25e congrès francophone
ACTUALITÉS EN RÉANIMATION
Médecine Intensive, Surveillance Continue
et Urgences Graves

Ventilation Mécanique et Diaphragme

Martin Dres

Sorbonne Université, INSERM, UMRS1158
Neurophysiologie Respiratoire Expérimentale et Clinique

AP-HP. Sorbonne Université
Groupe Hospitalier Universitaire Pitié-Salpêtrière
Medical ICU
Paris - France

Liens d’intérêt

Lungpacer (expertise fees, travel expenses)

Dräger (congress)

Bioserenity (research contract)

Diaphragm dysfunction: causes and consequences

If the story was simple…

In the ICU

Mechanical Ventilation

↓

Disuse
Excessive unloading

↓

ventilation-induced diaphragm dysfunction

↓

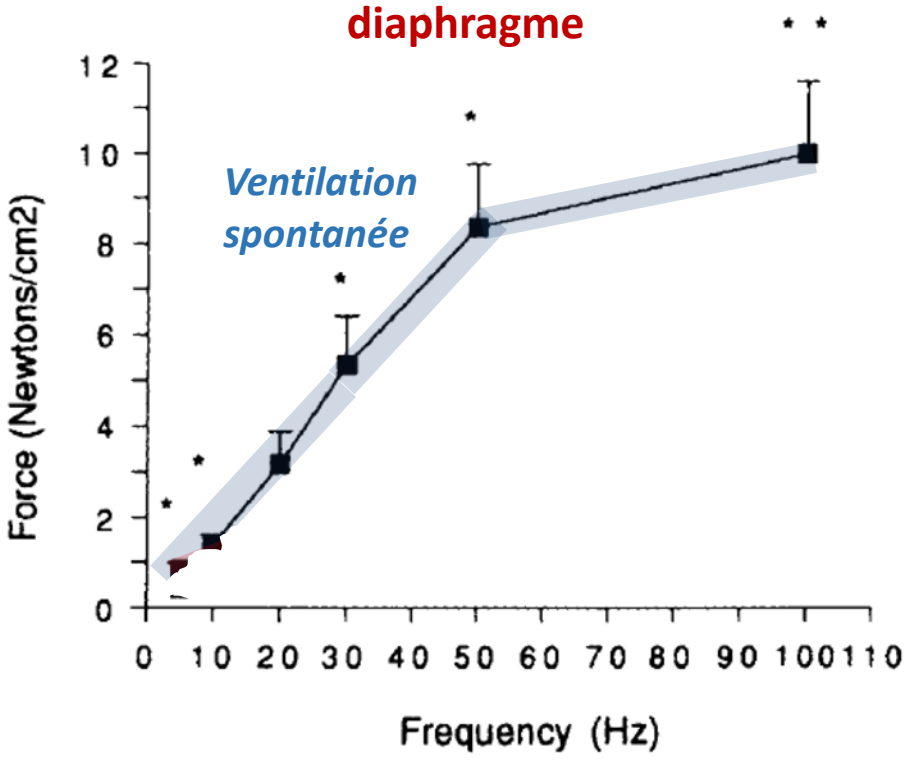
Diaphragm dysfunction

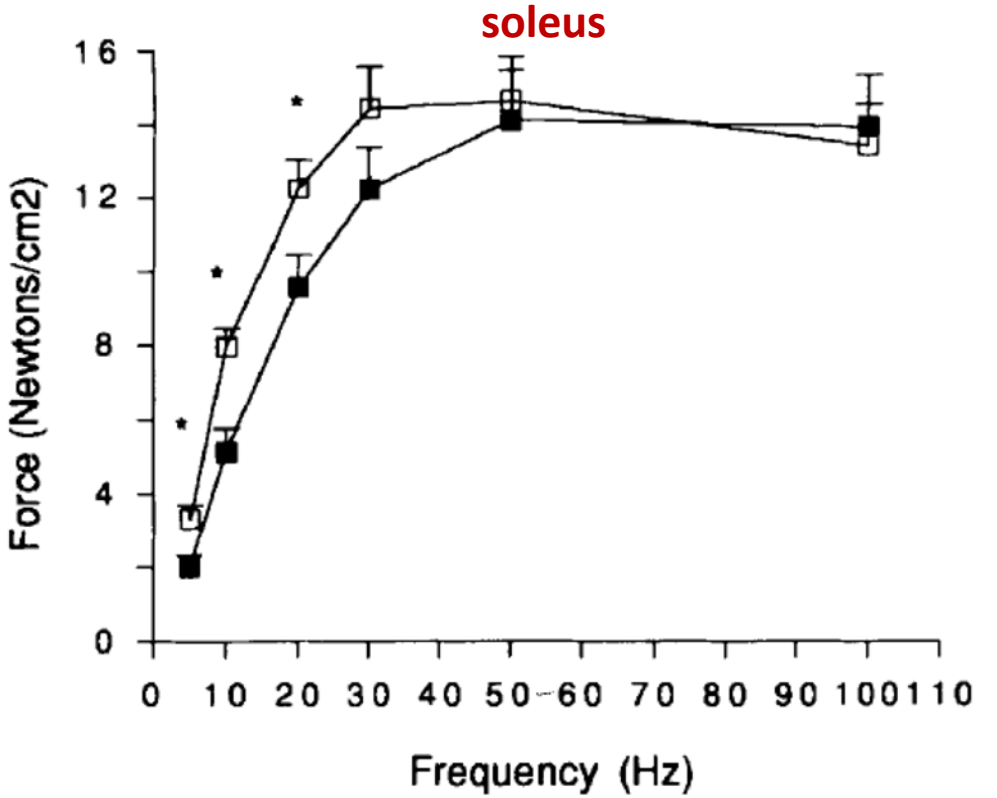
Thomas Pesquet "va vraiment bien"

Le médecin de l'astronaute français juge spectaculaire la vitesse à laquelle il récupère de ses 6 mois dans l'espace. Interview.
Source AFP

Effects of Mechanical Ventilation on Diaphragmatic Contractile Properties in Rats

GENEVIEVE LE BOURDELLES, NAÏMA VIIRES, JORGE BOCZKOWSKI, NATHALIE SETA, DRAGAN PAVLOVIC, and MICHEL AUBIER





AMERICAN JOURNAL OF RESPIRATORY AND CRITICAL CARE MEDICINE VOL 149 1994

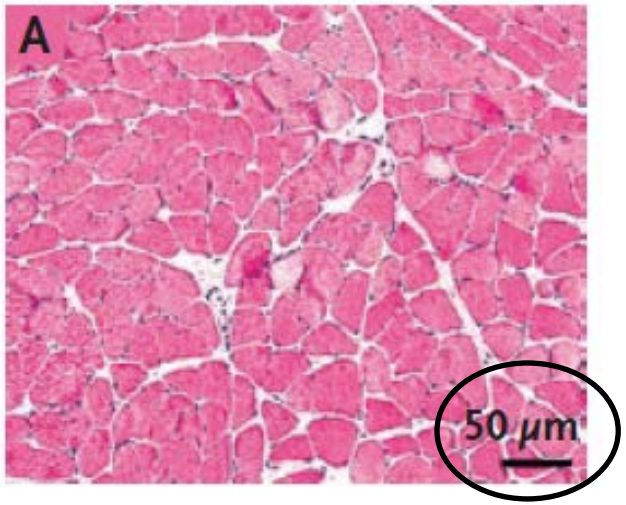
Diaphragm dysfunction: causes and consequences

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 MARCH 27, 2008 VOL. 358 NO. 13

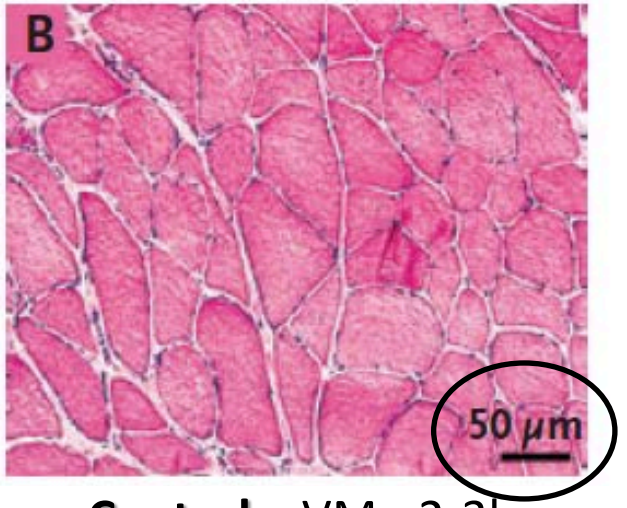
Rapid Disuse Atrophy of Diaphragm Fibers in Mechanically Ventilated Humans

Sanford Levine, M.D., Taitan Nguyen, B.S.E., Nyali Taylor, M.D., M.P.H., Michael E. Friscia, M.D., Murat T. Budak, M.D., Ph.D., Pamela Rothenberg, B.A., Jianliang Zhu, M.D., Rajeev Sachdeva, M.D., Seema Sonnad, Ph.D., Larry R. Kaiser, M.D., Neal A. Rubinstein, M.D., Ph.D., Scott K. Powers, Ph.D., Ed.D., and Joseph B. Shrager, M.D.



