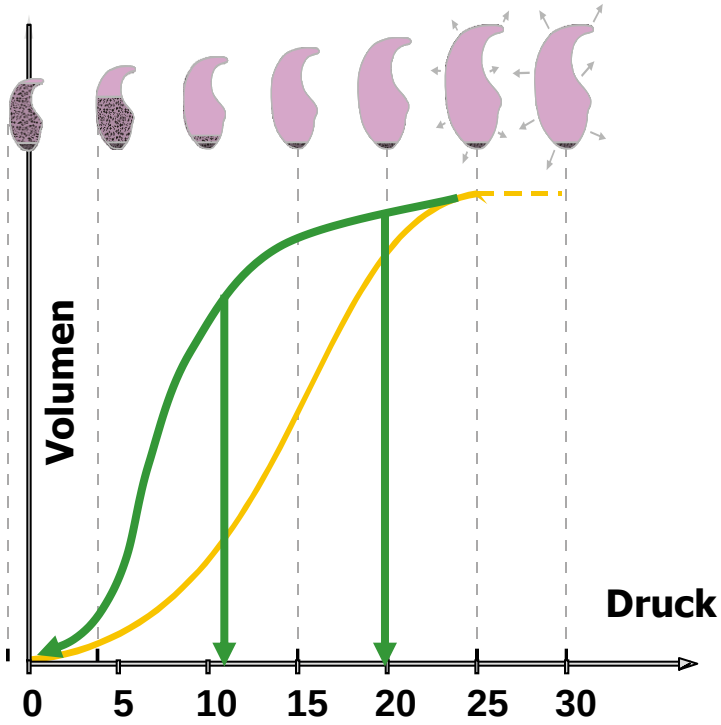
DREYFUSS & SAUMON: Am J Respir Crit Care Med Vol 157. pp 294–323, 1998

Alveolar Cycling

Neumann, Wrigge, Hedenstierna et al.

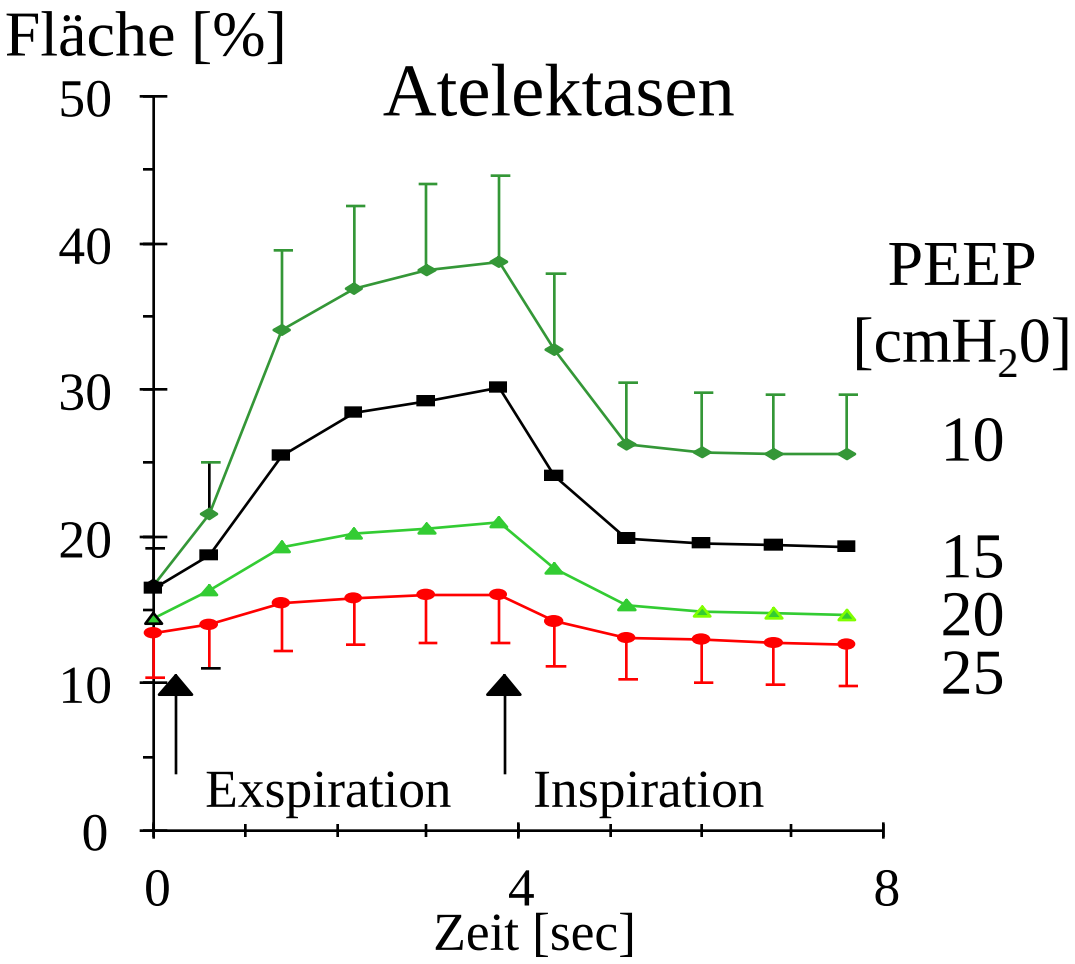
PV-Loop im ARDS





Barbas et al. 2005 Current Opinion in Critical Care, 11:18–28

PEEP und Atelektrauma



Neumann et al. AJRCCM 1998; 158: 1636 - 1643

Ventilator assoziierte Lungenschädigung

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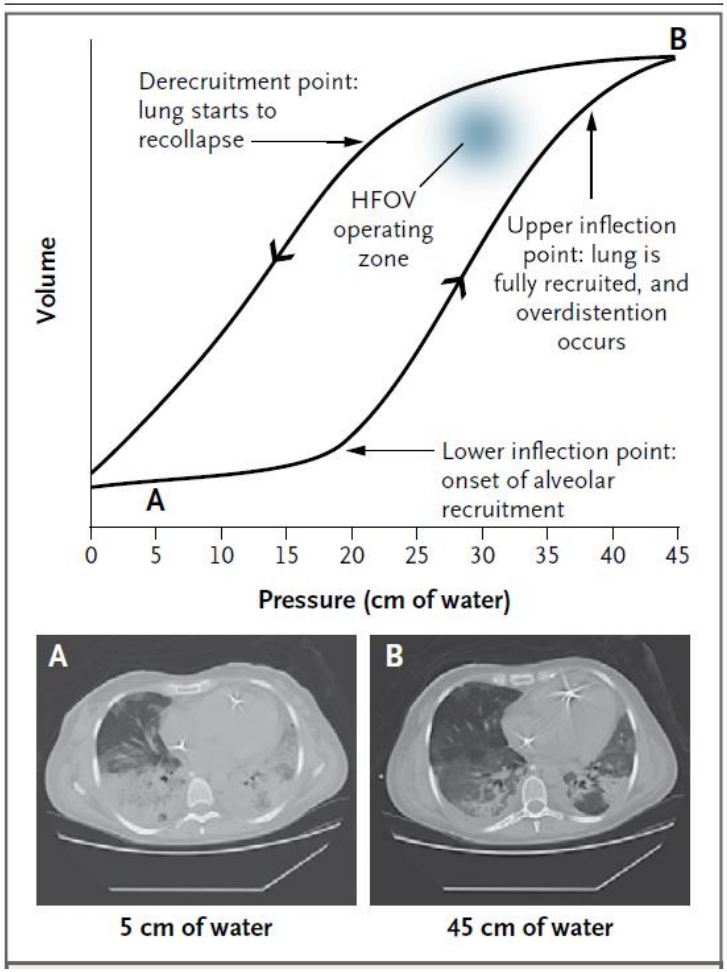
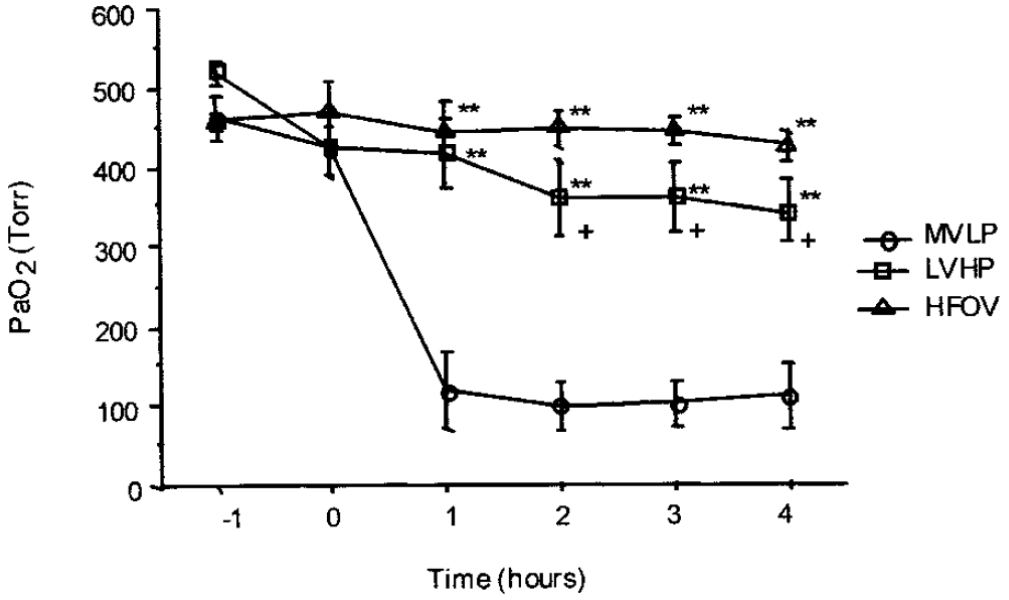


