

Oxygénothérapie Hyperbare

Intérêt dans le traitement de la douleur ?

- Principes
- Indications
- Littérature

Principe et physiologie de l'OHB

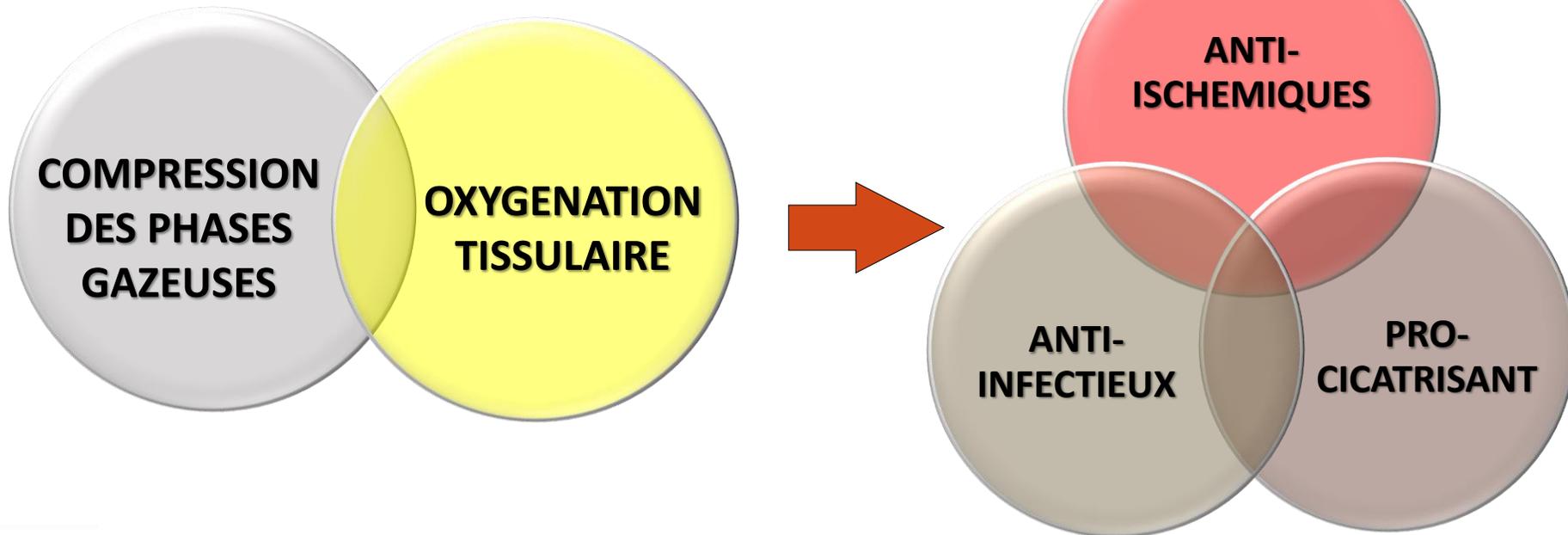
Modalité d'administration d'O₂ inhalé à des fins thérapeutiques sous une **pression supérieure** à la pression atmosphérique

↳ ↗ de la pression barométrique (*la technique*)

= « Effet pression »

↳ ↗ de la pression d'oxygène (*le médicament*)

= « Effet oxygénation »