Case – VM - 18-69h

atrophy induced by diaphragm **disuse**

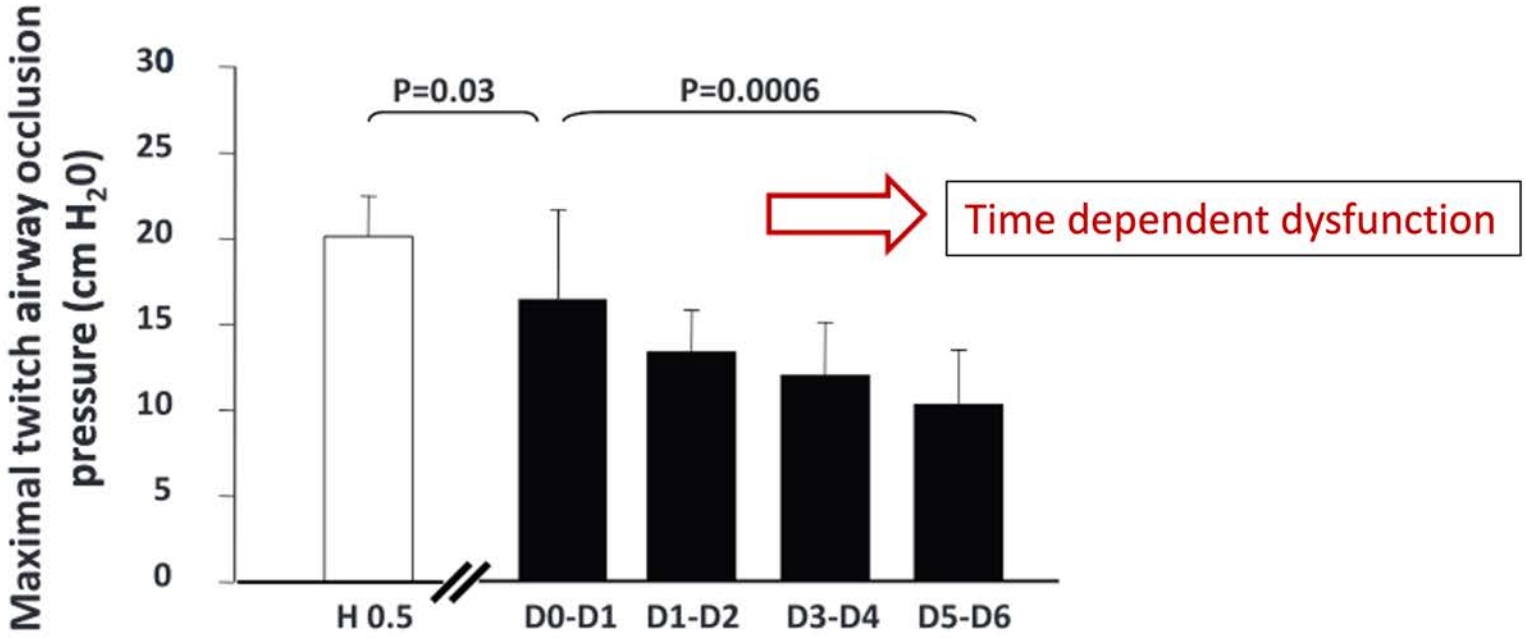


Control – VM - 2-3h

Diaphragm dysfunction: causes and consequences

Rapidly Progressive Diaphragmatic Weakness and Injury during Mechanical Ventilation in Humans

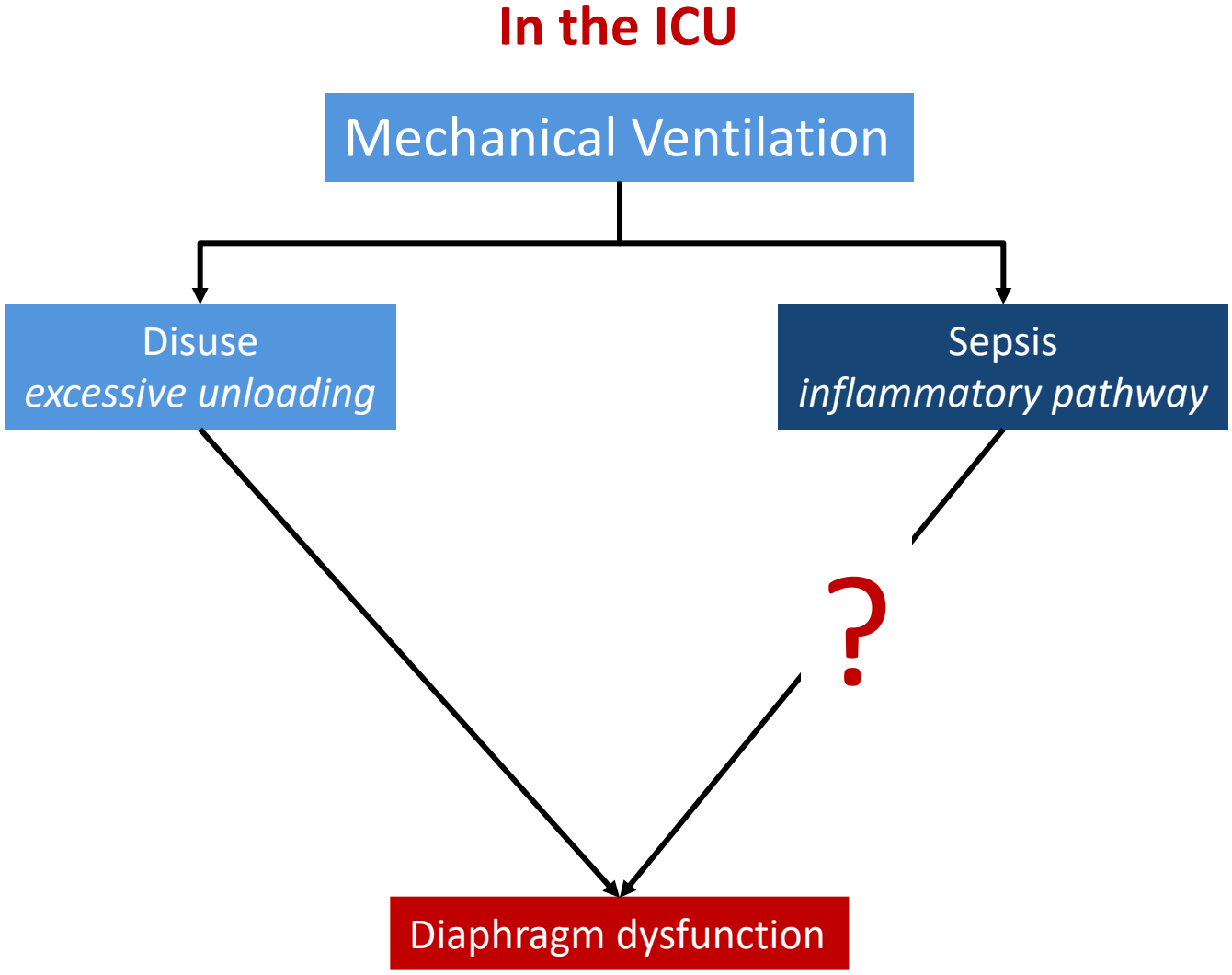
Samir Jaber[1,2,6], Basil J. Petrof[3], Boris Jung[1,2], Gérald Chanques[1,2], Jean-Philippe Berthet[4], Christophe Rabuel[5], Hassan Bouyabrine[6], Patricia Courouble[1,2], Christelle Koechlin-Ramonatxo[7], Mustapha Sebbane[1,2], Thomas Similowski[8], Valérie Scheuermann[9], Alexandre Mebazaa[5], Xavier Capdevila[1,2], Dominique Mornet[2], Jacques Mercier[2,10], Alain Lacampagne[9], Alexandre Philips[2], and Stefan Matecki[2,10]



Am J Respir Crit Care Med Vol 183. pp 364–371, 2011

Diaphragm dysfunction: causes and consequences

But the story is not simple…

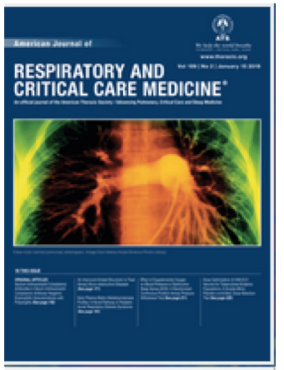


Diaphragm dysfunction: causes and consequences

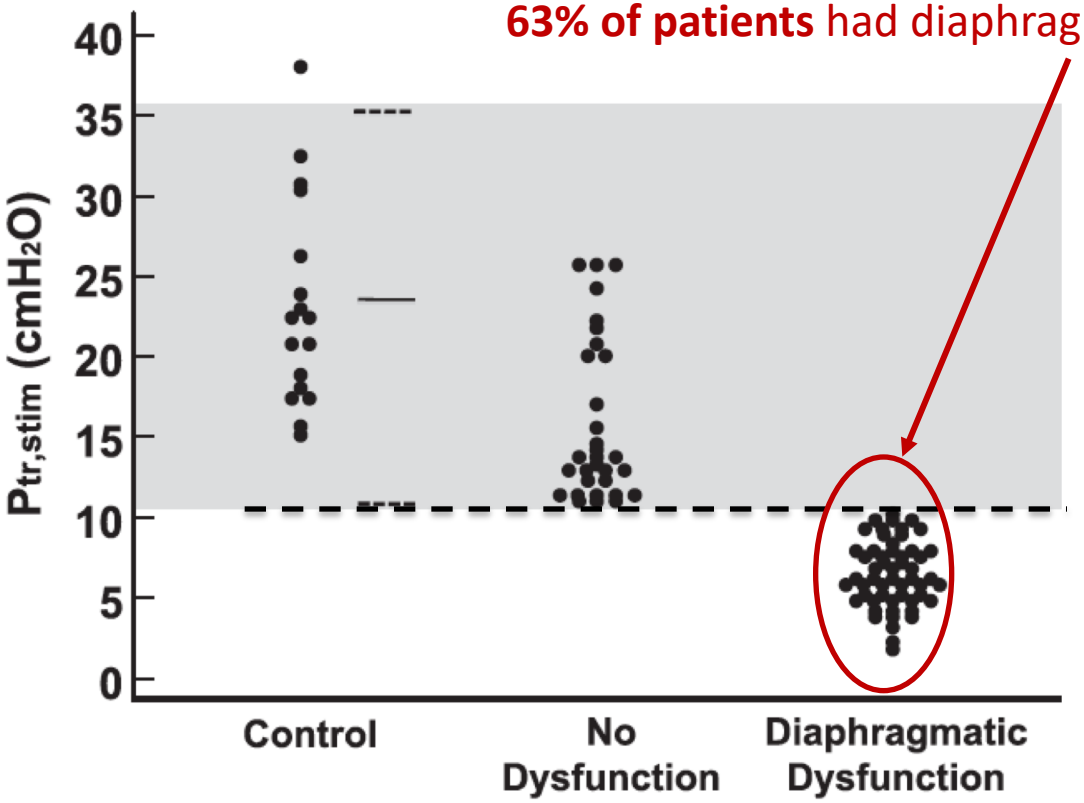
Diaphragm Dysfunction on Admission to the Intensive Care Unit

Prevalence, Risk Factors, and Prognostic Impact—A Prospective Study

Alexandre Demoule[1,2,3], Boris Jung[4,5], Hélène Prodanovic[2], Nicolas Molinari[6], Gerald Chanques[4,5], Catherine Coirault[3], Stefan Matecki[5,7], Alexandre Duguet[1,2], Thomas Similowski[1,2*], and Samir Jaber[4,5*]



