Physiopathologie et mécanismes du dérecrutement dans l'ARDS

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Le dérecrutement

- Définition: le dérecrutement alvéolaire est le terme couramment employé pour décrire la perte d'aération du parenchyme pulmonaire qui caractérise l'ARDS

Plan

- Définition de l'ARDS
- Dérecrutement lié à l'ARDS
- Dérecrutement *iatrogène*:
  - VILI
  - Diminution transitoire de la pression positive
  - Position du patient

ARDS : définition

- 1967: première description par Ashbaugh et al. Lancet.: *severe dyspnea, tachypnea, cyanosis refractory to oxygen supplementation, decreased lung compliance, and diffuse chest X-ray infiltrates.*
- 1988: Murray JF, et al. An expanded definition of the adult respiratory distress syndrome. Am Rev Respir Dis 1988; 138:720–723.

Table 1. Lung Injury Score

	Score				
	0	1	2	3	4
Chest X-ray, number of quadrants	None	1	2	3	4
Oxygenation, P/F ratio	≥300	225–299	175–224	100–174	<100
PEEP, cm H_2O	≤5	6–8	9–11	12–14	≥15
Lung compliance, ml/cm H_2O	≥80	60–79	40–59	20–39	≤19

ARDS définition (2)

- 1994: conférence de consensus

Table 2. Criteria for acute lung injury (ALI) and acute respiratory distress syndrome (ARDS)

	Timing	Oxygenation, P/F ratio	Frontal chest X-ray	Pulmonary artery wedge pressure
ALI	Acute onset	<300 mmHg	Bilateral infiltrates	<18 mmHg or no clinical evidence of left atrial hypertension
ARDS		≤200 mmHg		

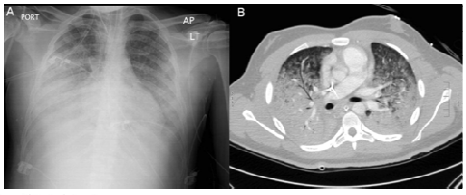
- 2013: conférence de consensus

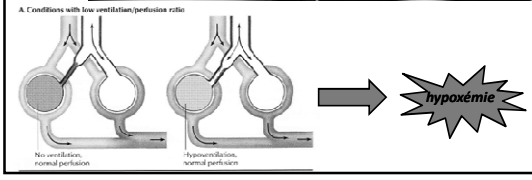
Table 3. The Berlin definition of the acute respiratory distress syndrome (ARDS)

	ARDS
Timing	Within 1 week of a known clinical insult or worsening respiratory symptoms
Chest imaging	Bilateral opacities – not fully explained by effusions, lobar/lung collapse, or nodules
Origin of edema	Not of cardiac origin or fluid overload. Objective assessment required in the absence of risk factors for ARDS
Oxygenation (P/F ratio) (mmHg)	
Mild	(200–300) with PEEP or CPAP ≥5cm H_2O
Moderate	(100–200) with PEEP ≥5 cm H_2O
Severe	<100 with PEEP ≥5 cm H_2O

ARDS

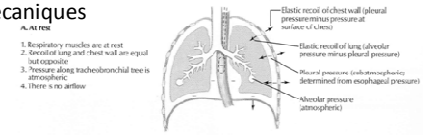
- Infiltrats bilatéraux, hypoxémie



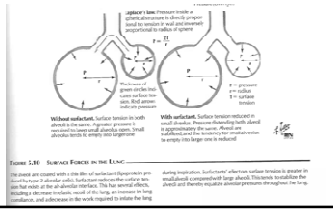


Le poumon normal

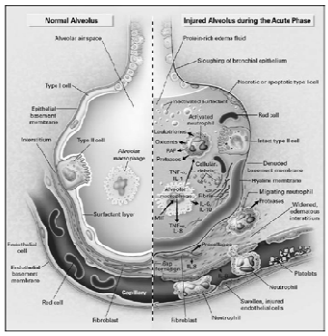
- Alvéoles aérées:
  - Forces mécaniques