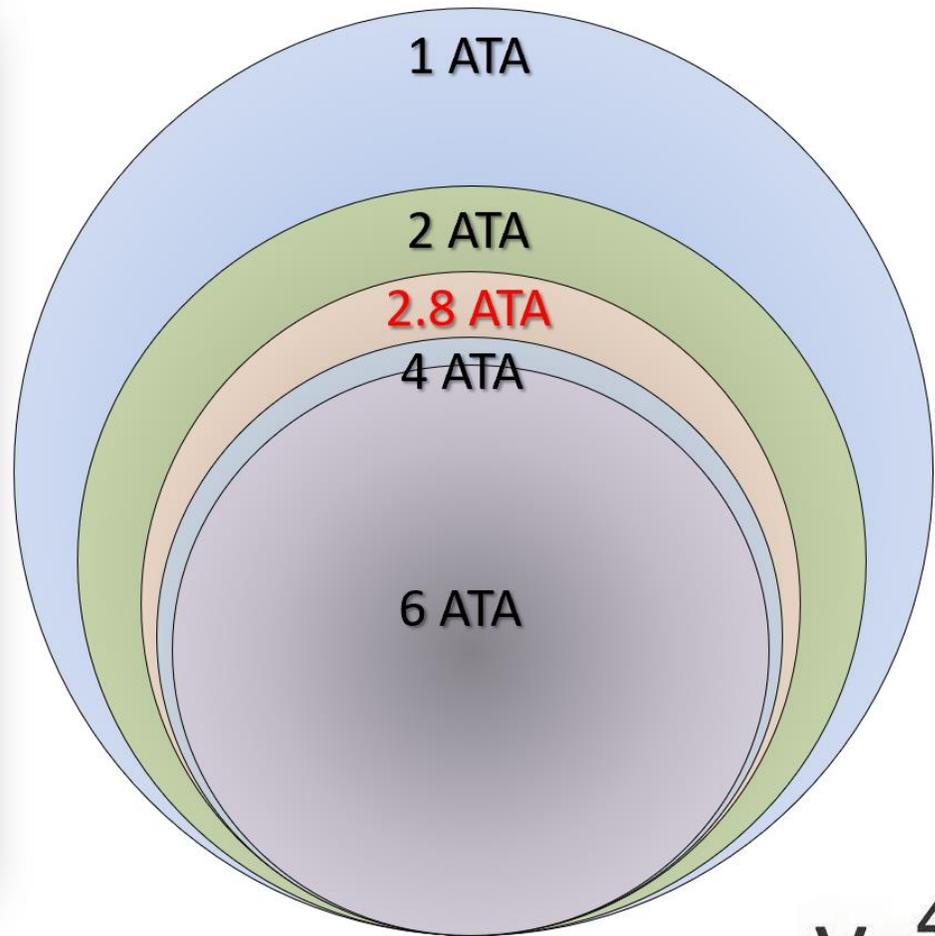
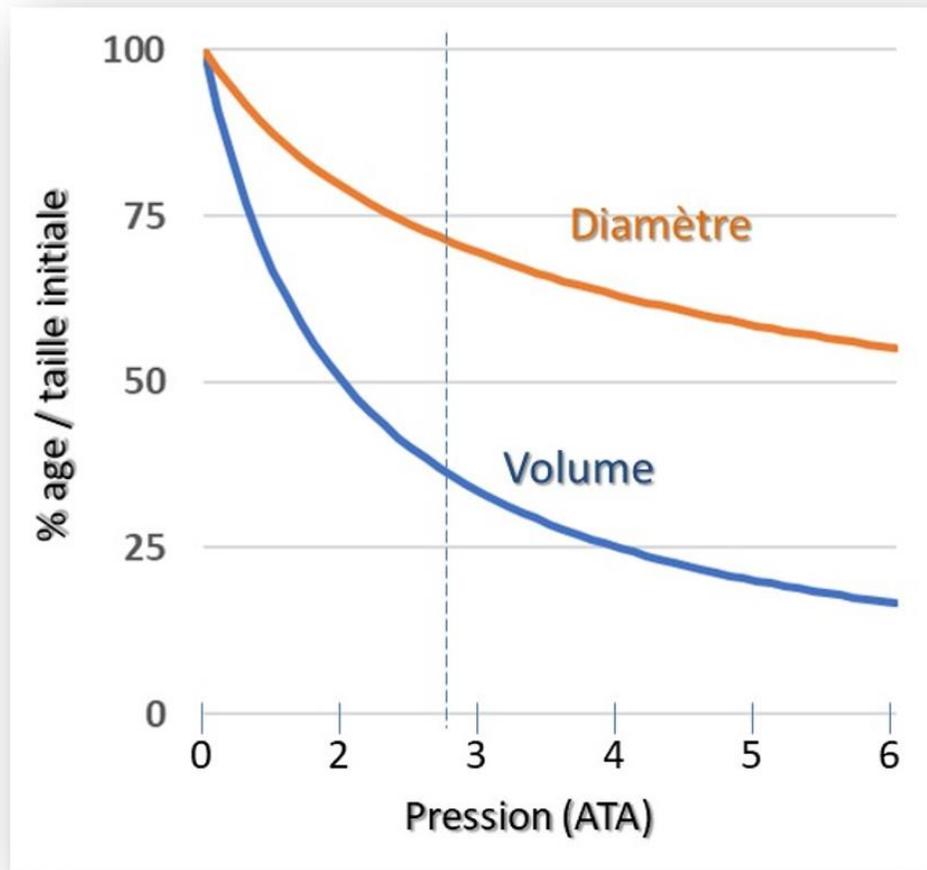
EFFETS PHYSIQUES