63% of patients had diaphragm dysfunction on admission



No diaphragm dysfunction

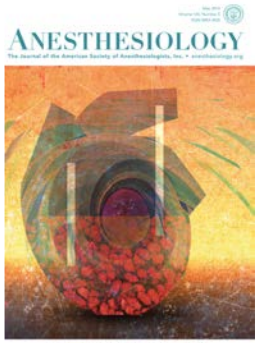
diaphragm dysfunction

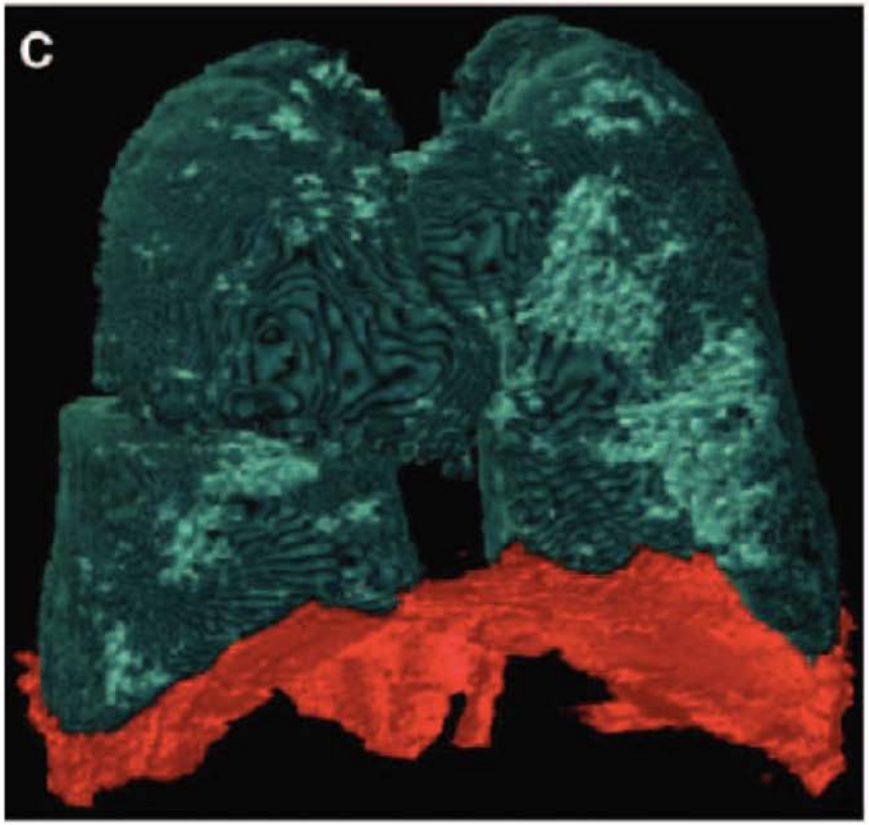
Am J Respir Crit Care Med Vol 188, Iss. 2, pp 213–219, Jul 15, 2013

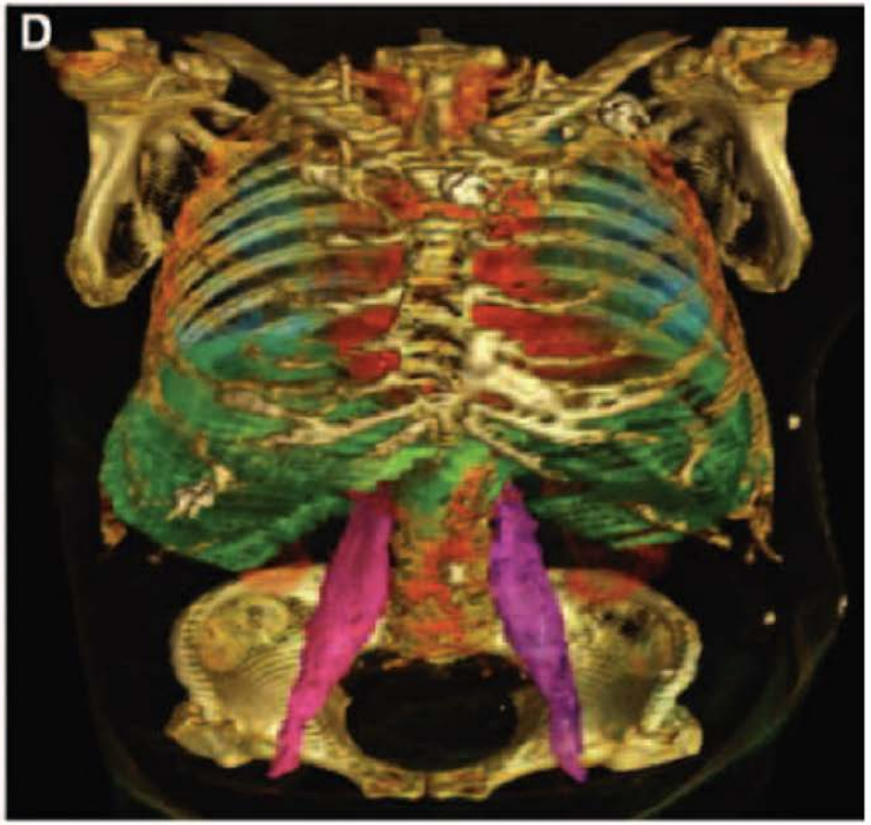
Diaphragm dysfunction: causes and consequences

Sepsis Is Associated with a Preferential Diaphragmatic Atrophy

Boris Jung, M.D., Ph.D., Stephanie Nougaret, M.D., M.Sc., Matthieu Conseil, M.D., M.Sc., Yannaël Coisel, M.D., M.Sc., Emmanuel Futier, M.D., Ph.D., Gerald Chanques, M.D., Ph.D., Nicolas Molinari, Ph.D., Alain Lacampagne, Ph.D., Stefan Matecki, M.D., Ph.D., Samir Jaber, M.D., Ph.D.





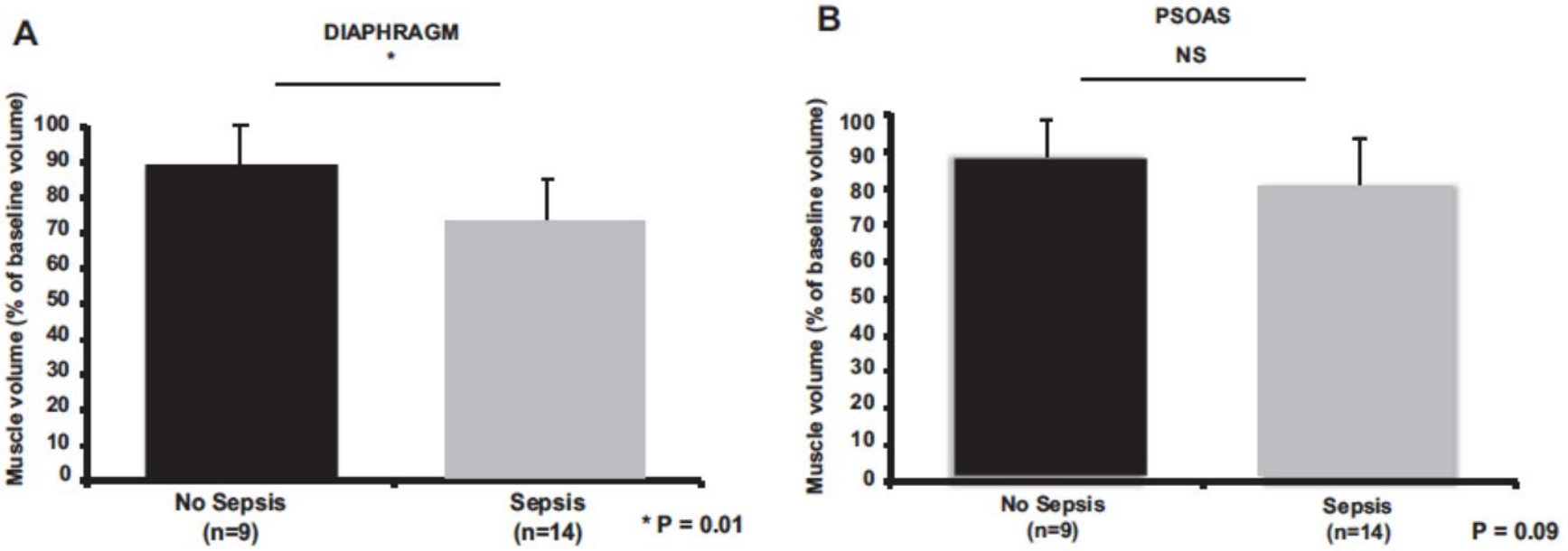


Diaphragm dysfunction: causes and consequences

Sepsis Is Associated with a Preferential Diaphragmatic Atrophy

Boris Jung, M.D., Ph.D., Stephanie Nougaret, M.D., M.Sc., Matthieu Conseil, M.D., M.Sc., Yannaël Coisel, M.D., M.Sc., Emmanuel Futier, M.D., Ph.D., Gerald Chanques, M.D., Ph.D., Nicolas Molinari, Ph.D., Alain Lacampagne, Ph.D., Stefan Matecki, M.D., Ph.D., Samir Jaber, M.D., Ph.D.

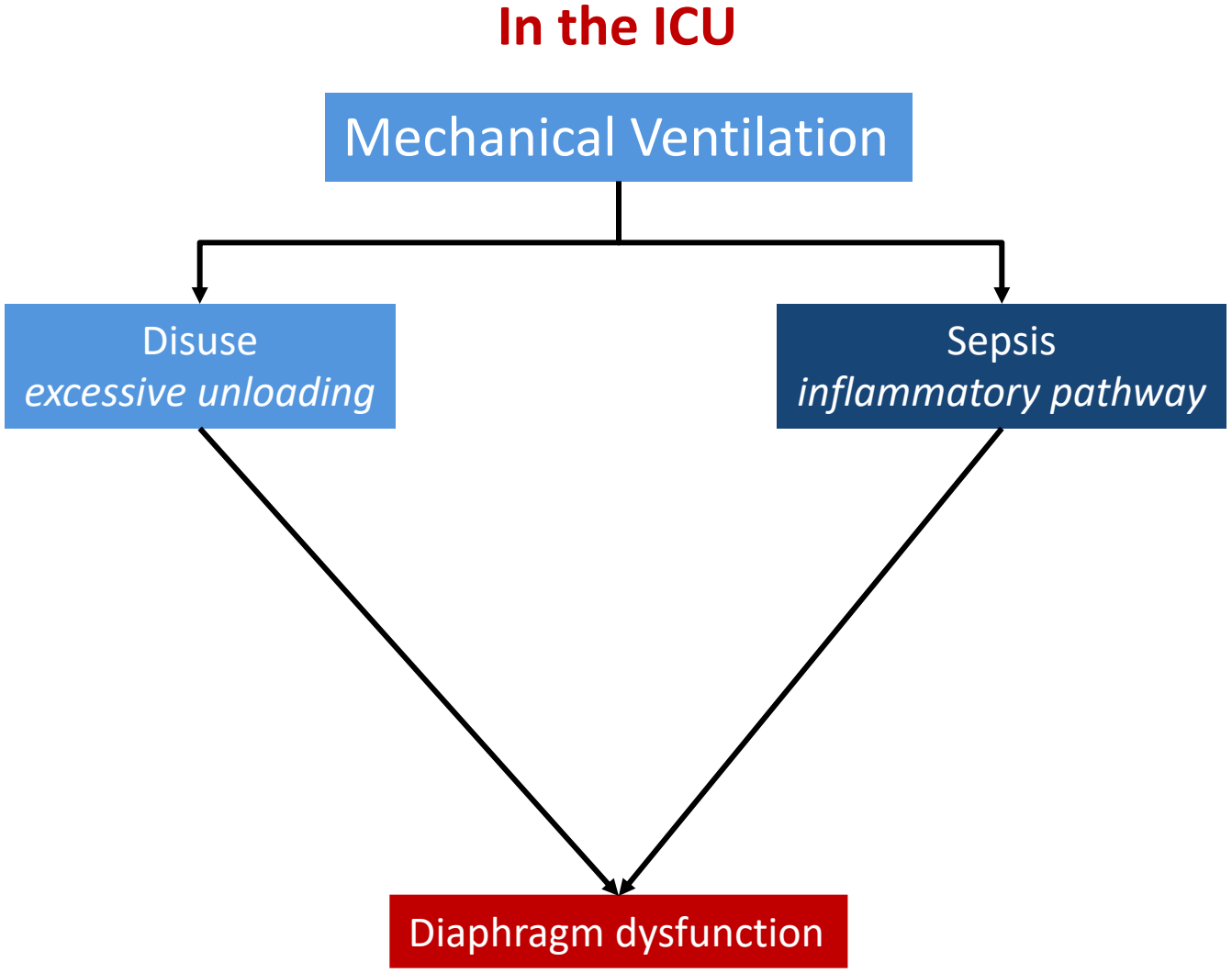
Diaphragm and Psoas volumes assessed with CT scan