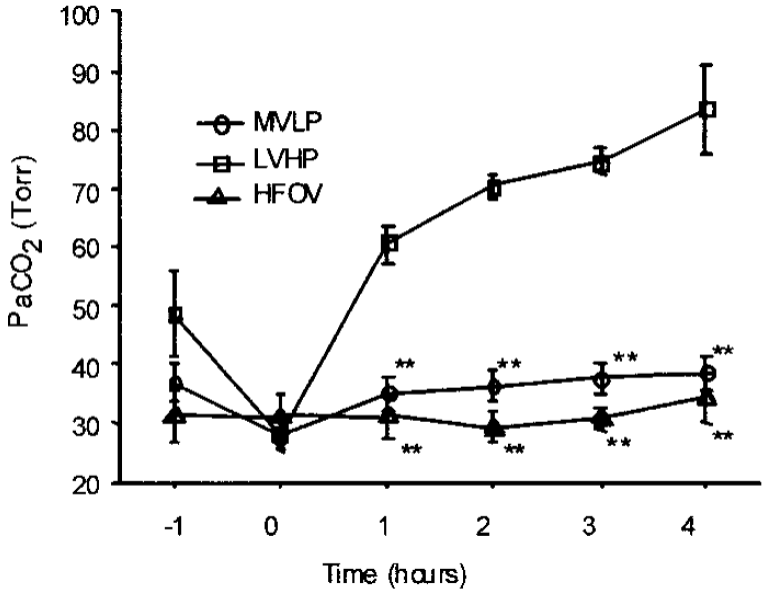
Figure 1. Schematic Diagram of a Pressure-Volume Curve of a Lung in a Patient with the Acute Respiratory Distress Syndrome.

The inflation limb (lower curve) and deflation limb (upper curve) differ from one another. The lower inflection point defines the onset of alveolar recruitment from a state of substantial collapse; the lung below this point is illustrated in the axial computed tomographic (CT) scan in Panel A. The upper inflection point is thought to reflect the point at which recruitment is no longer occurring and overdistention may start to occur; the lung in this condition is illustrated in the axial CT scan in Panel B. High-frequency oscillatory ventilation (HFOV) is performed on the deflation limb of the pressure-volume curve; in this form of ventilation, small volumes should help to limit overdistention, and high mean airway pressures should prevent injury from repetitive collapse and reopening of the lung. CT scans adapted from Gattinoni et al.[13] The CT scans in Panels A and B correspond to the areas marked A and B in the upper panel.

Malhotra & Drazen NEJM 368;9 february 28, 2013

HFOV und Beatmungsschäden (VILI)





MVLP = moderate volume ***(10 ml/kg KG)*** low PEEP *(4-5 cm H_2O)*
LVHP = low volume ***(6 ml/kg KG)*** high PEEP *(8-10 cm H_2O)* **- „protektive Beatmung“**
HFOV = high-frequency oscillatory ventilation

Imai et al. 2001: J Appl Physiol 91:1836-1844

HFOV und Beatmungsschäden (VILI)

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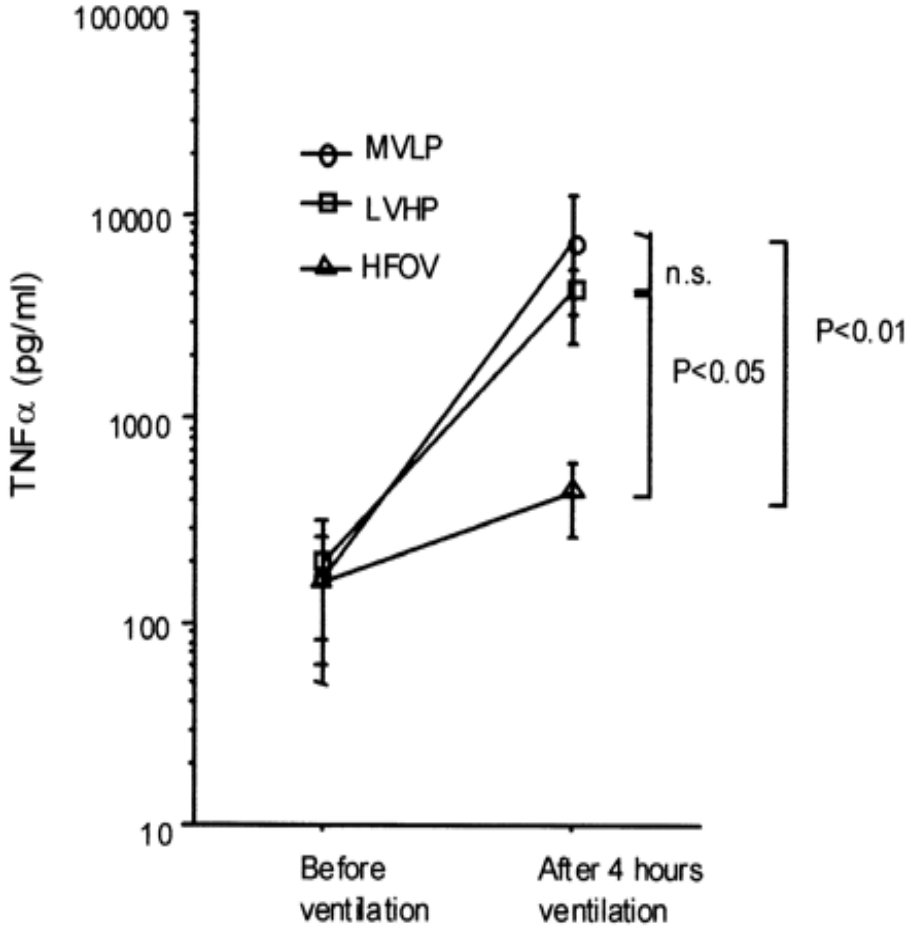

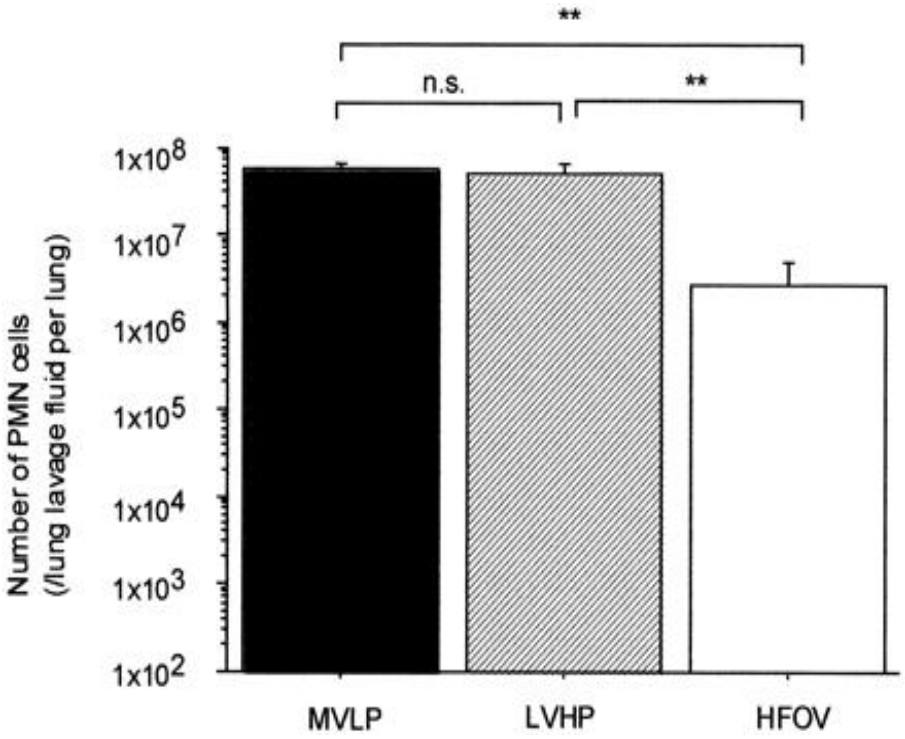

Imai et al. 2001: J Appl Physiol 91:1836-1844

HFOV und Beatmungsschäden (VILI)