1 – Compression des phases gazeuses

Loi de Boyle et Mariotte

$$PV = cste$$



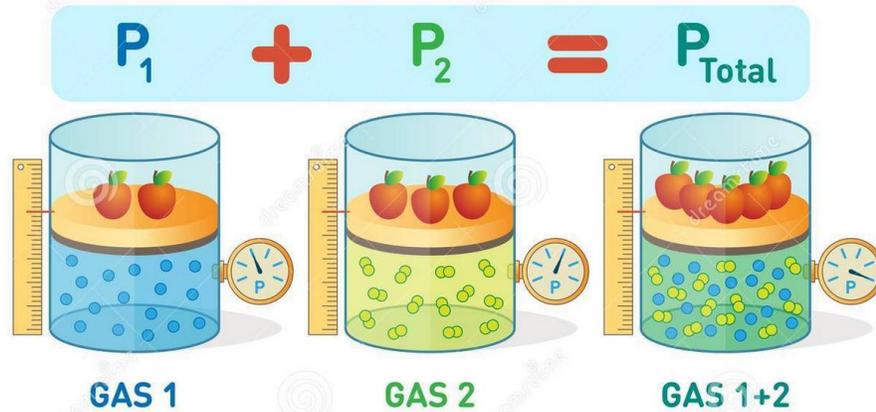


$$V = \frac{4}{3} \pi r^3$$

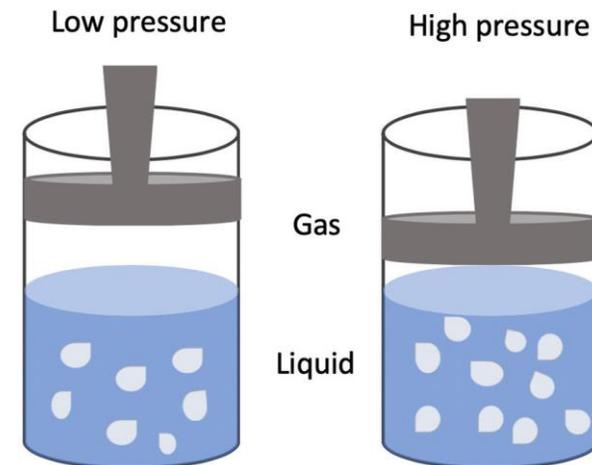
EFFETS PHYSIQUES

2 – Oxygénation tissulaire