↘ diaphragm volume **but not psoas volume** in septic patients

Diaphragm dysfunction: causes and consequences

The story is actually complicated…

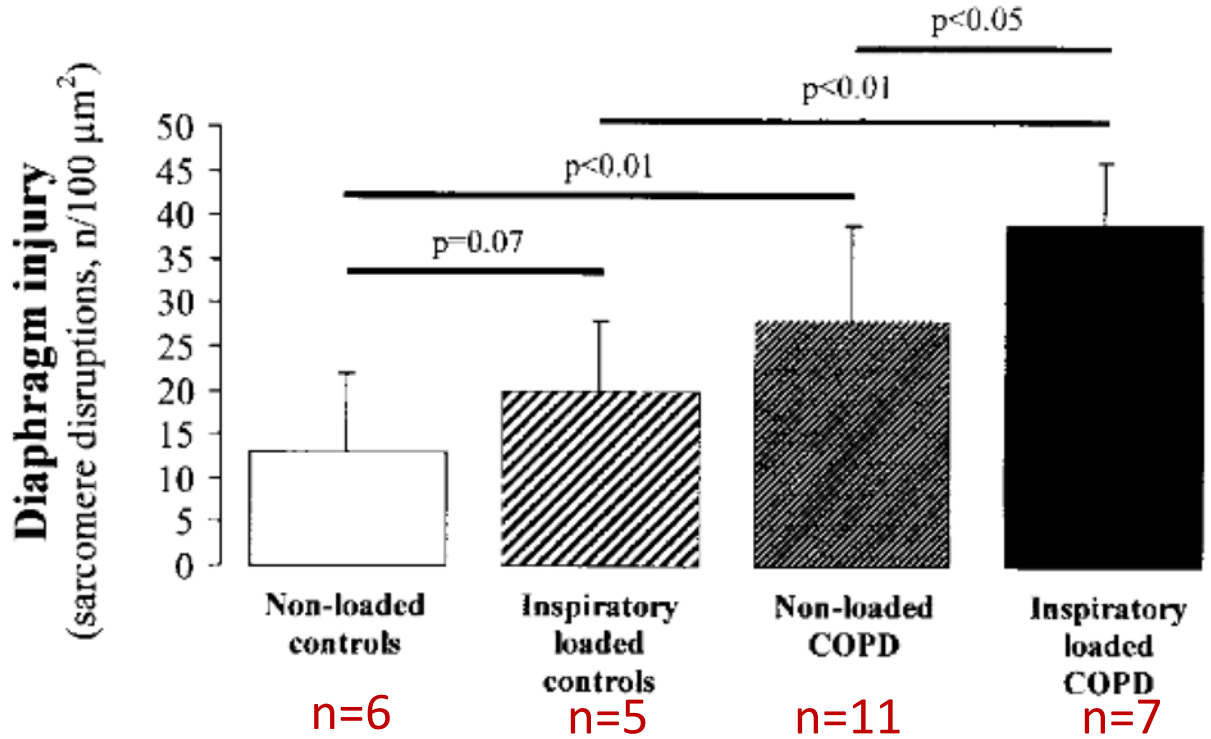


Diaphragm dysfunction: causes and consequences

Injury of the Human Diaphragm Associated with Exertion and Chronic Obstructive Pulmonary Disease

MAURICIO OROZCO-LEVI, JOSEP LLORETA, JOAN MINGUELLA, SERGI SERRANO, JOAN M. BROQUETAS, and JOAQUIM GEA

Diaphragm biopsies in **healthy** and **COPD** patients



diaphragm injury increases with loading

load-induced injury ?

AMERICAN JOURNAL OF RESPIRATORY AND CRITICAL CARE MEDICINE VOL 164 2001

Diaphragm dysfunction: causes and consequences

Mechanical Ventilation–induced Diaphragm Atrophy Strongly Impacts Clinical Outcomes

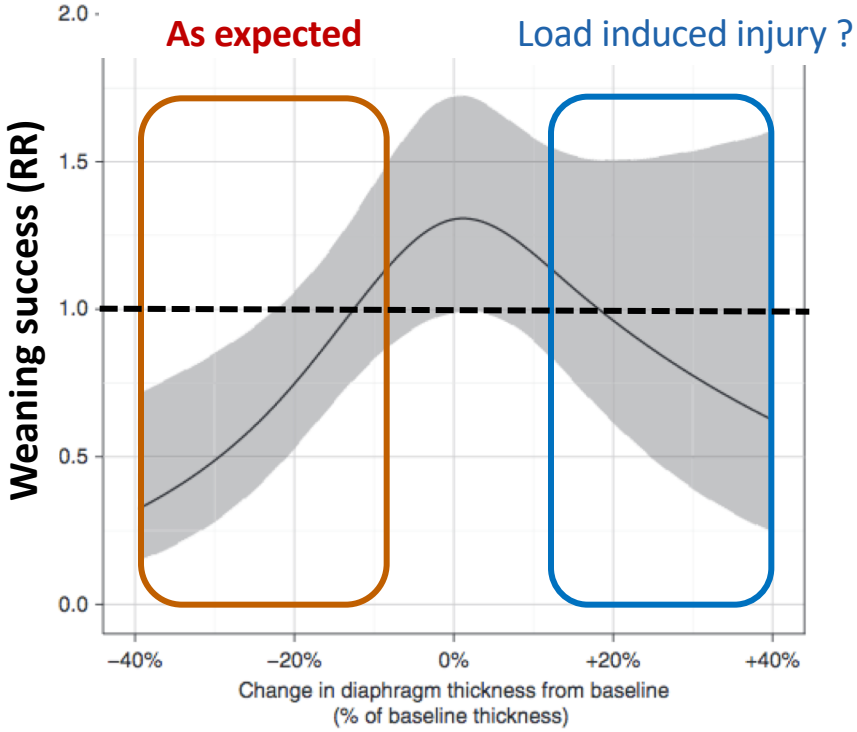
Ewan C. Goligher[1,2,3,4], Martin Dres[5,6], Eddy Fan[1,2,4,7], Gordon D. Rubenfeld[1,4,7,8], Damon C. Scales[1,4,7,8], Margaret S. Herridge[1,2,4,9], Stefannie Vorona[2], Michael C. Sklar[5,10], Nuttapol Rittayamai[5], Ashley Lanys[5], Alistair Murray[2], Deborah Brace[2], Cristian Urrea[2], W. Darlene Reid[11], George Tomlinson[2], Arthur S. Slutsky[1,4,5], Brian P. Kavanagh[1,3,10,12], Laurent J. Brochard[1,4,5*], and Niall D. Ferguson[1,2,3,4,7,9*]

191 patients under MV

↘ **Thickness (Atrophy)**
n=78 (41%)

⇆ **Thickness**
n=66 (35%)

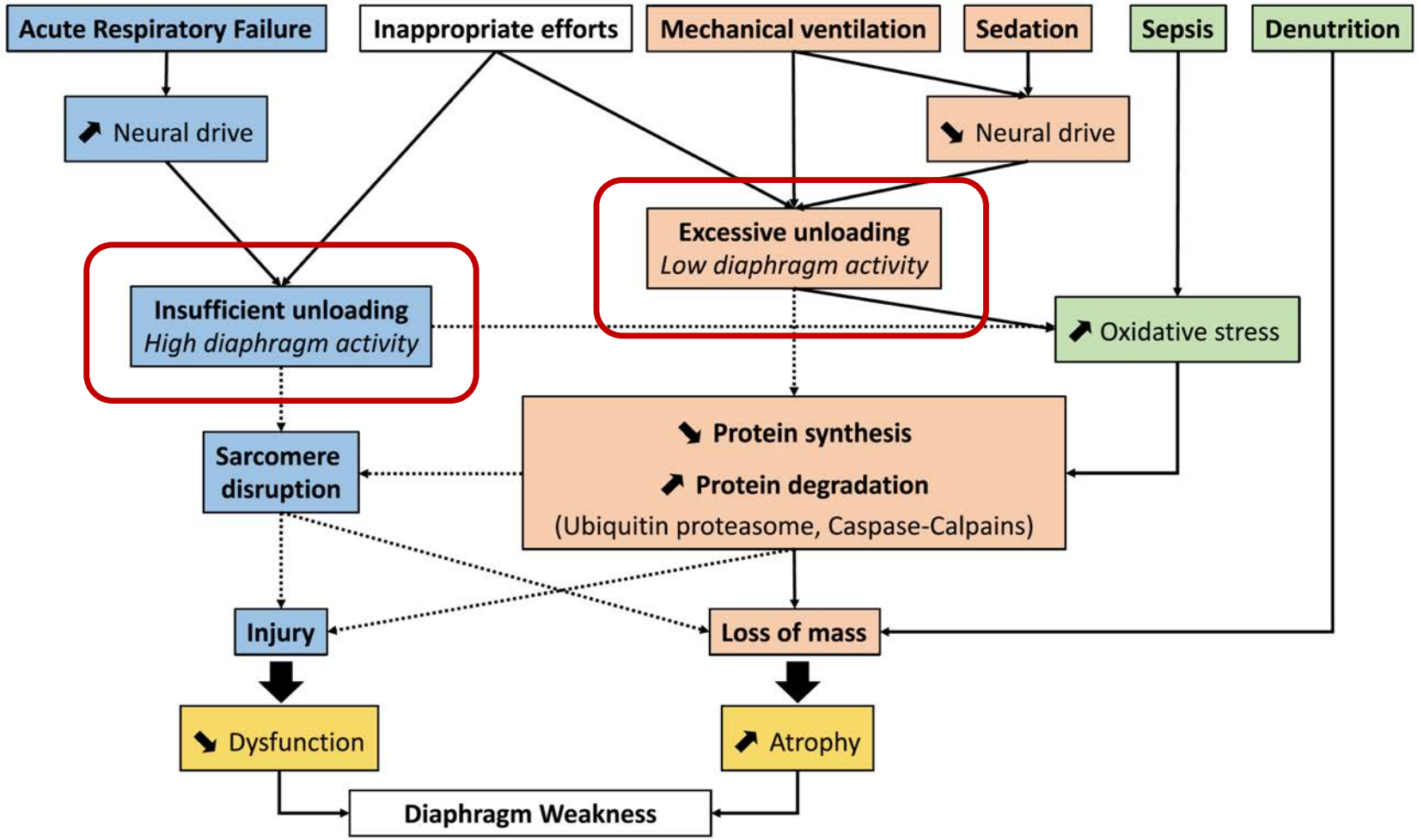
↗ **Thickness**
n=47 (24%)



American Journal of Respiratory and Critical Care Medicine Volume 197 Number 2 | January 15 2018

Diaphragm dysfunction: causes and consequences

The story is much more complicated...