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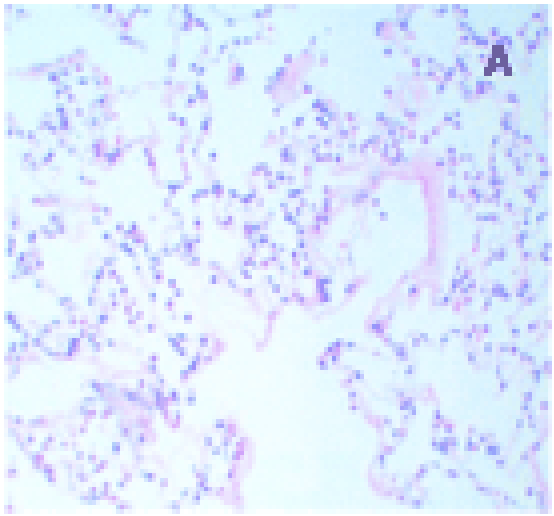

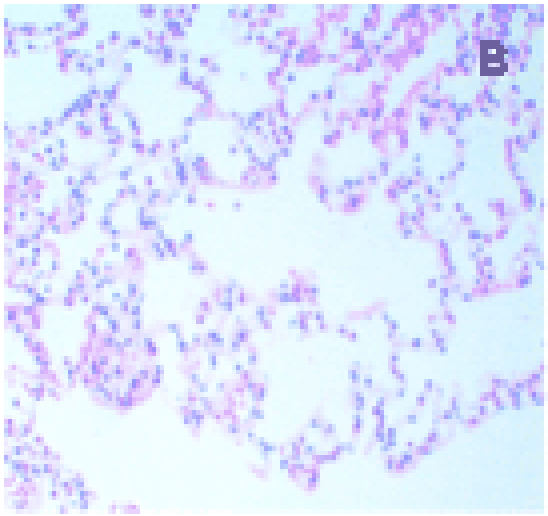

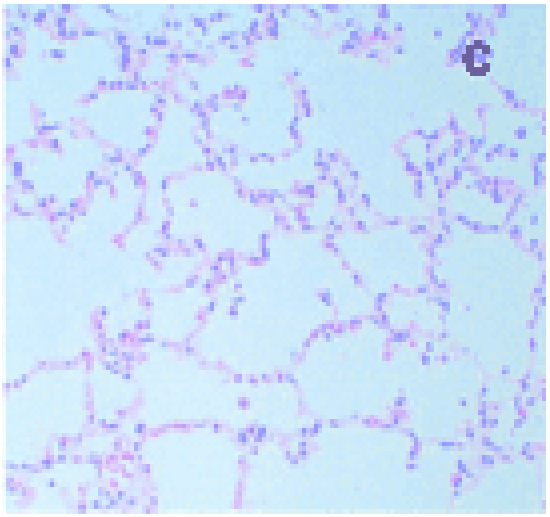

MVLP

LVHP

HFOV

MVLP = moderate volume ***(10 ml/kg KG)*** low PEEP *(4-5 cm H_2O)*
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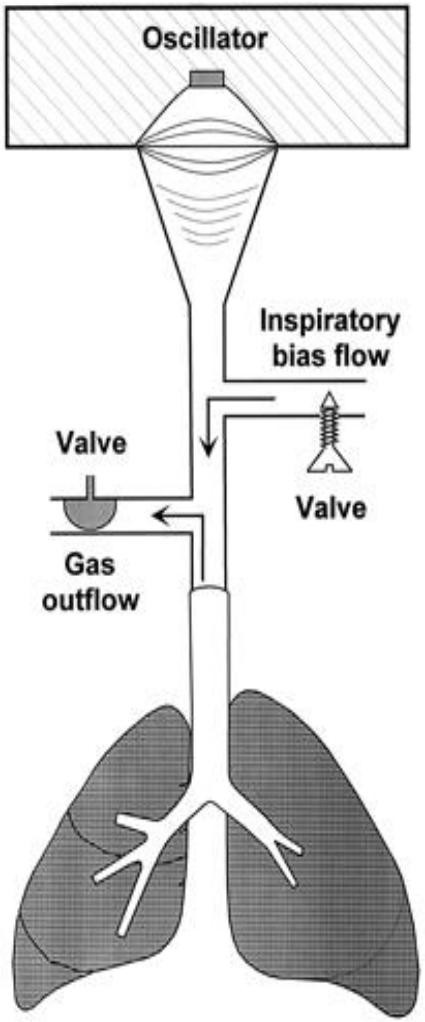
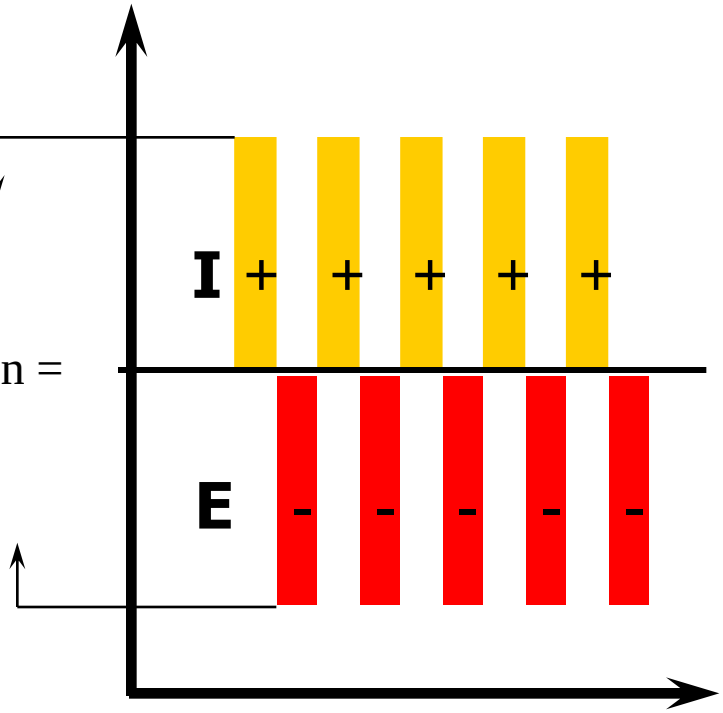
Imai et al. 2001: J Appl Physiol 91:1836-1844