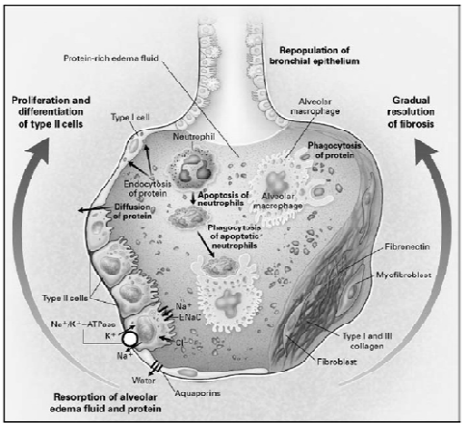


  - Surfactant



Les lésions alvéolaires de l'ARDS





Le dérecrutement *iatrogène*

- Lésions induites par la ventilation (VILI)
- Diminution transitoire de la pression positive
- Position

Les lésions induites par la ventilation: VILI (ventilation induced lung injury)

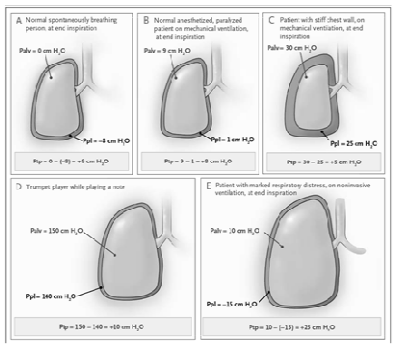
Ni la pression plateau ni le volume courant ne sont des bons prédicteurs du stress et du strain pulmonaire -> principaux déterminants des lésions pulmonaires induites par la ventilation:

- Baro trauma => stress pulmonaire (Ptranspulmonaire)
- Volo trauma => strain pulmonaire (ΔV (Vol tidal+Vol PEEP)/CRF)
- Atelectrauma: phénomènes d'ouverture fermeture alvéolaire

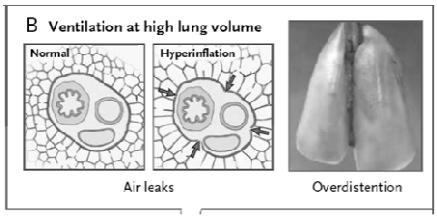
NO ventilation = NO VILI !

Am J Respir Crit Care Med Vol 178. pp 346-355, 2008

La pression transpulmonaire n'est pas la pression alvéolaire

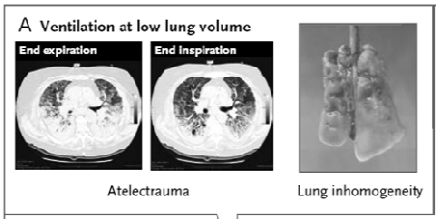


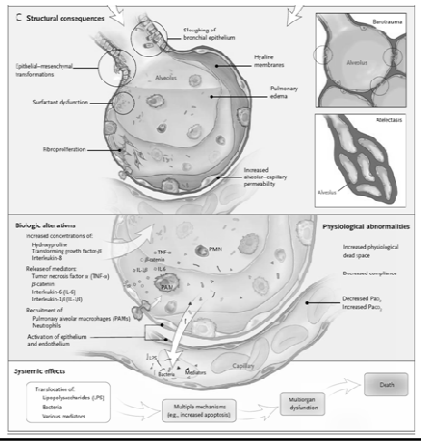
Lésions induites par les hauts volumes



Mais aussi….

Lésions induites par la ventilation à faible volume et atelectrauma





Prise en charge ventilatoire de l'ARDS

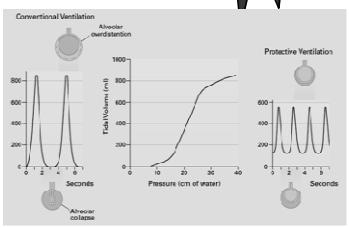
Les 3 zones de l'ARDS

- Poumon sain (concept de baby lung)
- Poumon recrutable
- Poumon non recrutable

Les principes de la ventilation dans l'ARDS

- Petits volumes courants (baby lung)
- Pression plateau limitée (baby lung)
- Pression positive de fin d'expiration (recrutement)
- Curarisation (48h)