VIDD ⇨ ICU-DD?

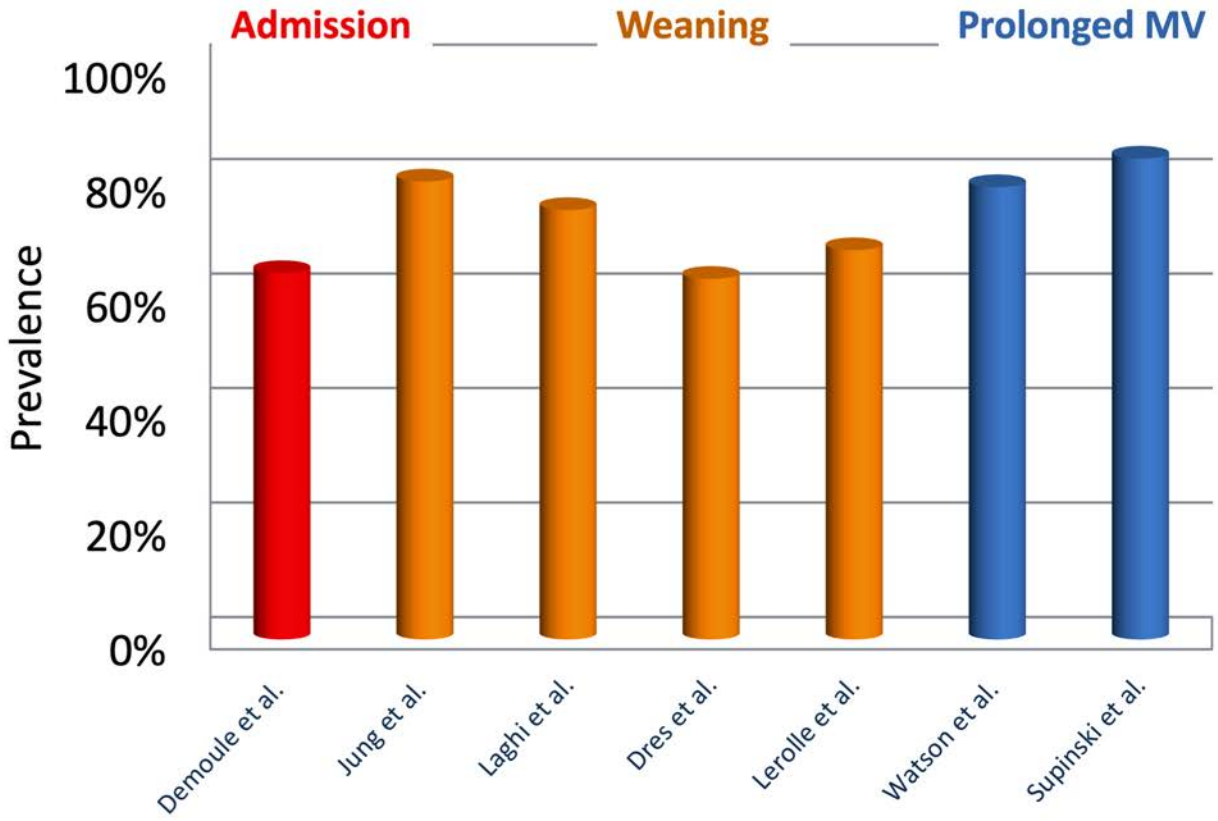
Dres, Goligher, Heunks and Brochard ICM 2017

Diaphragm dysfunction: at the time of weaning

REVIEW

Critical illness-associated diaphragm weakness

Martin Dres[1,2,3*], Ewan C. Goligher[4,5], Leo M. A. Heunks[6] and Laurent J. Brochard[3,5]



Diaphragm dysfunction

> 60% of the patients

Diaphragm dysfunction: at the time of weaning

Coexistence and Impact of Limb Muscle and Diaphragm Weakness at Time of Liberation from Mechanical Ventilation in Medical Intensive Care Unit Patients

Martin Dres[1,2*], Bruno-Pierre Dubé[1,3*], Julien Mayaux[2], Julie Delemazure[2], Danielle Reuter[2], Laurent Brochard[4,5], Thomas Similowski[1,2], and Alexandre Demoule[1,2]

	Overall Population (*n* = 76)	Diaphragm Dysfunction		
		Yes (*n* = 48)	No (*n* = 28)	*P* Value
Difficult weaning, n (%)	25 (33)	23 (48)	2 (7)	<0.001
Prolonged weaning, n (%)	8 (10)	8 (17)	0 (0)	0.02
Total duration of MV, d	5 (2–10)	7 (4–12)	4 (1–6)	0.04
Length of ICU stay, d	8 (4–15)	10 (5–16)	6 (3–10)	0.05
Length of hospital stay, d	21 (9–30)	23 (15–32)	18 (6–29)	0.09
ICU mortality, n (%)	8 (10)	8 (17)	0 (0)	0.02
Hospital mortality, n (%)	12 (16)	11 (23)	1 (4)	0.04

Am J Respir Crit Care Med Vol 195, Iss 1, pp 57–66, Jan 1, 2017

Diaphragm dysfunction: at the time of weaning

Intensive Care Med
DOI 10.1007/s00134-015-4125-2

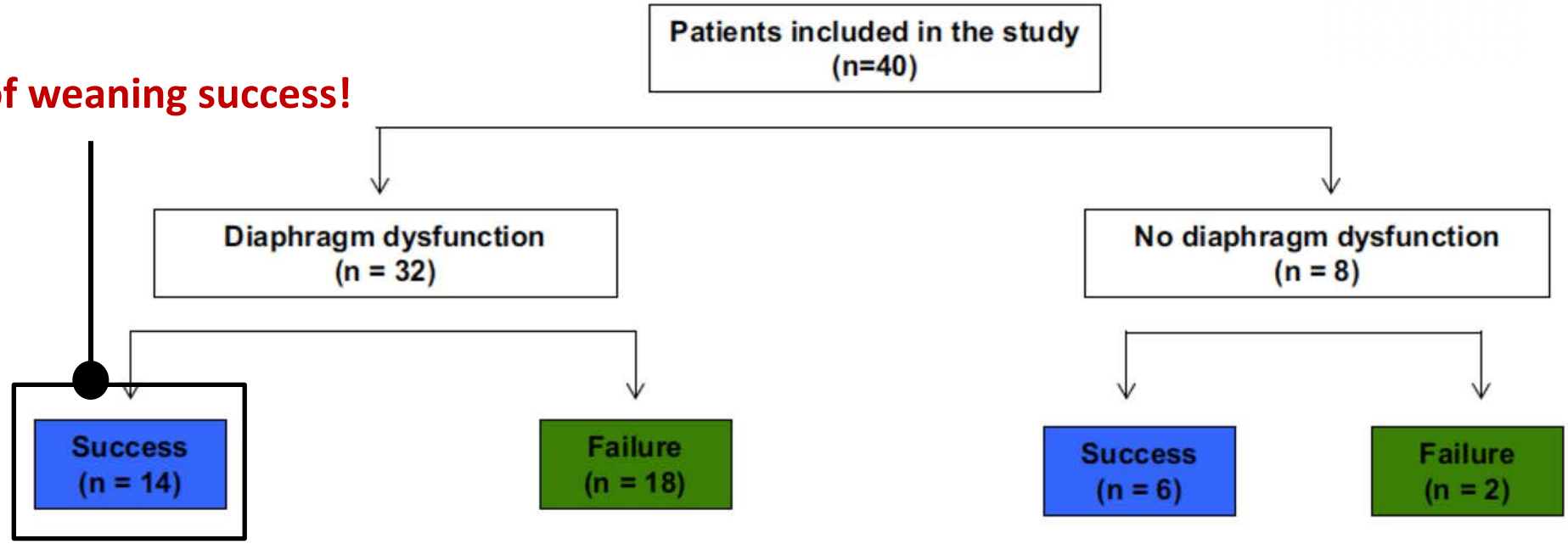
ORIGINAL

Boris Jung
Pierre Henri Moury
Martin Mahul
Audrey de Jong
Fabrice Galia
Albert Prades
Pierre Albaladejo
Gerald Chanques
Nicolas Molinari
Samir Jaber

Diaphragmatic dysfunction in patients with ICU-acquired weakness and its impact on extubation failure

…should not discourage weaning

44% of weaning success!