HFOV



Amplitude
delta p =
Tidalvolumen =
Ventilation



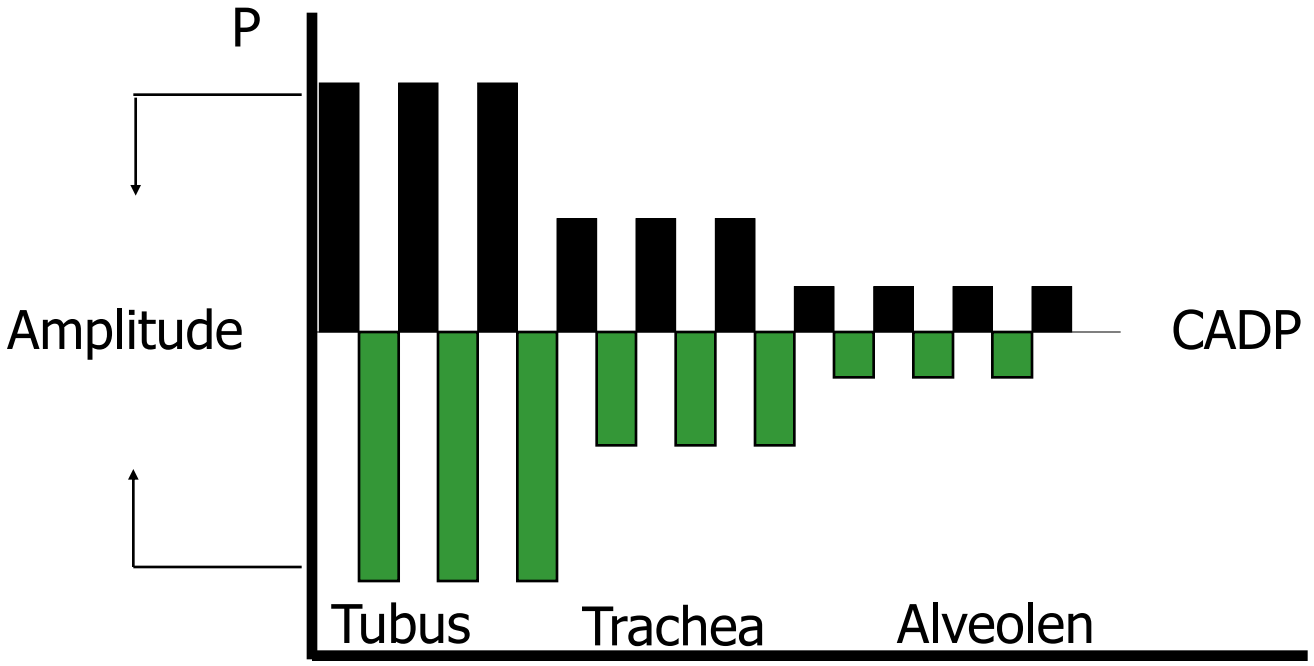
C(A)DP =

Krishnan et al. 2000 Chest; 118:795-807

Druckamplitude in den Atemwegen

Die Druckamplitude distal des ETT (8,0 mm Tubus, 5 Hz):

Beträgt ~ 15 % der Amplitude proximal des ETT



Fort P et al Crit Care Med 1997;25:937-947

Hoch Frequenz Oscillator

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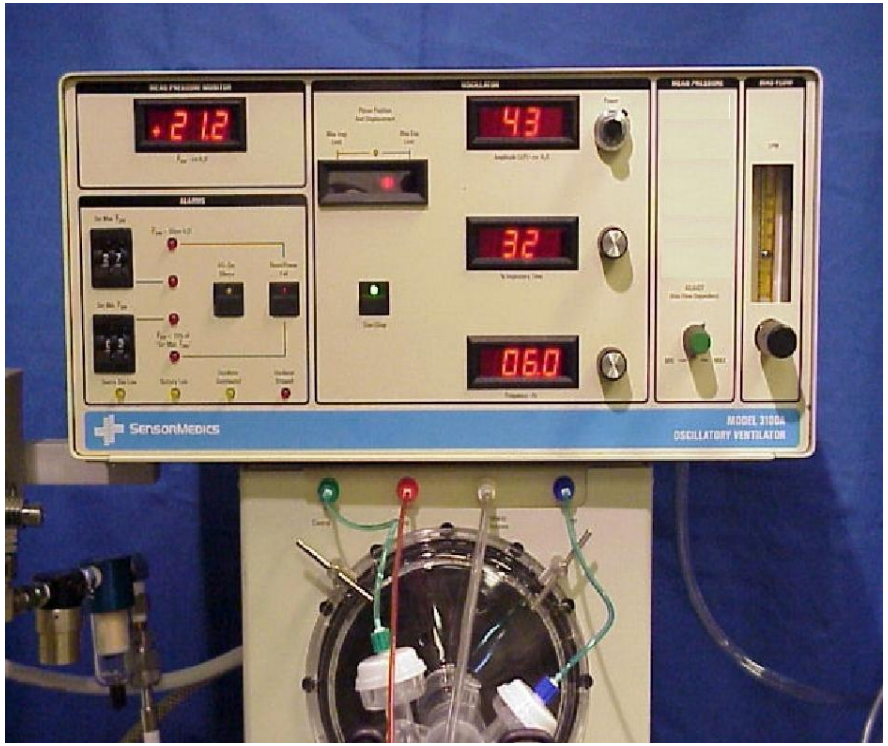
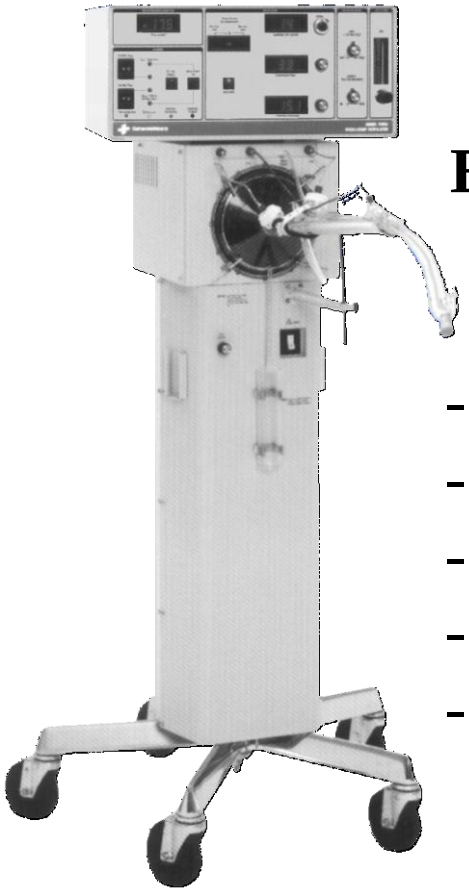
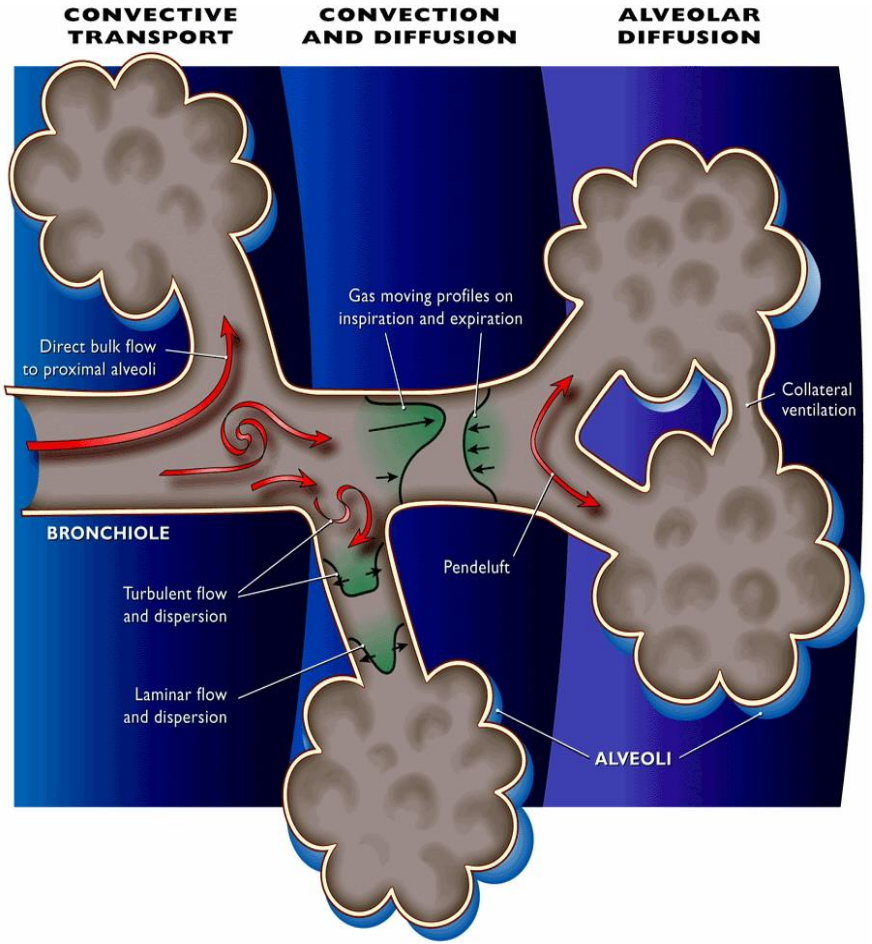




Einzustellende Parameter:

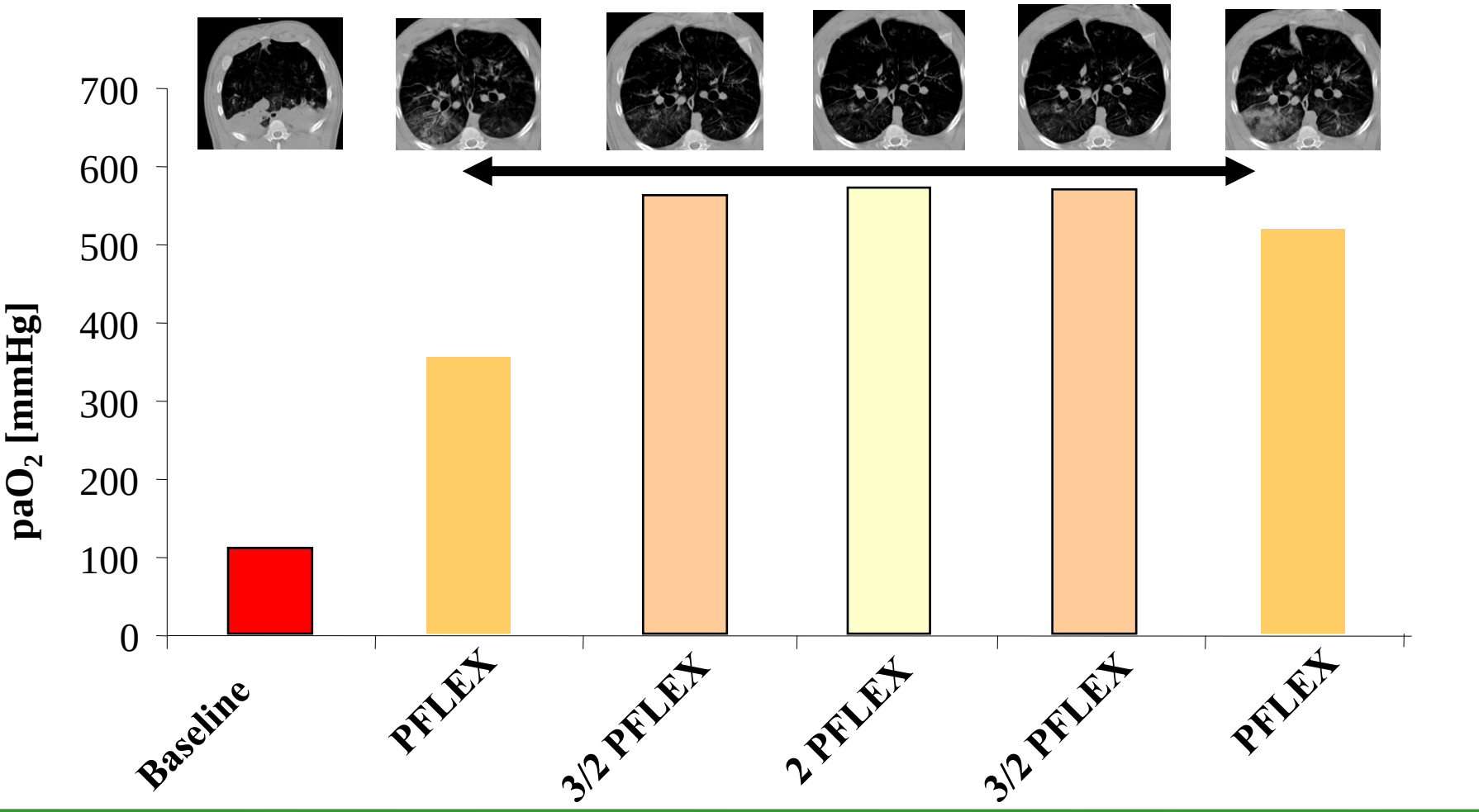
- FiO_2
- CADP
- Frequenz
- Amplitude
- I:E-Verhältnis

Gasaustausch



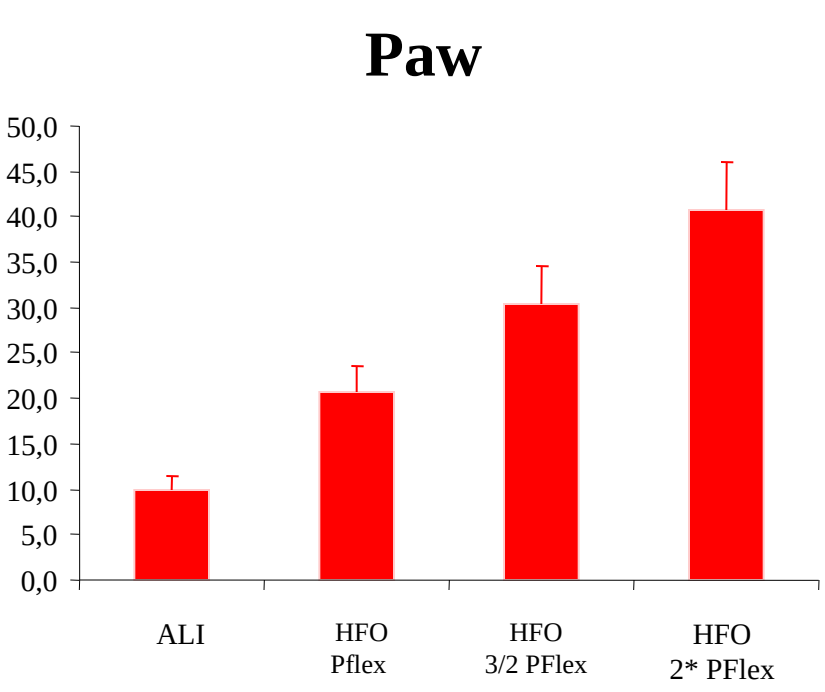
Bouchut JC, et al. Anesthesiology 2004; 100:1007-12