DALTON'S LAW OF PARTIAL PRESSURE

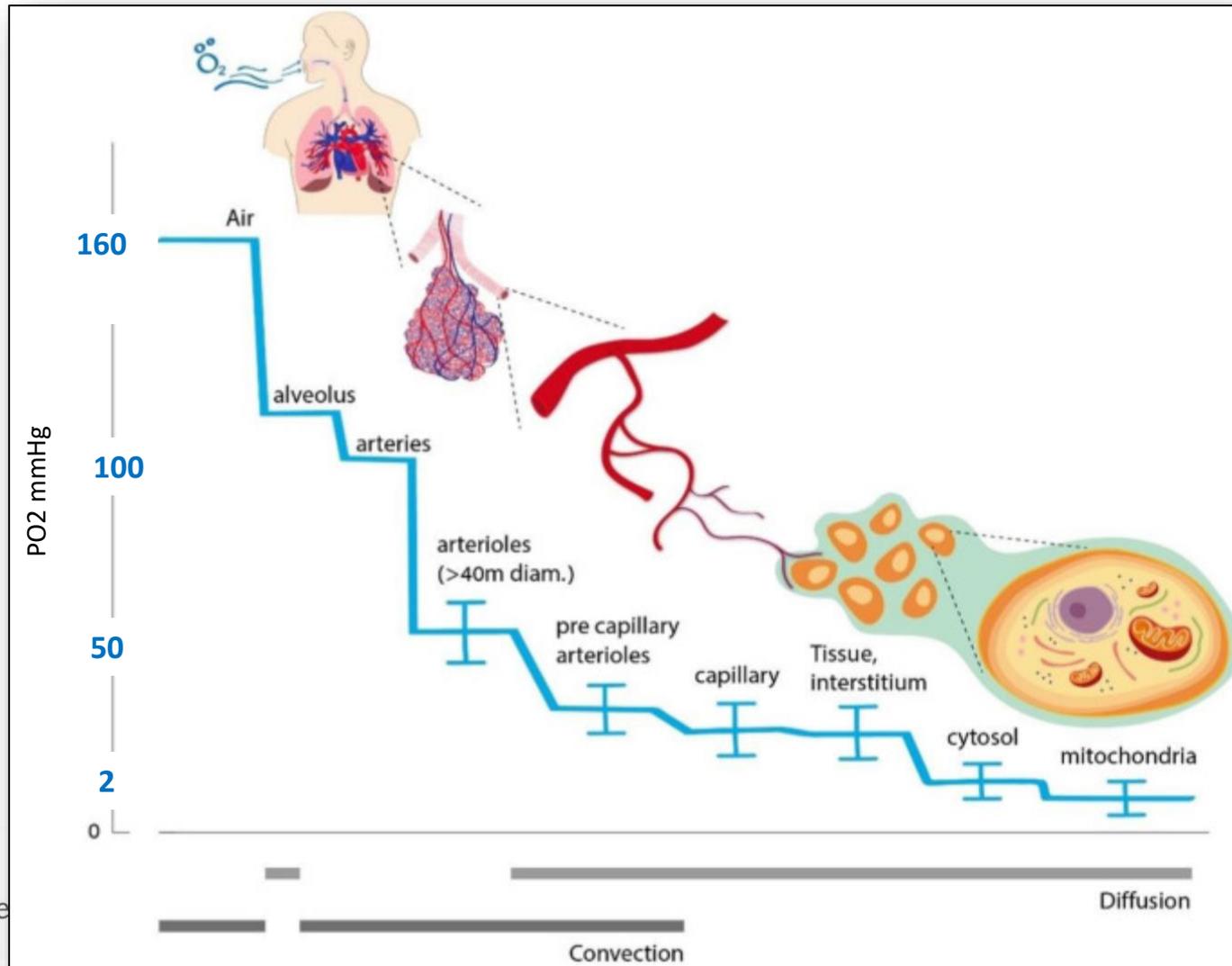


Henry's Law



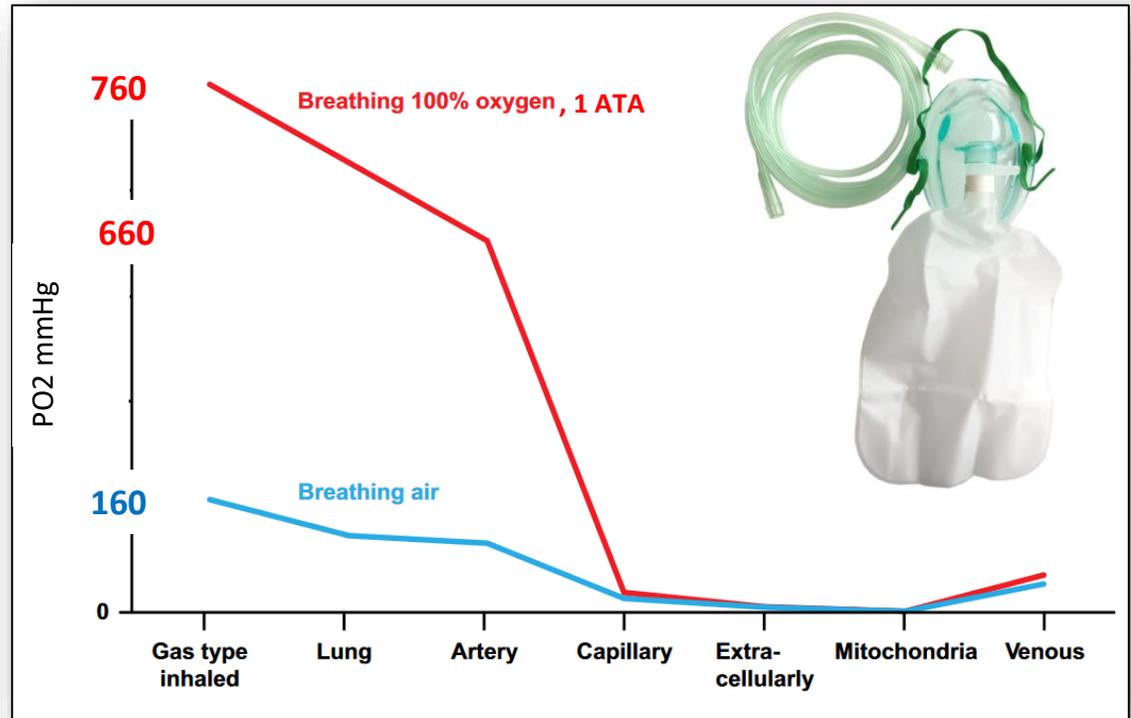
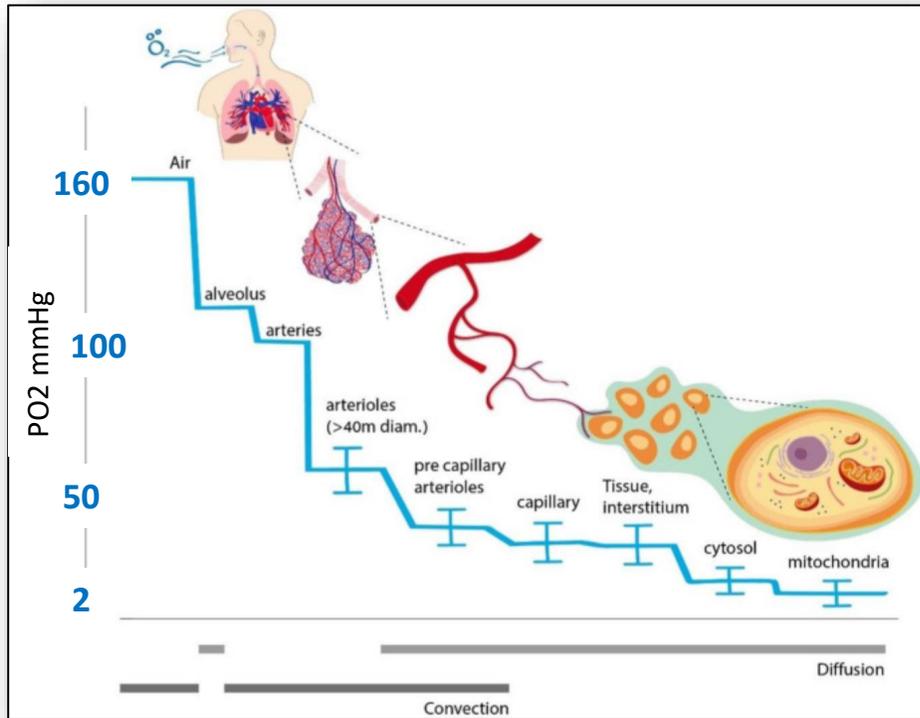
Principe et physiologie de l'OHB

Au niveau de la mer
(1 ATA, 760mmHg)