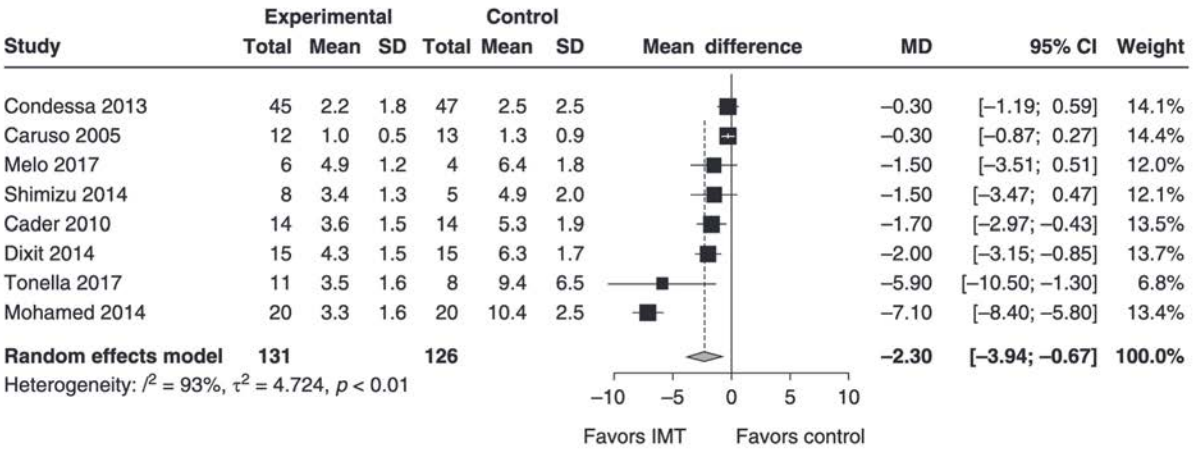


Diaphragm dysfunction: curative strategies

Inspiratory Muscle Rehabilitation in Critically Ill Adults
A Systematic Review and Meta-Analysis

Stefannie Vorona[1], Umberto Sabatini[1], Sulaiman Al-Maqbali[1], Michele Bertoni[1], Martin Dres[2,3], Bernie Bissett[4,5], Frank Van Haren[5,6,7], A. Daniel Martin[8], Cristian Urrea[1], Debbie Brace[1], Matteo Parotto[9,10,11], Margaret S. Herridge[1,9,12], Neill K. J. Adhikari[9,13,14], Eddy Fan[1,9,12,15], Luana T. Melo[16], W. Darlene Reid[9,16], Laurent J. Brochard[2,9,12], Niall D. Ferguson[1,9,12,14,15], and Ewan C. Goligher[1,9,15]

inspiratory muscle training: effect on the duration of weaning



- *« control » group is not well defined*
- *IMT requires patient **cooperation***
- *IMT is **not specific** of diaphragm dysfunction*

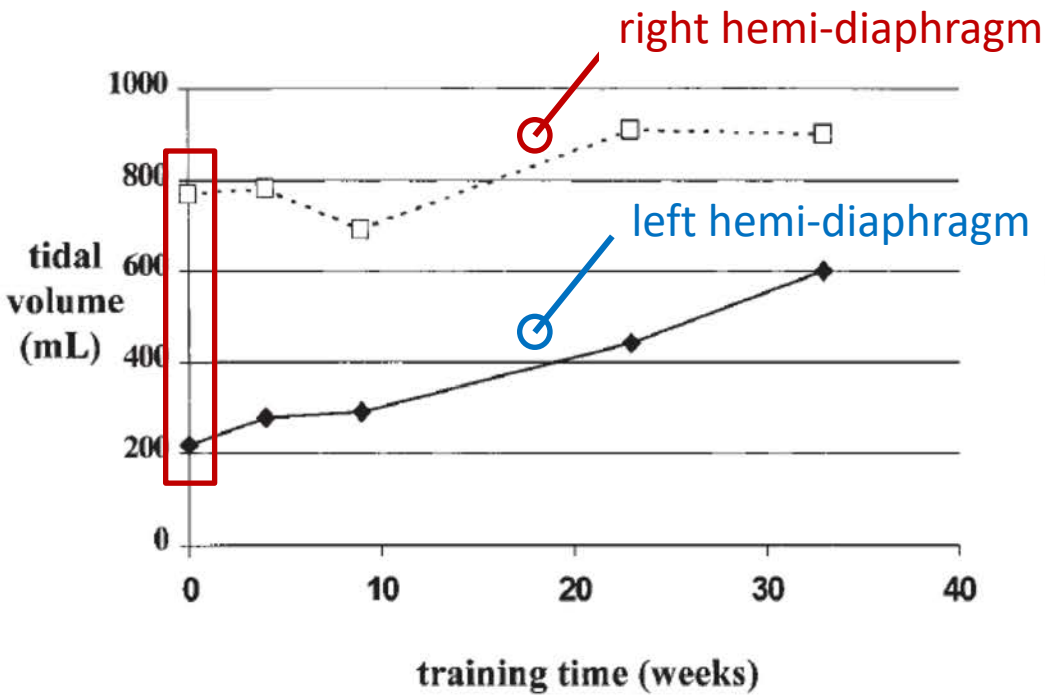
Ann Am Thorac Soc Vol 15, No 6, pp 735–744, Jun 2018

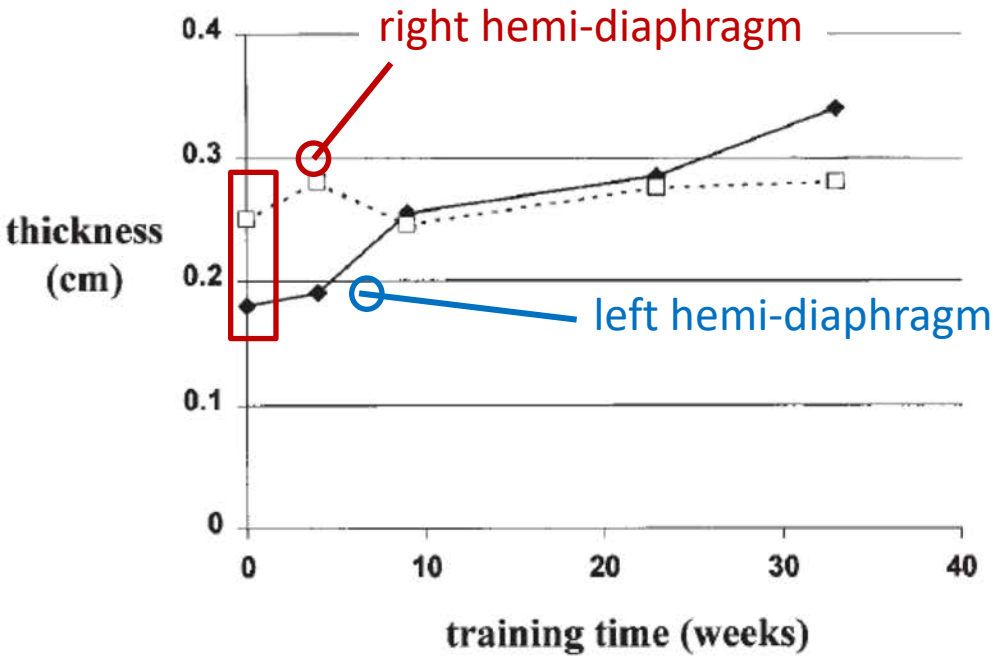
Diaphragm dysfunction: curative strategies

Prevention of Human Diaphragm Atrophy with Short Periods of Electrical Stimulation

NAJIB T. AYAS, F. DENNIS McCOOL, ROBERT GORE, STEVEN L. LIEBERMAN, and ROBERT BROWN

49 yo male with high spinal cord injury
Assessment 8 months after removal of left phrenic nerve stimulator





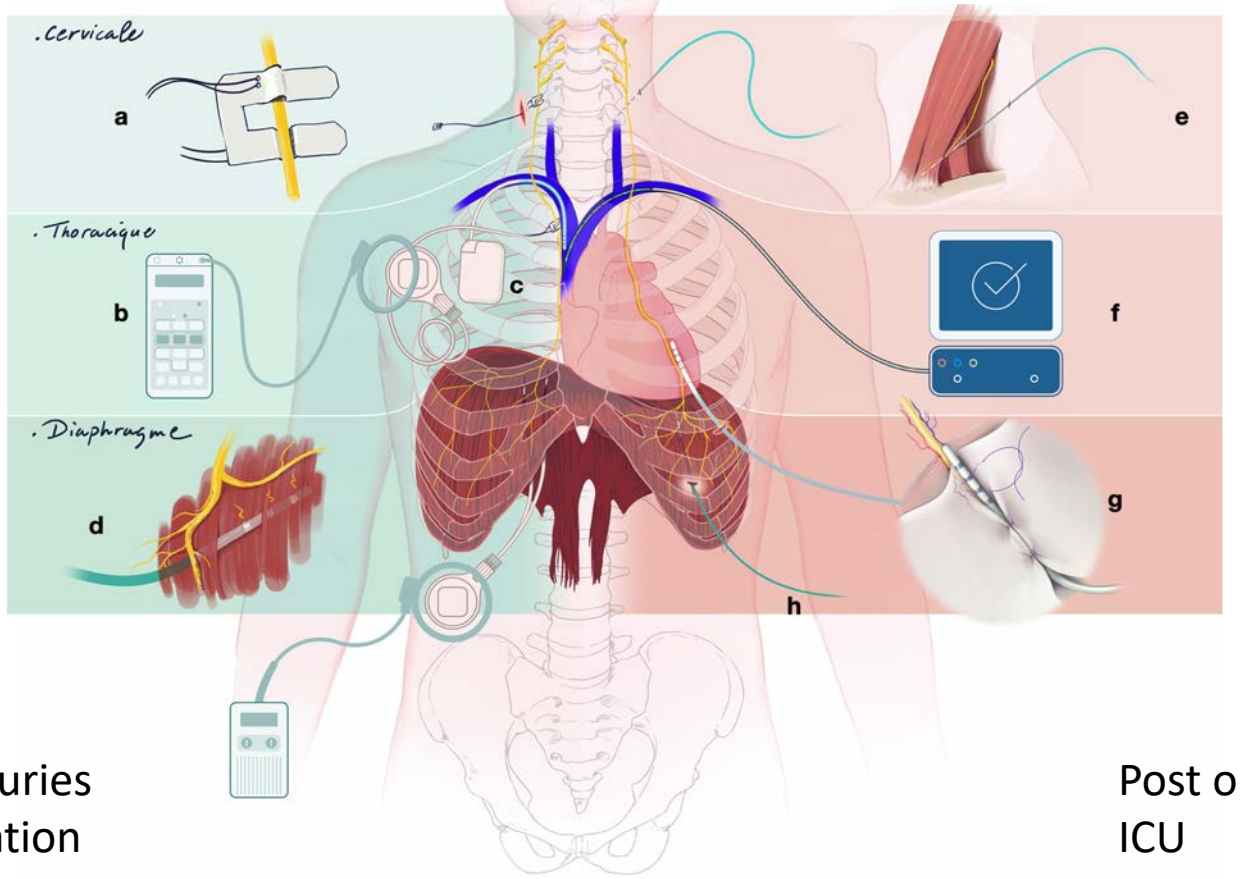
AM J RESPIR CRIT CARE MED 1999;159:2018–2020.