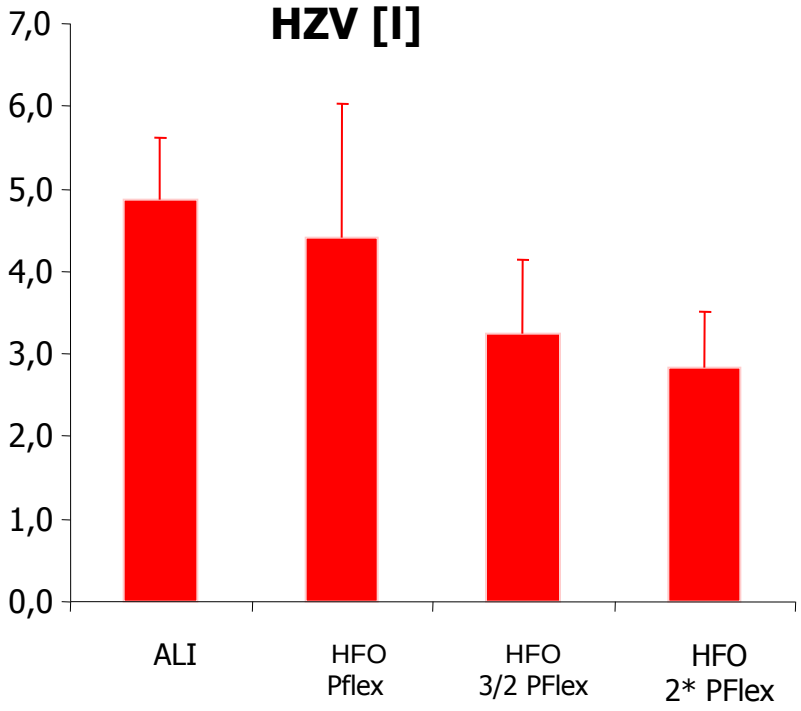
Oxygenierung und CADP



Luecke et al. 2003: Anesthesiology 99: 1313 - 1322

CADP und Herzzeitvolumen





Luecke et al. 2003: Anesthesiology 99: 1313 - 1322

CADP, Oxygenierung & EELV

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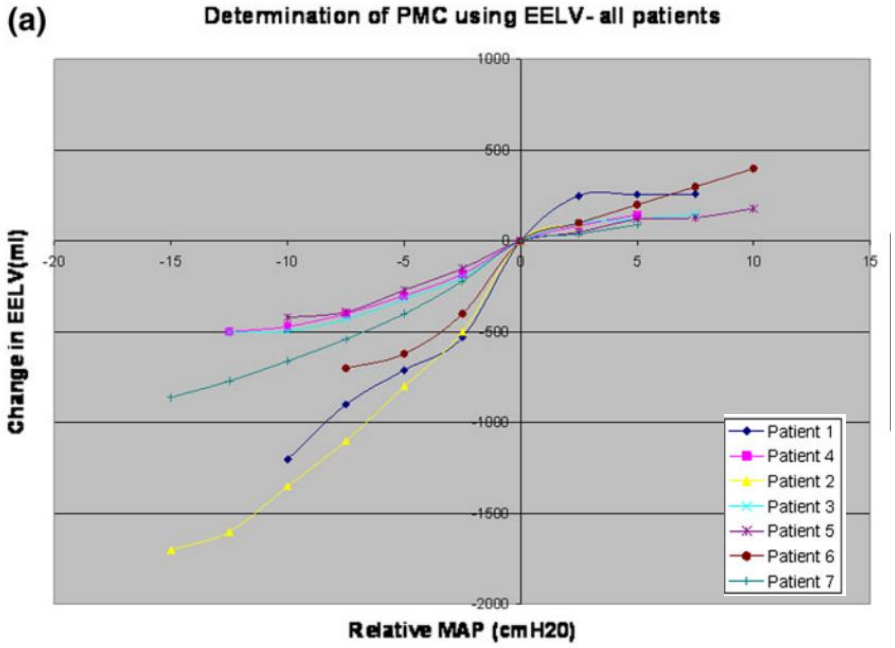
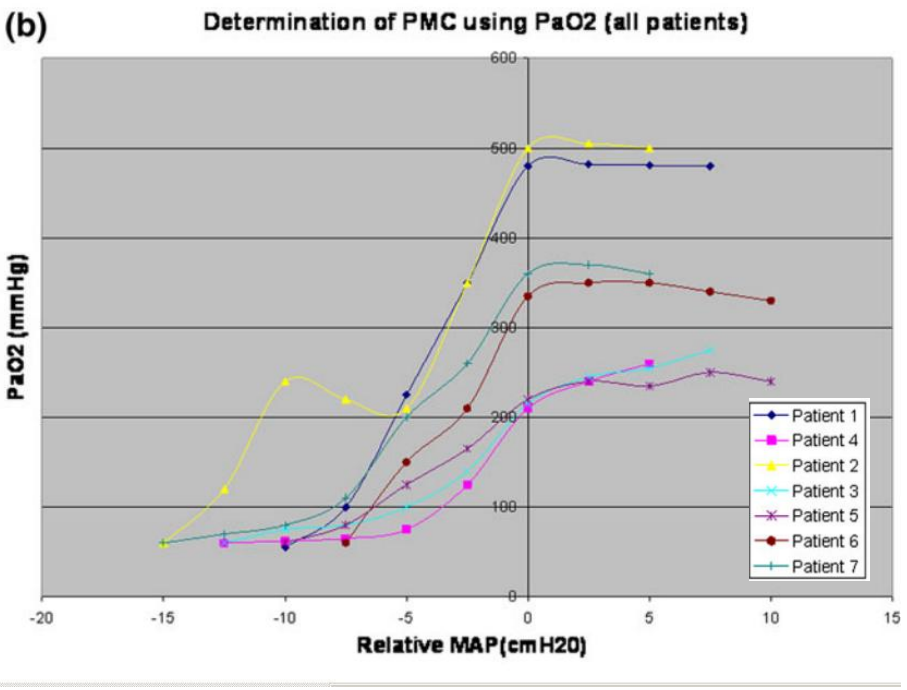
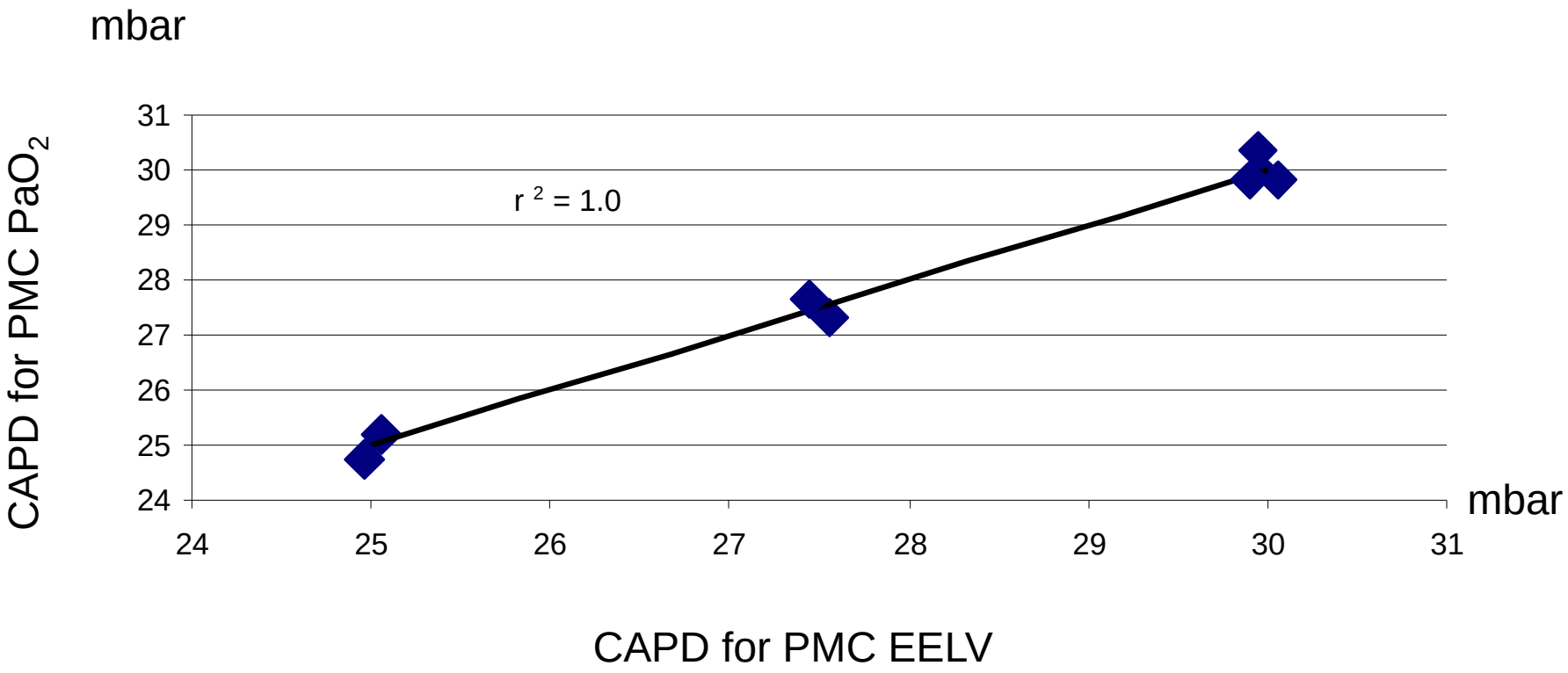




PMC = Point of maximal curvature

Casserly et al. 2013:Lung 191:69–76

CADP, Oxygenierung & EELV



Casserly et al. 2013:Lung 191:69–76

HFOV
klinische Anwendung

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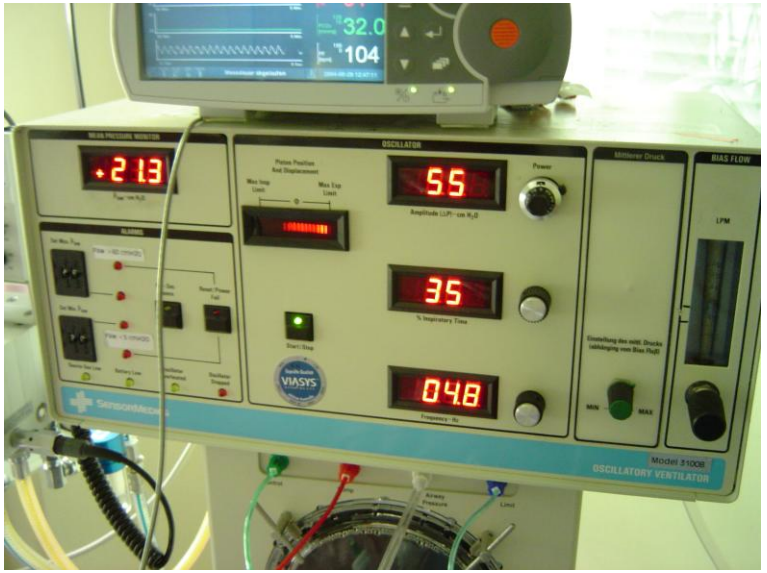