Principe et physiologie de l'OHB

O₂ = le médicament



HUG

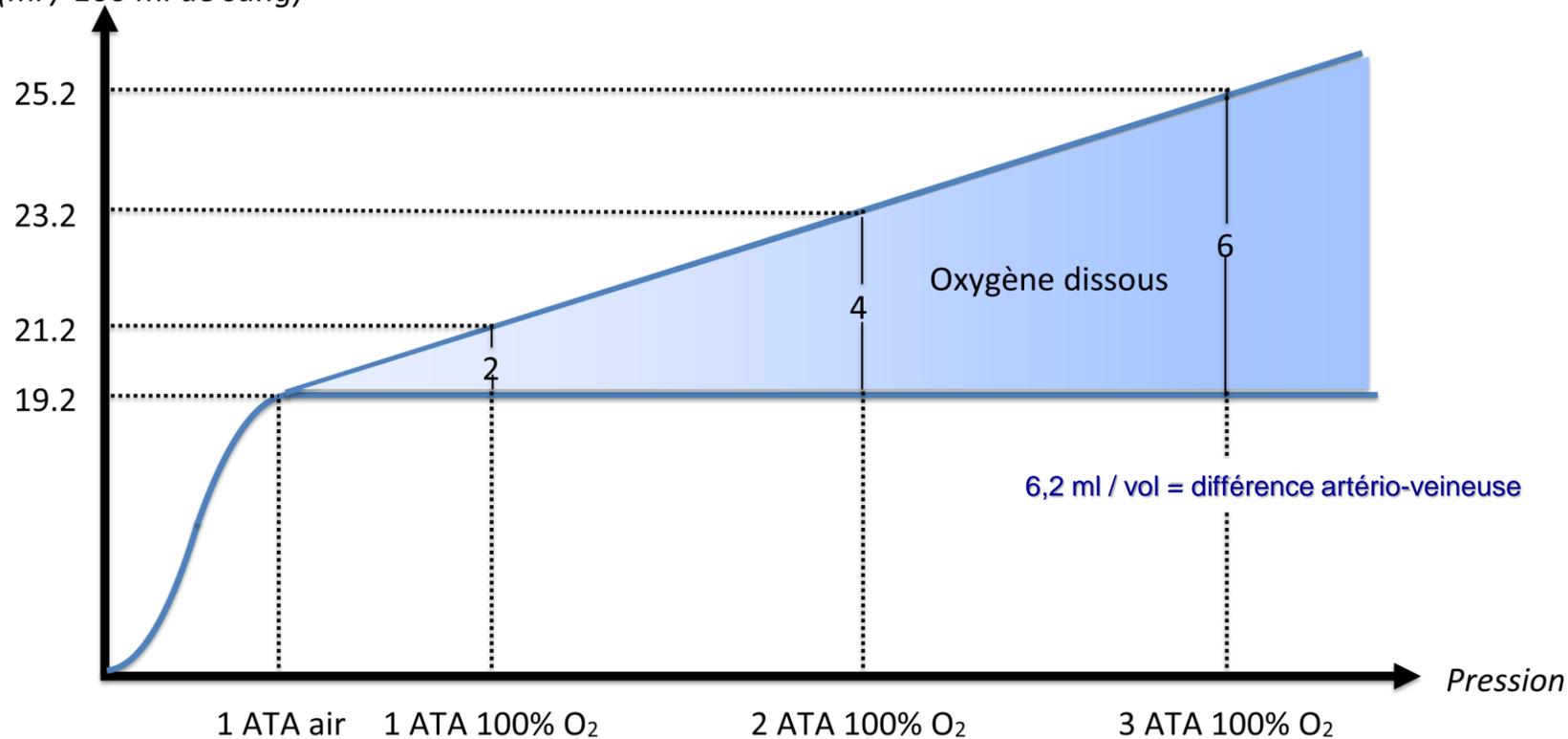
$$CaO_2 = (Hb \times 1,34 \times SaO_2) + (PaO_2 \times 0,003)$$

CaO₂ (ml/100ml)
19,7 vs 20,1 + 1,8 (dissout)

Principe et physiologie de l'OHB

L'OHB augmente significativement l'O₂ dissout (effet suppléance)

Contenu en O₂ (ml / 100 ml de sang)



$$\text{CaO}_2 = (\text{Hb} \times 1,34 \times \text{SaO}_2) + (\text{PaO}_2 \times 0,003)$$

OHB

	Air ambient	Oxygène pur		
Pression en ATA	1	1	2	3
PAO ₂ (mmHg)	100	673	1433	2193
PaO₂ (mmHg)	98	660	1400	2150
O ₂ <u>OxyHémoglobinique</u> (vol %)	19.7	20.1	20.1	20.1
O₂ Plasmatique (vol %)	0.285	1.88	3.8	6

ORIGINAL PAPERS

is reproduced exactly as written. It was originally published in the Journal of the most often cited papers in all of hyperbarics, yet it is extremely difficult to here as a reference, as well as foundational support for future indications that m. The ultimate findings of this paper are so profound that many don't realize we see today. I want to point out how crucial these findings are to sustaining ansport has been compromised for any reason – frostbite, arterial occlusion of any kind, stroke, heart attack, chemotherapy, radiation therapy, etc.) Hyperbarics is not a cure in any of these indications, but as stated in this paper, it can sustain life until other interventions can be arranged.