Diaphragm dysfunction: curative strategies

Diaphragm/phrenic nerves pacing

Surgical approaches
permanent

Mini-invasive approaches
Easily removable



- Percutaneous
- Transvenous
- Per-operative

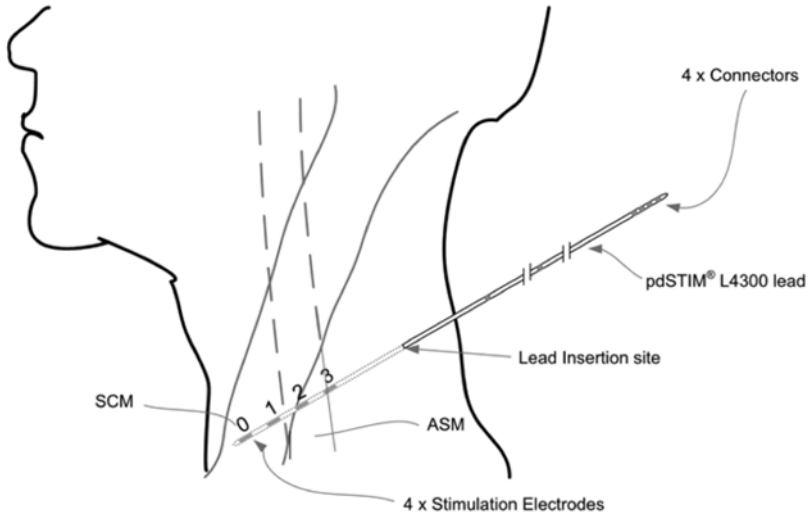
High spinal cord injuries
Central hypoventilation

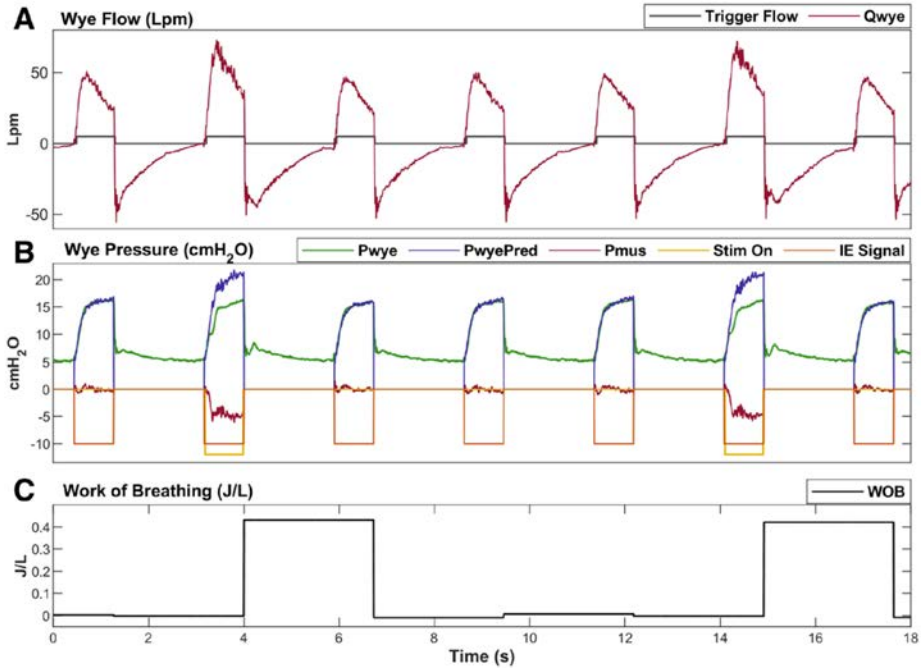
Post operative
ICU

Diaphragm dysfunction: curative strategies

Initial Assessment of the Percutaneous Electrical Phrenic Nerve Stimulation System in Patients on Mechanical Ventilation

James O'Rourke, MB[1]; Michal Soták, MD[2,3]; Gerard F. Curley, MB[1]; Aoife Doolan, MB[1]; Tomáš Henlín, MD[2]; Gerard Mullins, MB[4]; Tomáš Tyll, MD[2]; William Omlie, MD[5]; Marco V. Ranieri, MD[6]

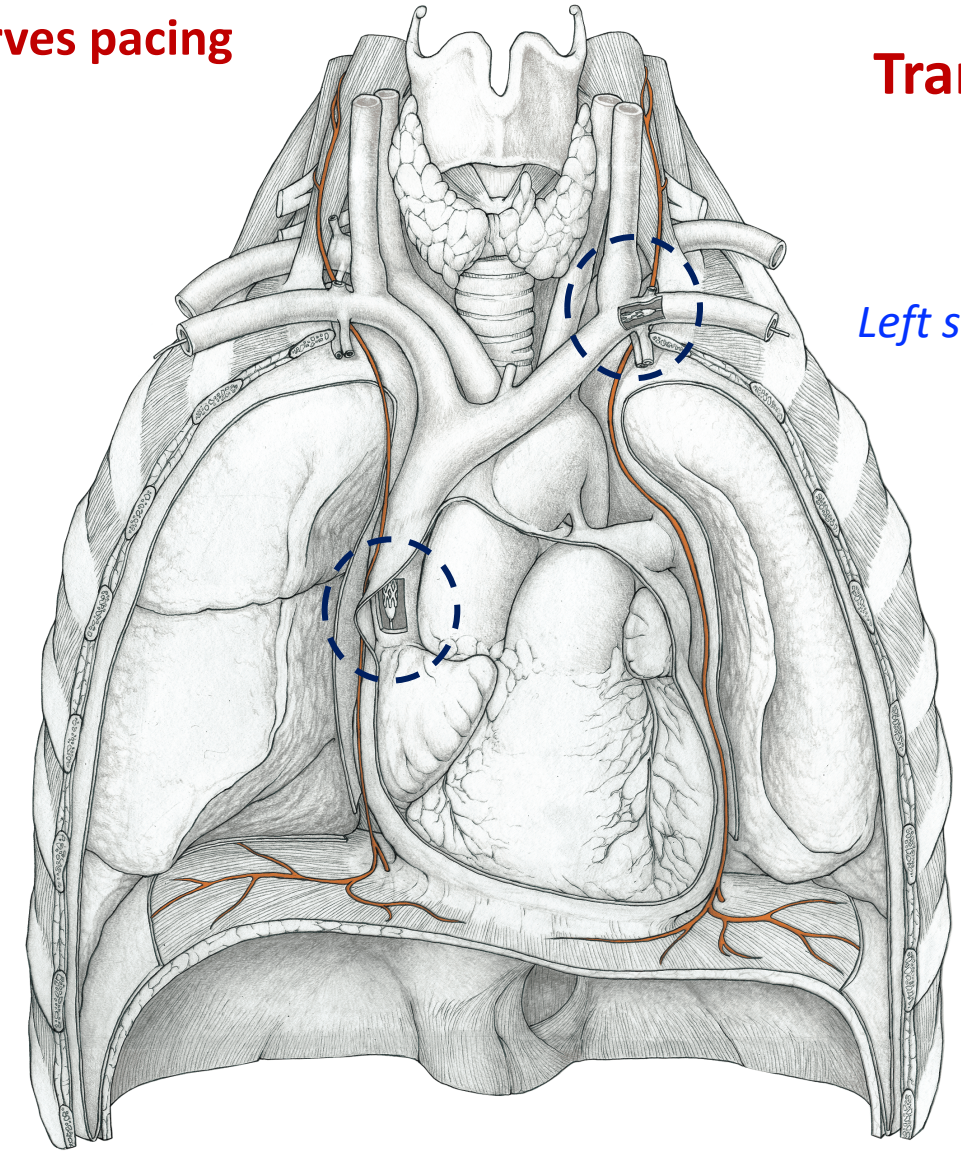




Crit Care Med 2020; 48:e362–e370

Diaphragm dysfunction: curative strategies

Temporary phrenic nerves pacing



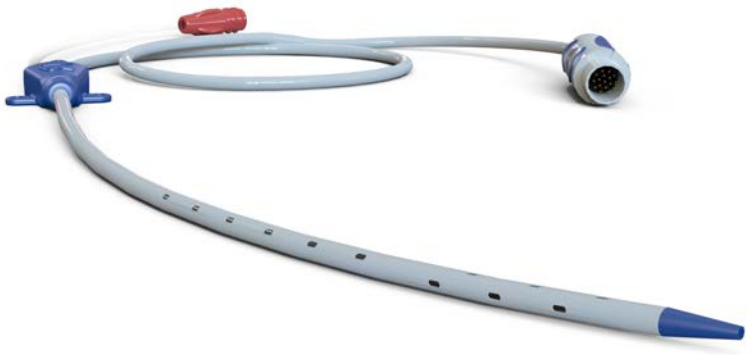
Transvenous approach

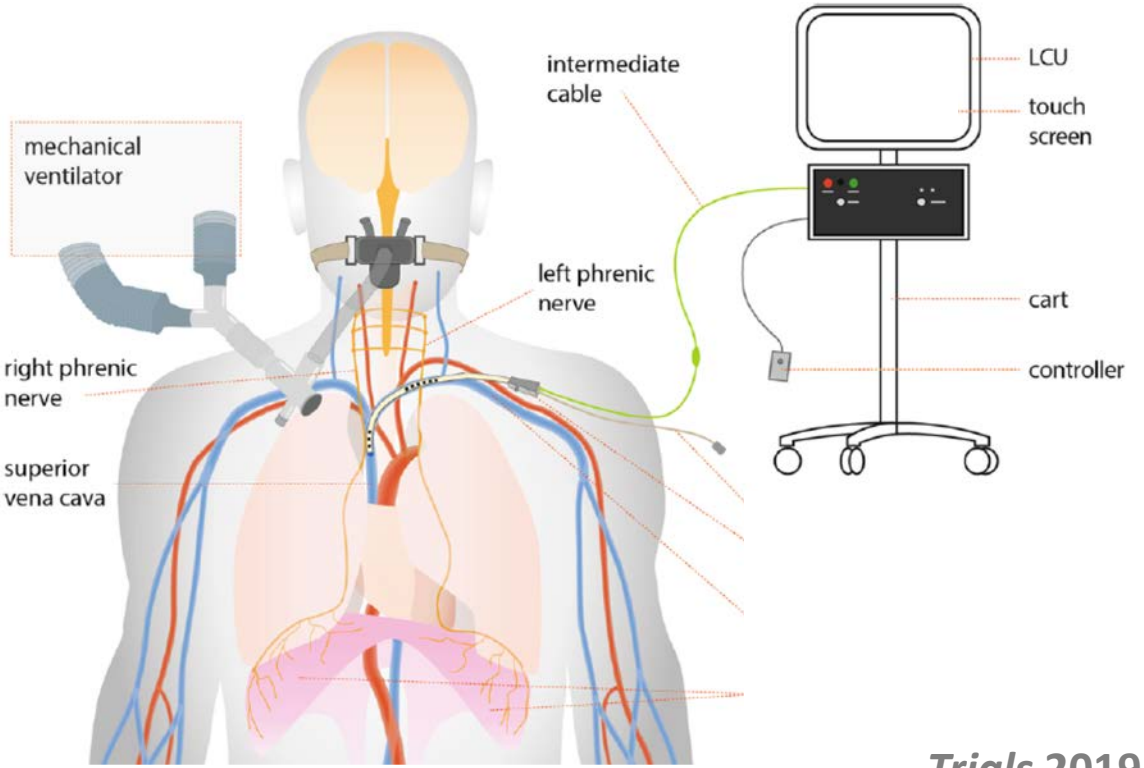
Left subclavier vein

Diaphragm dysfunction: curative strategies

Temporary transvenous diaphragm pacing vs. standard of care for weaning from mechanical ventilation: study protocol for a randomized trial