Metaanalyse 2010

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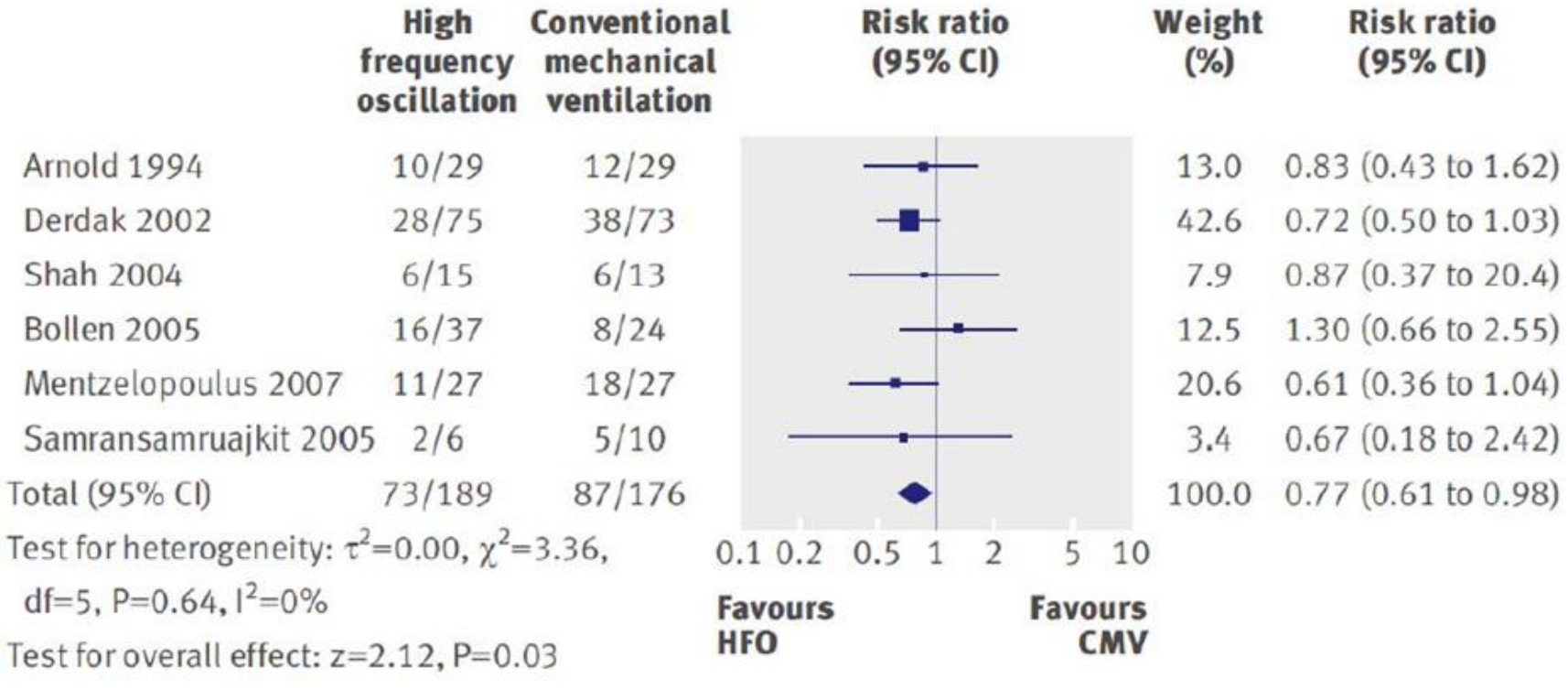

Fig 2 | Hospital or 30 day mortality in patients with acute lung injury/acute respiratory distress syndrome allocated to high frequency oscillation or conventional mechanical ventilation

Sud et al. BMJ 2010; 340:c 2327

Metaanalyse 2010

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Conclusion

„In summary, based on the available data, high frequency oscillation might reduce mortality in patients with ARDS compared with conventional ventilation and is unlikely to cause harm. It improves the PaO2/FiO2 ratio by increasing the mean airway pressure but not the oxygenation index. Clinicians who currently use or are considering high frequency oscillation to treat ARDS can be reassured by these results.“

Sud et al. BMJ 2010; 340:c 2327

ORIGINAL ARTICLE

High-Frequency Oscillation in Early Acute Respiratory Distress Syndrome

RCT, 5 Länder (Canada, USA, Saudi Arabia, Chile, India)

SensorMedics 3100B

Einschlusskriterien: ARDS < 14 Tage, Alter 16 – 85 J, $PaO_2/FiO_2 \leq 200$ mmHg und $FiO_2 \geq 0{,}5$, Gewicht < 1kg/cm

Einschluss → **Standard Beatmung**: PCV, PEEP $\geq$ 10 mbar, VT 6 ml/kg, $FiO_2 = 0{,}6$; Randomisierung wenn $PaO_2/FiO_2 \leq 200$ mmHg

Ferguson et al. N Engl J Med 2013. DOI: 10.1056/NEJMoa1215554

Oscillate Studie

Table 1. Ventilator Protocols.*

Component Variable	HFOV	Control Ventilation
Ventilator mode	High-frequency oscillatory ventilation	Pressure control
Tidal volume target (ml/kg of predicted body weight)	NA	6
Tidal volume range (ml/kg of predicted body weight)	NA	4–8
Plateau airway pressure (cm of water)	NA	≤35
Positive end-expiratory pressure (cm of water)	NA	Adjusted according to oxygenation†
Mean airway pressure (cm of water)	Adjusted according to oxygenation†	Measured but not adjusted
Respiratory frequency	3–12 Hz	≤35 breaths/min
Pressure amplitude target (cm of water)	90	NA
Partial pressure of arterial oxygen (mm Hg)	55–80	55–80
Oxygen saturation by pulse oximetry (%)	88–93	88–93
Arterial blood pH	7.25–7.35	7.30–7.45
Ratio of inspiratory-to-expiratory time	1:2	1:1–1:3
Recruitment maneuvers	Yes	Yes

* The full version of the study protocol is available at NEJM.org. HFOV denotes high-frequency oscillatory ventilation, and NA not applicable.
† For more information on the protocol for adjustment, see Table 2.

Table 2. Usual Combinations of the Fraction of Inspired Oxygen (F_{IO_2}) and Positive End-Expiratory Pressure (PEEP) or Mean Airway Pressure Used to Adjust Ventilators.

HFOV		Control Ventilation	
F_{IO_2}	Mean Airway Pressure	F_{IO_2}	PEEP
	cm of water		*cm of water*
0.4	20	0.3	5
0.4	22	0.3	8
0.4	24	0.3	10
0.4	26	0.4	10
0.4	28	0.4	12
0.4	30	0.4	14
0.5	30	0.4	16
0.6	30	0.4	18
0.6	32	0.5	18
0.6	34	0.5	20
0.7	34	0.6	20
0.8	34	0.7	20
0.9	34	0.8	20
1.0	34	0.8	22
1.0	36	0.9	22
1.0	38	1.0	22
		1.0	24

HFOV: Beginn mit RM 40 x 40, dann CADP = 30 cm H_2O

CAPD: Tag 1 = 31 $\pm$ 2,6 mbar, Tag 2 = 28 $\pm$ 4,2 mbar

Ferguson et al. N Engl J Med 2013. DOI: 10.1056/NEJMoa1215554

Oscillate Studie

Übergang von HFOV to konventioneller Beatmung:

möglich wenn CAPD < 24 cmH_2O für > 12h

verpflichtend wenn CAPD < 20 cmH_2O für > 12 h

zurück zu HFOV wenn FiO_2 > 0,4 und PEEP > 14 cm H_2O für > 1h innerhalb der nächsten 2 Tage

Ferguson et al. N Engl J Med 2013. DOI: 10.1056/NEJMoa1215554

Oscillate Studie

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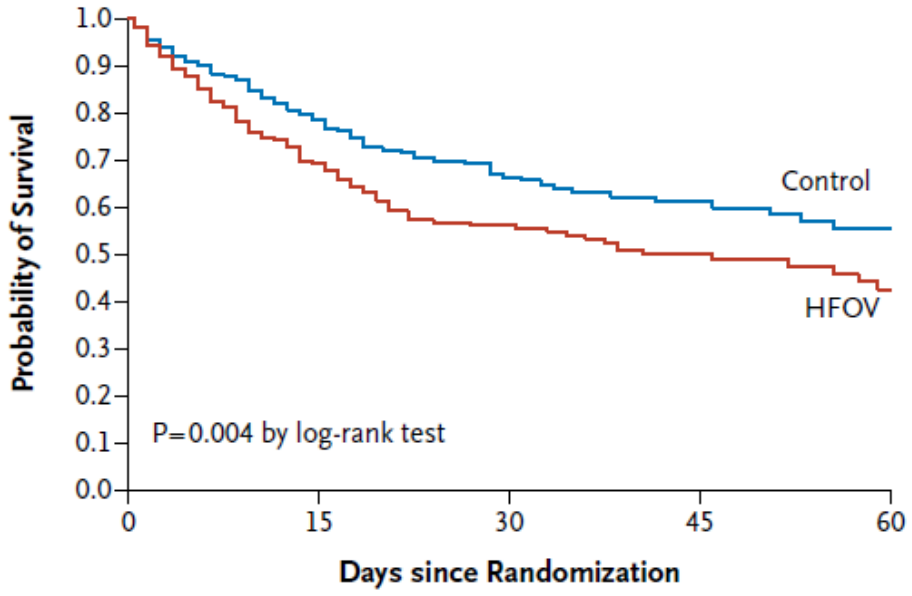
Table S5 – Cointerventions During the First 28 Days of Study