Life Without Blood

(A study of the influence of high atmospheric pressure and hypothermia on dilution of the blood)

by

I. BOÉREMA(*), N. G. MEYNE, W. K. BRUMMELKAMP
S. BOUMA, M. H. MENSCH, F. KAMERMANS, M. STERN HANF
and W. VAN AALDEREN

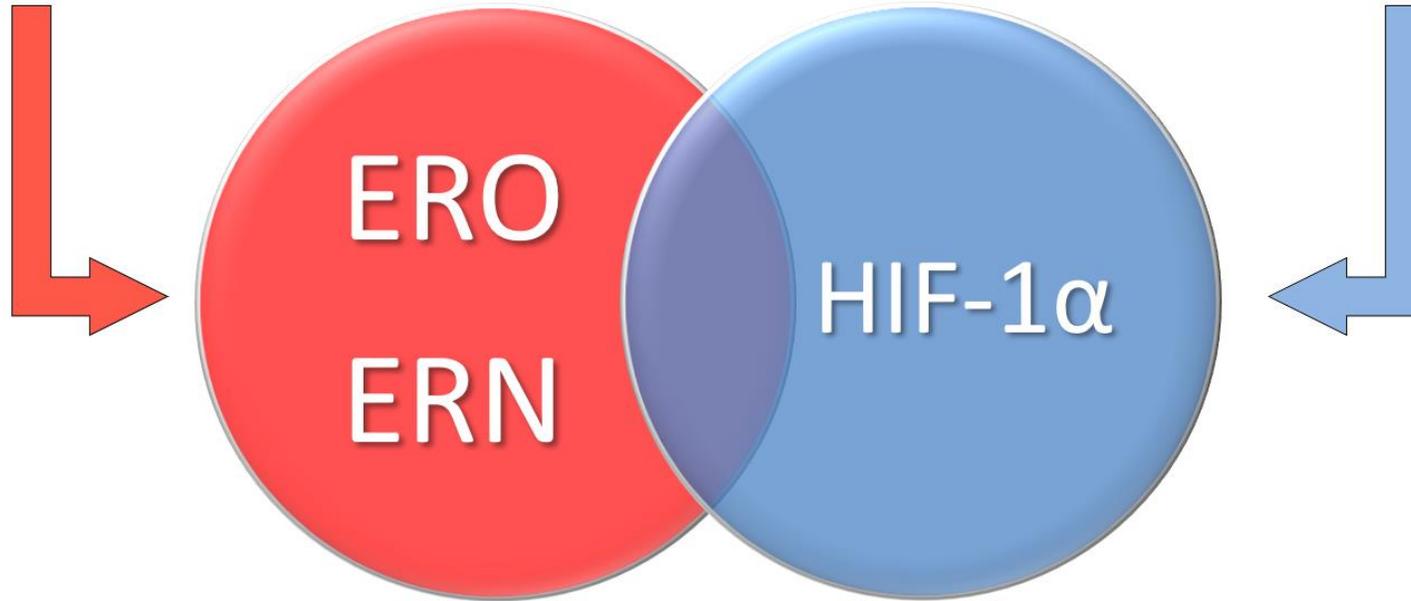
(from the Surgical Department of the University of Amsterdam)

When in 1948 we (first al research) started our experiment on hypothermia¹¹⁻¹³ our ultimate aim was to reduce the metabolism of a warm-blooded animal to such an extent that all the physiological processes would almost come to a standstill.