Douglas Evans[1,10], Deborah Shure[2], Linda Clark[1], Gerard J. Criner[3], Martin Dres[4], Marcelo Gama de Abreu[5], Franco Laghi[6], David McDonagh[7], Basil Petrof[8], Teresa Nelson[9] and Thomas Similowski[4*]





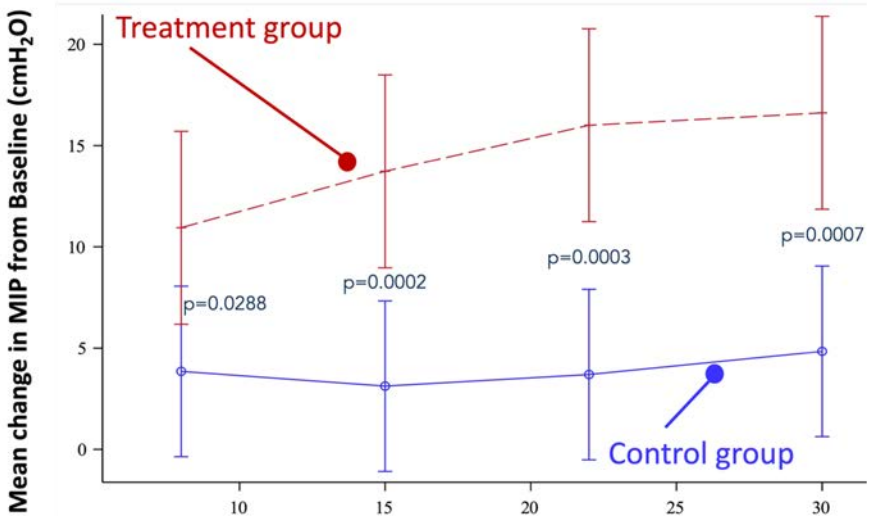
Trials 2019

Diaphragm dysfunction: curative strategies

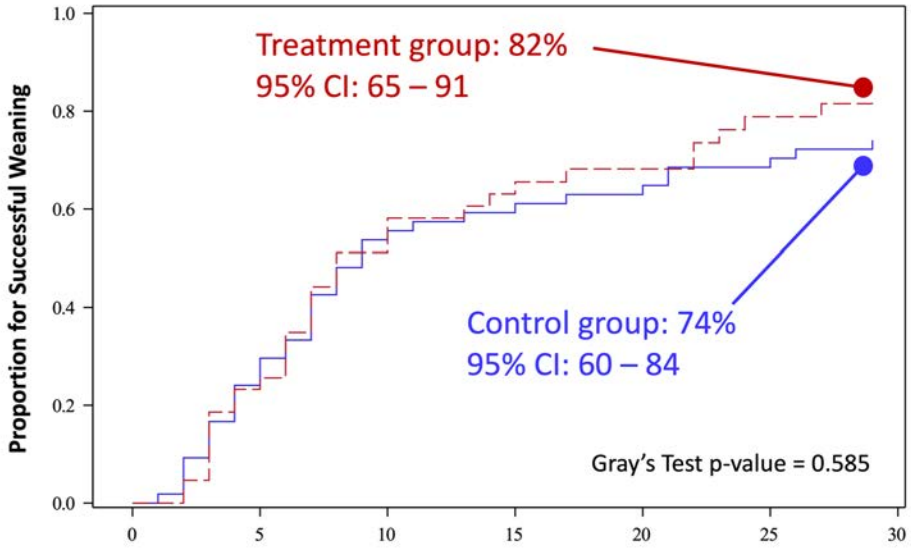
Preliminary findings of the Rescue-2 trial

transvenous diaphragm stimulation versus protocolized weaning

Change in MIP during the study



Weaning

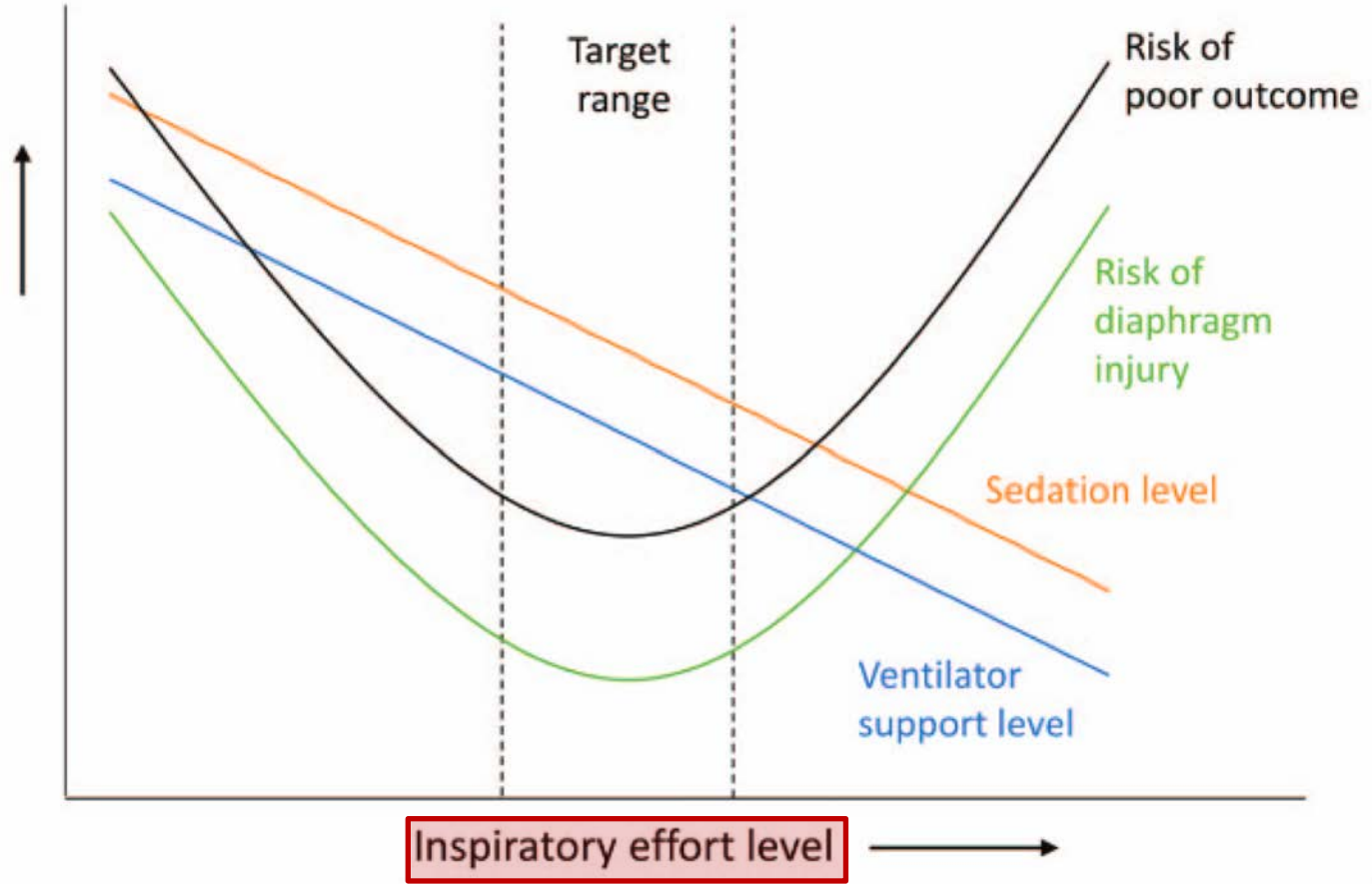


Rescue-3 is ongoing (>200 patients)

Diaphragm dysfunction: preventive strategies

Diaphragm-protective mechanical ventilation

Tom Schepens[a], Martin Dres[b,c], Leo Heunks[d], and Ewan C. Goligher[e,f,g]



Spontaneous breathing

Curr Opin Crit Care 2019, 25:77–85

Diaphragm dysfunction: preventive strategies

Lung- and Diaphragm-Protective Ventilation

Ewan C. Goligher[1,2,3], Martin Dres[4,5], Bhakti K. Patel[6], Sarina K. Sahetya[7], Jeremy R. Beitler[8], Irene Telias[1,2,9], Takeshi Yoshida[10], Katerina Vaporidi[11], Domenico Luca Grieco[12,13], Tom Schepens[14], Giacomo Grasselli[15,16], Savino Spadaro[17], Jose Dianti[1,2,18], Marcelo Amato[19], Giacomo Bellani[20], Alexandre Demoule[4,5], Eddy Fan[1,2,3,21], Niall D. Ferguson[1,2,3,21,22], Dimitrios Georgopoulos[11], Claude Guérin[23], Robinder G. Khemani[24,25], Franco Laghi[26,27], Alain Mercat[28], Francesco Mojoli[29], Coen A. C. Ottenheijm[30], Samir Jaber[31], Leo Heunks[32*], Jordi Mancebo[33*], Tommaso Mauri[13,14], Antonio Pesenti[13,14], and Laurent Brochard[1,9*]; for the Pleural Pressure Working Group, Acute Respiratory Failure Section of the European Society of Intensive Care Medicine

Goal	Potential Therapeutic Target*
Prevent overassistance myotrauma	Any 1 of: Pmus $\geq$ 3 to 5 cm H_2O ΔPdi $\geq$ 3 to 5 cm H_2O ΔPes $\leq$ −3 to −2 cm H_2O $P_{0.1}$ > 1 to 1.5 cm H_2O TFdi $\geq$ 15% EAdi $\geq$ target value selected on the basis of Pocc-EAdi index and above targets
Prevent underassistance myotrauma	Any 1 of: Pmus $\leq$ 10 to 15 cm H_2O ΔPdi $\leq$ 10 to 15 cm H_2O ΔPes $\geq$ −12 to −8 cm H_2O Pocc $\geq$ −20 to −15 cm H_2O $P_{0.1}$ < 3.5 to 5 cm H_2O TFdi $\leq$ 30% to 40% EAdi $\leq$ limit value selected on the basis of Pocc-EAdi index and above targets

American Journal of Respiratory and Critical Care Medicine Volume 202 Number 7 | October 1 2020

Méd. Intensive Réa. 29(2020)(in press)
DOI : 10.37051/mir-00014

Médecine Intensive Réanimation

MISE AU POINT / *UPDATE*

Dysfonction diaphragmatique en réanimation : physiopathologie, diagnostic et prise en charge

Diaphragmatic dysfunction in Intensive Care Unit: physiopathology, diagnosis and treatment

Q. Fossé[1,2] • M. Dres[1,2*]

Merci pour votre attention

martin.dres@aphp.fr