Strain < 2
Stress < 27
Atelectrauma



Le dérecrutement *iatrogène*

- VILI
- Diminution transitoire de la pression positive : déconnexion, aspirations, fibroscopie
- Position

Repeated Derecruitments Accentuate Lung Injury During Mechanical Ventilation*

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Objectives: The aim of our study was to assess whether repeated derecruitments induced by the repetitive withdrawal of high positive end-expiratory pressure could induce lung injury in a swine model.
Design: Prospective, randomized, experimental animal study.
Setting: University laboratory.
Subjects: Specific pathogen-free pigs (Okasung-Ang Laboratory Animals, Seoul, Korea) weighing around 30 kg.
Interventions: After lung injury was induced by repeated saline lavage, pigs were ventilated in pressure-limited mode with the highest possible positive end-expiratory pressure with a tidal volume of 9 mL/kg and maximum inspiratory pressure of 30 cm H_2O. With this initial ventilator setting, the control group ($n = 5$) received ventilation without derecruitments for 4 hours, and in the derecruitment group ($n = 5$), derecruitments were repeatedly induced by intentional disconnection of the ventilatory circuit for 30 seconds every 5 minutes for 4 hours.
Measurements and Main Results: After the initial increase in positive end-expiratory pressure, the Pao_2 increased to greater than 450 mm Hg in both groups. The Pao_2 remained at greater than 450 mm Hg in the control group persistently, but in the derecruitment group, Pao_2 significantly decreased to 427.7 mm Hg (adjusted $p = 0.03$) after 2 hours and remained significant for the rest of the study. $Paco_2$, oxygenation index, and alveolar-arterial oxygen gradient also significantly increased after 2 hours compared with the control group. However, the variables of respiratory mechanics except for minute volume at 2 hour point showed no difference between the two groups for the duration of the study. Histologically, significant bronchiolar injury was observed in the dependent portion of the derecruitment group compared with the controls ($p = 0.03$), but not in the nondependent area of the lung.
Conclusions: Repeated derecruitments exacerbated lung injury, particularly at the bronchiolar level in the dependent portion. Strategies to minimize this type of injury should be incorporated when designing optimal ventilator strategies in acute respiratory distress syncrome patients. (*Crit Care Med* 2013; 41:e423–e430)
Key Words: acute lung injury; alveolar collapse; bronchiole; mechanical ventilation; pig; positive end-expiratory pressure

Méthodes

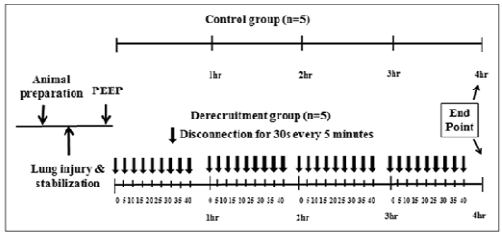

Figure 1. Schematic diagram of the experimental protocol used in this study. In the control group, the animals were ventilated with positive end-expiratory pressure (PEEP) as high as possible without increasing the plateau pressure of 30 cm H_2O for 4 hr of the study. In the derecruitment group, the endotracheal tube was intentionally disconnected from the ventilator for 30 s at min 0, 5, 10, 15, 20, 25, 30, 35, and 40 of each hr to induce alveolar derecruitment (*arrows*).

Effets sur la PaO2, la PaCO2 et la compliance thoraco-pulmonaire

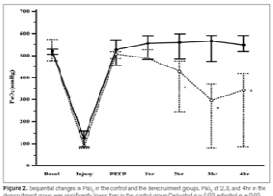

Figure 2. Sequential changes in Pao_2 in the control and the derecruitment groups. Pao_2 at 0, 2, and 4hr in the derecruitment group was significantly lower than in the control group ($p = 0.05$, adjusted $p = 0.03$, and adjusted $p = 0.03$ at 2, 3, and 4hr, respectively). *Solid circles*, control group; *open circles*, derecruitment group. PEEP = positive end-expiratory pressure.