EFFETS BIOLOGIQUES

↗ PO_2

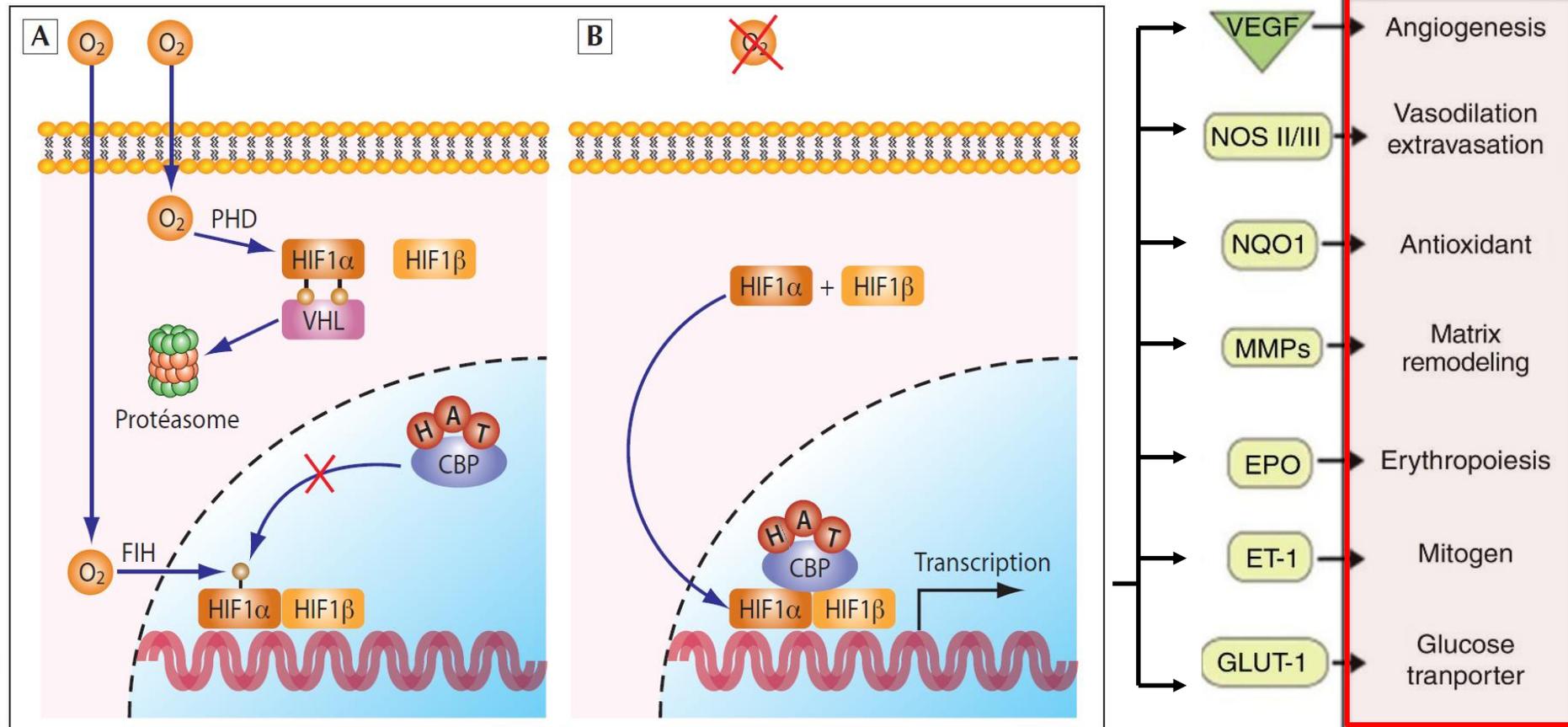
Alternance
Hyperoxie/Normoxie



Action sur les HIF-1 α

Hyperbaric oxygen therapy activates hypoxia-inducible factor 1 (HIF-1), which contributes to improved wound healing in diabetic mice

Vivekananda Gupta Sunkari, PhD^{1*}; Folke Lind, MD, PhD²; Ileana Ruxandra Botusan, MD, PhD¹; Abad Kashif, MD³; Zhao-Jun Liu, PhD³; Seppo Ylä-Herttuala, PhD⁴; Kerstin Brismar, MD, PhD¹; Omaid Velazquez, MD, PhD³; Sergiu-Bogdan Catrina, MD, PhD¹