	HFOV Group	Control Group	P-value
Vasoactive Drugs, No. (%)	250 (90.9%)	228 (83.5%)	0.01
Days of vasoactive drugs, median (IQR)	5 (2-9)	3 (1-7)	0.01
Pulmonary artery catheter, No. (%)	14 (5.1%)	19 (7.0%)	0.36
Neuromuscular blockade, No. (%)	228 (82.9%)	186 (68.1%)	<0.0001
Days of neuromuscular blockade, median (IQR)	3(1-6)	2 (0-4)	0.001
Corticosteroids, No. (%)	155 (56.4%)	162 (59.3%)	0.48
Renal Replacement Therapy, No. (%)	92 (33.5%)	89 (32.6%)	0.83
Rescue Therapy, No. (%)			
High-Frequency oscillation		31 (11%)	
Inhaled nitric oxide	25 (9.1%)	28 (10.3%)	0.64
Prone positioning	7 (2.6%)	10 (3.7%)	0.45
Extracorporeal support	3 (1.1%)	3 (1.1%)	0.98
Other Rescue Therapy	16 (5.8%)	25 (9.2%)	0.14

Ferguson et al. N Engl J Med 2013. DOI: 10.1056/NEJMoa1215554

Oscillate Studie



No. at Risk					
HFOV	275	169	98	54	26
Control	273	181	92	54	39

Figure 2. Probability of Survival from the Day of Randomization to Day 60 in the HFOV and Control Groups.

Ferguson et al. N Engl J Med 2013. DOI: 10.1056/NEJMoa1215554

ORIGINAL ARTICLE

High-Frequency Oscillation for Acute Respiratory Distress Syndrome

OSCAR Studie

RCT, England, Scotland Wales (29 Krankenhäuser)

Novalung R 100 (Metran)

Einschlusskriterien: Beatmung für < 7 Tage, ARDS, PaO_2/FiO_2 < 200 mmHg und PEEP > 5 mbar

Young et al. N Engl J Med 2013. DOI: 10.1056/NEJMoa1215716

High-Frequency Oscillation for Acute Respiratory Distress Syndrome

EVANGELISCHES KRANKENHAUS GÖTTINGEN-WEENDE
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OSCAR Studie

HFOV-Settings:

RR 10 HZ
CAPD = Paw_{mean} + 5 cm H_2O
Bias flow 20 l / min
Cycle Volume 100 ml
I:E ratio = 1:1
FiO_2 = 1,0

Übergang von HFOV zu konventioneller Beatmung:

wenn CAPD < 24 cmH_2O für > 12h mit
$FiO_2 \leq 0{,}4$ und $PaO_2 \geq 60$ mmHg

Young et al. N Engl J Med 2013. DOI: 10.1056/NEJMoa1215716

High-Frequency Oscillation for Acute Respiratory Distress Syndrome

OSCAR Studie

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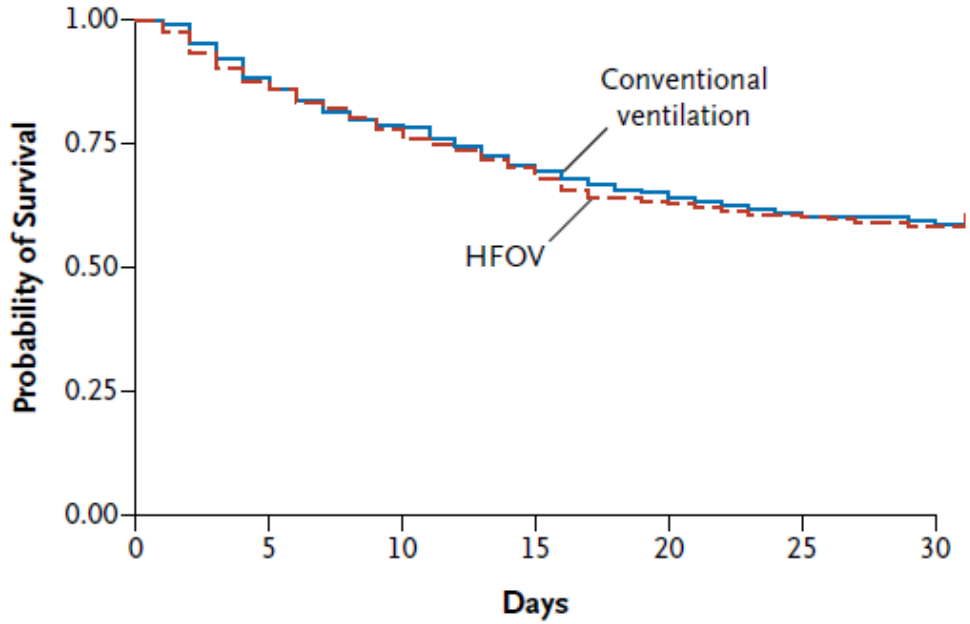
Table 2. Ventilatory Variables during the First 3 Study Days.*

Variable	Day 1		Day 2		Day 3	
	HFOV	Conventional Ventilation	HFOV	Conventional Ventilation	HFOV	Conventional Ventilation
No. of patients	370	392	326	374	240	348
Mean airway pressure (HFOV) or plateau pressure (conventional ventilation) — cm of water	26.9±6.2	30.9±11.0	25.3±5.5	29.5±10.7	25.1±5.4	28.5±11.2
Total respiratory frequency — Hz (HFOV) or breaths/min (conventional ventilation)	7.8±1.8	21.7±8.4	7.5±1.8	22.7±9.0	7.2±1.8	23.3±8.2
Cycle volume (HFOV) or tidal volume (conventional ventilation) — ml (HFOV) or ml/kg of ideal body weight (conventional ventilation)	213±72	8.3±2.9	228±75	8.2±2.5	240±75	8.3±3.0
Positive end-expiratory pressure — cm of water (conventional ventilation only)	NA	11.4±3.6	NA	11.0±3.6	NA	10.5±3.7
Pa_{O_2}:F_{IO_2} ratio — mm Hg	192±77	154±61	212±69	163±66	217±69	166±63
Pa_{CO_2} — mm Hg	55±17	50±19	56±16	49±13	56±17	48±13
Arterial pH	7.30±0.10	7.35±0.10	7.32±0.09	7.37±0.10	7.34±0.10	7.39±0.09
Medication use — no. (%)†						
Neuromuscular-blocking agent	209 (52.5)	165 (41.6)	147 (36.9)	115 (29.0)	110 (27.6)	77 (19.4)
Vasoactive or inotropic agent	173 (43.5)	177 (44.6)	158 (40.0)	146 (36.8)	126 (31.7)	112 (28.2)
Sedative agent	390 (98.0)	388 (97.7)	371 (93.2)	363 (91.4)	341 (85.7)	335 (84.4)

Young et al. N Engl J Med 2013. DOI: 10.1056/NEJMoa1215716

High-Frequency Oscillation for Acute Respiratory Distress Syndrome



No. at Risk							
Conventional ventilation	397	351	312	281	259	243	236
HFOV	398	349	311	280	253	241	233

Figure 3. Kaplan–Meier Survival Estimates during the First 30 Study Days.

Young et al. N Engl J Med 2013. DOI: 10.1056/NEJMoa1215716

Schlussfolgerungen

EVANGELISCHES KRANKENHAUS GÖTTINGEN-WEENDE
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- Nach dem derzeitigen Erkenntnisstand verbessert HFOV nicht die Prognose von Patienten mit einem schweren ARDS.

- Deshalb ist HFOV keine „first line therapy“ für die Behandlung von ARDS-Patienten, sondern lediglich ein Rescueverfahren bei therapierefraktärer Hypoxämie.


LOST
CONFUSED
UNSURE
UNCLEAR
PERPLEXED
DISORIENTED
BEWILDERED