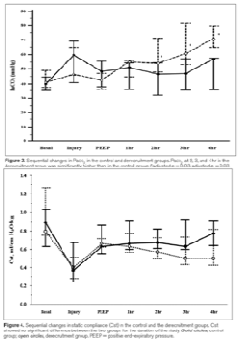

Figure 4. Sequential changes in static compliance (Cst) in the control and the derecruitment groups. Cst in the derecruitment group was significantly lower than in the control group ($p = 0.05$, adjusted $p = 0.03$ at 2, 3, and 4hr, respectively). *Solid circles*, control group; *open circles*, derecruitment group. PEEP = positive end-expiratory pressure.

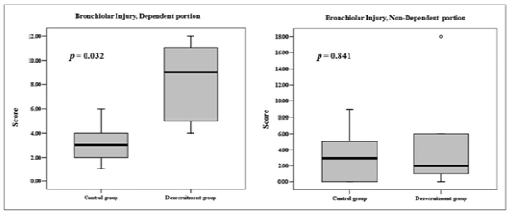

Figure 5. Bronchial injury scores according to the portion (dependent vs nondependent) for control and derecruitment groups. There was a significant difference in bronchial injury score of the dependent portion between the control and derecruitment groups, whereas no significant difference in bronchial injury score was noticed in the nondependent portion between the control and derecruitment groups.

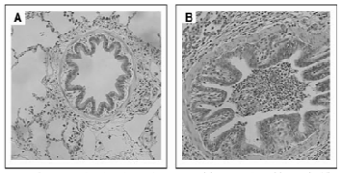

Figure 6. Dependent portion Histological lung from the control (**A**) and derecruitment (**B**) groups (×400). In the derecruitment group, bronchioles showed marked injury, with epithelial necrosis and sloughing.

In conclusion, repeated derecruitments of previously recruited lung may exacerbate the lung injury associated with mechanical ventilation, especially at the bronchiole level in the dependent portion of the lung. Strategies to minimize this type of injury should be incorporated when designing optimal ventilator strategies in ARDS patients.

Facteurs favorisant le dérecrutement répété

- Ventilation avec des petits volumes courants (surtout avec un niveau insuffisant de Peep)
- Aspirations, déconnexions, fibroscopie

Decreasing the Adverse Effects of Endotracheal Suctioning During Mechanical Ventilation by Changing Practice

Salvatore Maurizio Maggiore MD PhD, François Lellouche MD, Claudia Pignataro MD, Emmanuelle Girou PharmD, Bernard Maitre MD, Jean-Christophe M Richard MD PhD, François Lemaire MD, Christian Brun-Buisson MD, and Laurent Brochard MD

- 79 patients ventilés , 4506 procédures d'aspiration (3 mois)
- Application des guidelines
- 68 patients ventilés 4994 procédures d'aspiration

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Effets des aspirations endotrachéales

- Désaturation (46.8%)
- Secrétions hémorragiques (31.6%)
- Hypertension ou Hypotension (24%)
- Bradycardie (10%)

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Guidelines

- Fréquence des aspirations: ?
- Déconnection: ?
- Profondeur: ?
- Instillation de LP: ?
- Taille de la sonde d'aspiration: ?
- Durée de l'aspiration: ?
- Pression d'aspiration: ?
- ARDS: ?

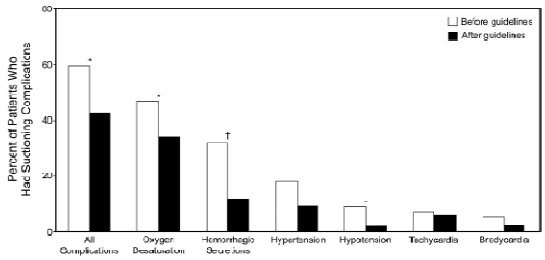
American Association for Respiratory Care. Clinical Practice Guidelines. Endotracheal suctioning of mechanically ventilated patients with artificial airways 2010. Respir Care 2010;55(6):758-764.

Guidelines

- Fréquence des aspirations: uniquement si nécessaire
- Déconnection: non
- Profondeur: le tube et la trachée (pas jusqu'à la garde)
- Instillation de LP: à éviter, si nécessaire remplacer filtre par humidificateur chauffant
- Taille de la sonde d'aspiration: < 50% au diamètre du tube
- Durée de l'aspiration 15s maximum
- Pression d'aspiration 200 à 250 mmHg
- ARDS: système clos et auto triggering possible pendant aspiration, recrutement après aspi si hypoxémie

American Association for Respiratory Care. Clinical Practice Guidelines. Endotracheal suctioning of mechanically ventilated patients with artificial airways 2010. Respir Care 2010;55(6):758-764.

Effets de l'application des guidelines



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Facteurs de risque pour effets secondaires des aspirations: analyse multivariée

	Odds Ratio	95% CI	p
Oxygen desaturation (n = 60)			
PEEP > 5 cm H_2O	2.96	1.26–6.95	.01
> 6 suctionings/d	6	2.51–14.23	< .001
F_{IO_2} > 0.6	2.23	0.99–5.07	.052
No ARDS	0.31	0.1–0.9	.03
Period 2	0.4	0.17–0.93	.03
Hemorrhagic secretions (n = 33)			
Anticoagulation > 3 days	1.43	0.58–3.64	.43
> 6 suctionings/d	4.25	1.45–12.44	.008
Period 2	0.31	0.13–0.78	.01
Blood pressure changes (n = 26)*			
Oxygen desaturation	4	1.46–11	.007
> 6 suctionings/d	1.88	0.6–5.86	.28
Period 2	0.44	0.16–1.17	.09

* The blood pressure changes category includes hypertension and hypotension.
Period 2 = After implementation of guidelines.

Conclusion de l'étude:

- AET : complications fréquentes, principalement désaturation et secrétions hémorragiques
- L'implémentation des recommandations diminuent l'incidence des effets néfastes des AET
- AET fréquentes, PEEP >5, et ARDS sont des facteurs de risque de ces effets néfastes
- Désaturation est un facteur de risque pour altérations hémodynamiques durant les AET

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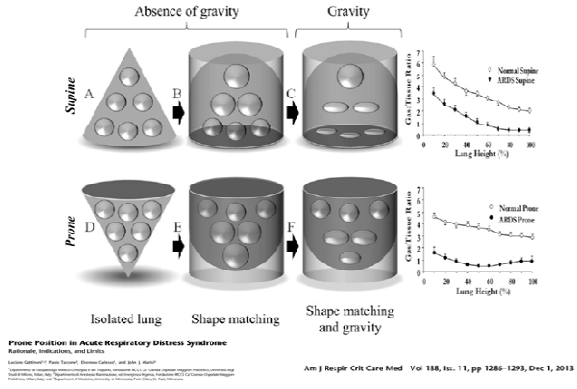
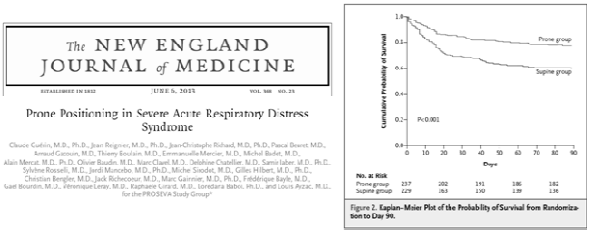
Le dérecrutement iatrogène

- VILI
- Diminution transitoire de la pression positive
- Position: decubitus dorsal vs prone position

Decubitus dorsal vs prone position



Effets de la position ventrale



Conclusion générale:

- Le dérecrutement dans l'ARDS est dû :
  - Aux lésions alvéolaires diffuses de l'ARDS
  - MAIS aussi aux manœuvres iatrogènes:
    - Lésions induites par la ventilation
    - Dérecrutement répété
    - Decubitus dorsal

Conclusion générale: comment éviter le dérecrutement

- Ventilation protectrice pour minimiser le VILI
- Peep optimale (surtout avec les petits volumes courants utilisés)
- Applications des recommandations pour les AET et éviter fibroscopies, aspirations et déconnexions intempestives.
- Prone position
- Réglage optimal de la FiO2 (éviter atélectasies de dénitrogénation)