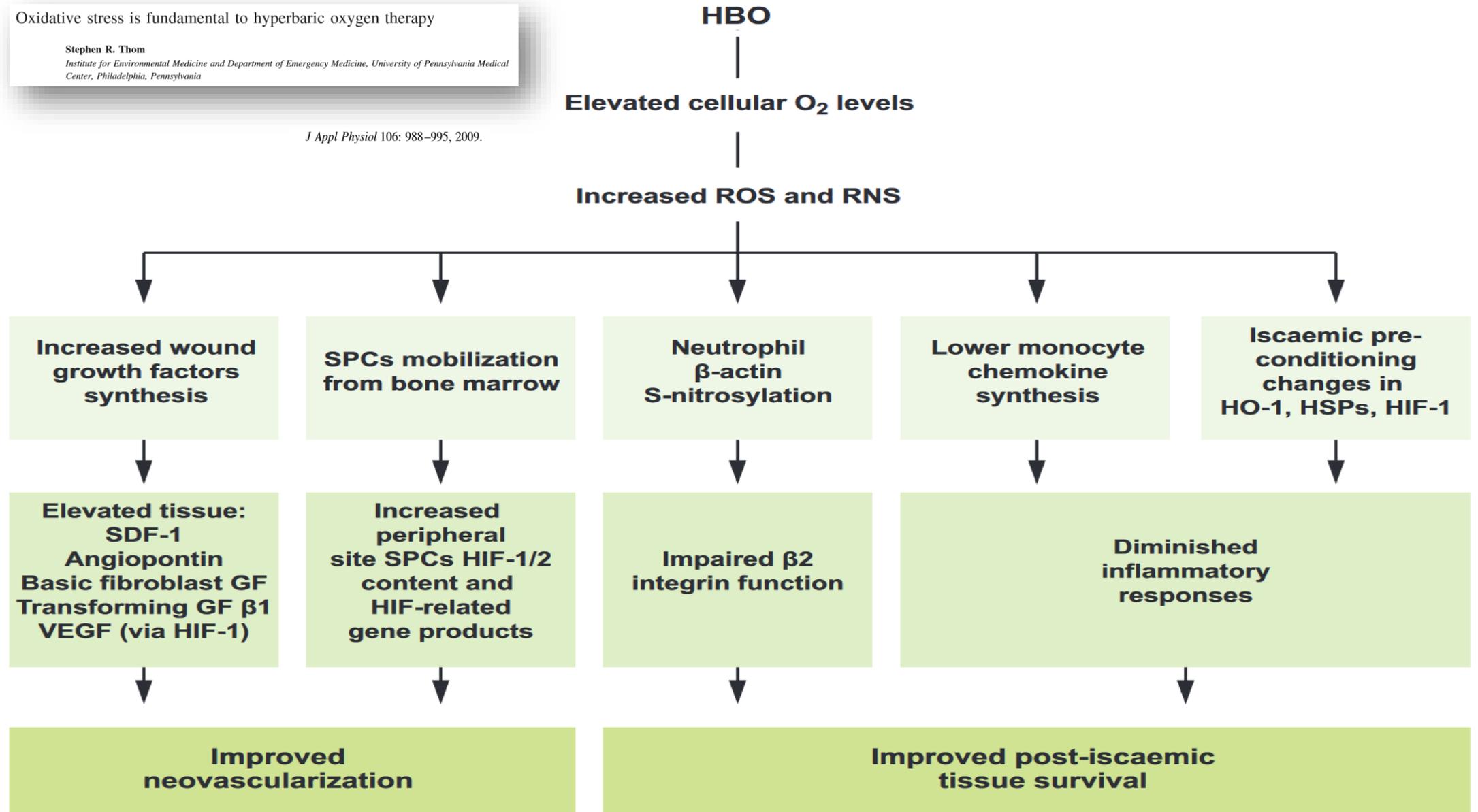


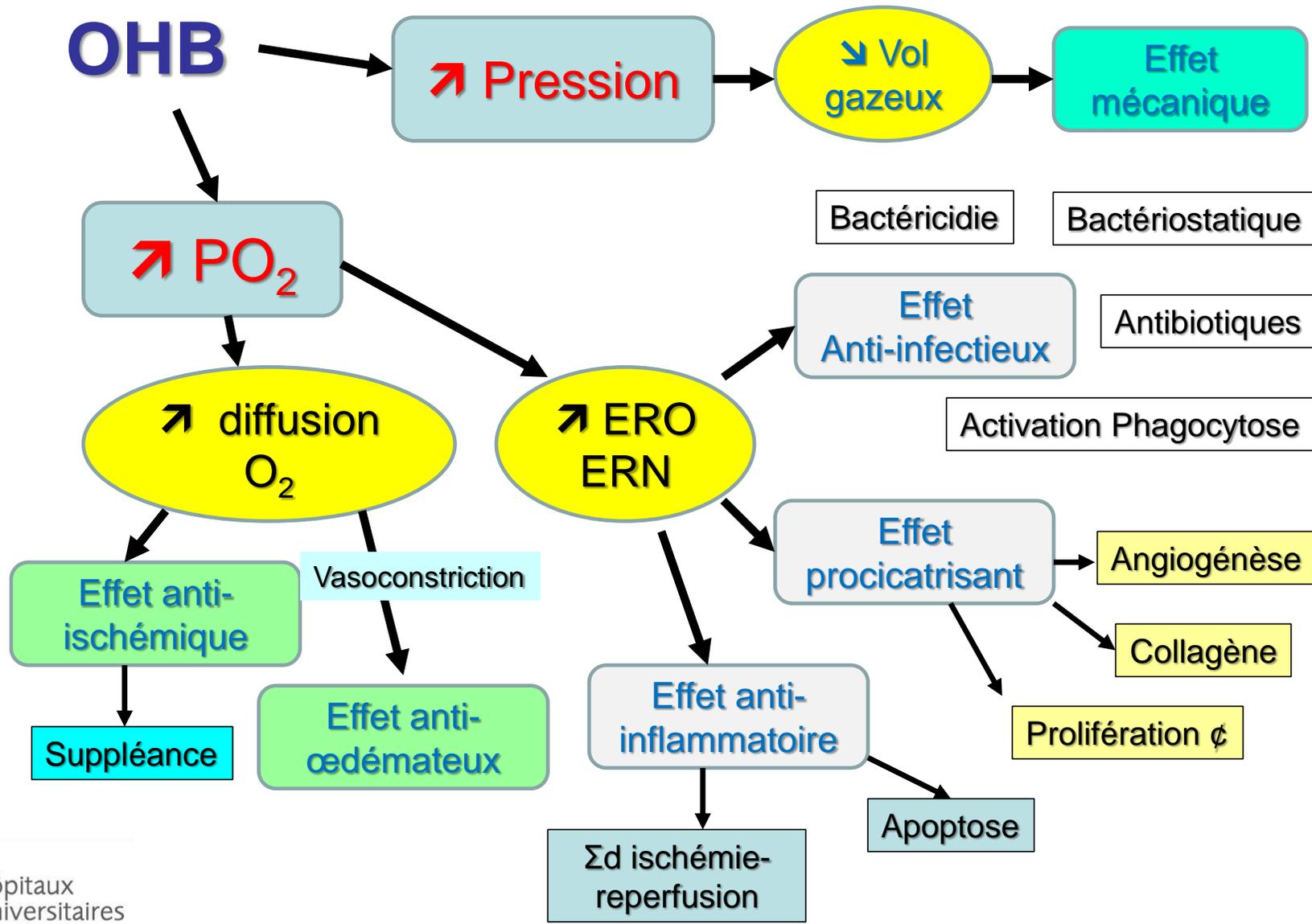
Oxidative stress is fundamental to hyperbaric oxygen therapy

Stephen R. Thom

Institute for Environmental Medicine and Department of Emergency Medicine, University of Pennsylvania Medical Center, Philadelphia, Pennsylvania

J Appl Physiol 106: 988–995, 2009.





- ✓ Aéroembolismes
- ✓ Accidents de décompression
- ✓ Intox CO
- ✓ Infections à germes anaérobies ou mixtes

Urgences

- ✓ ORN mandibulaire
- ✓ Lésions radio-induites
- ✓ Cystites radiques
- ✓ Rectites

Oncologie

OHB

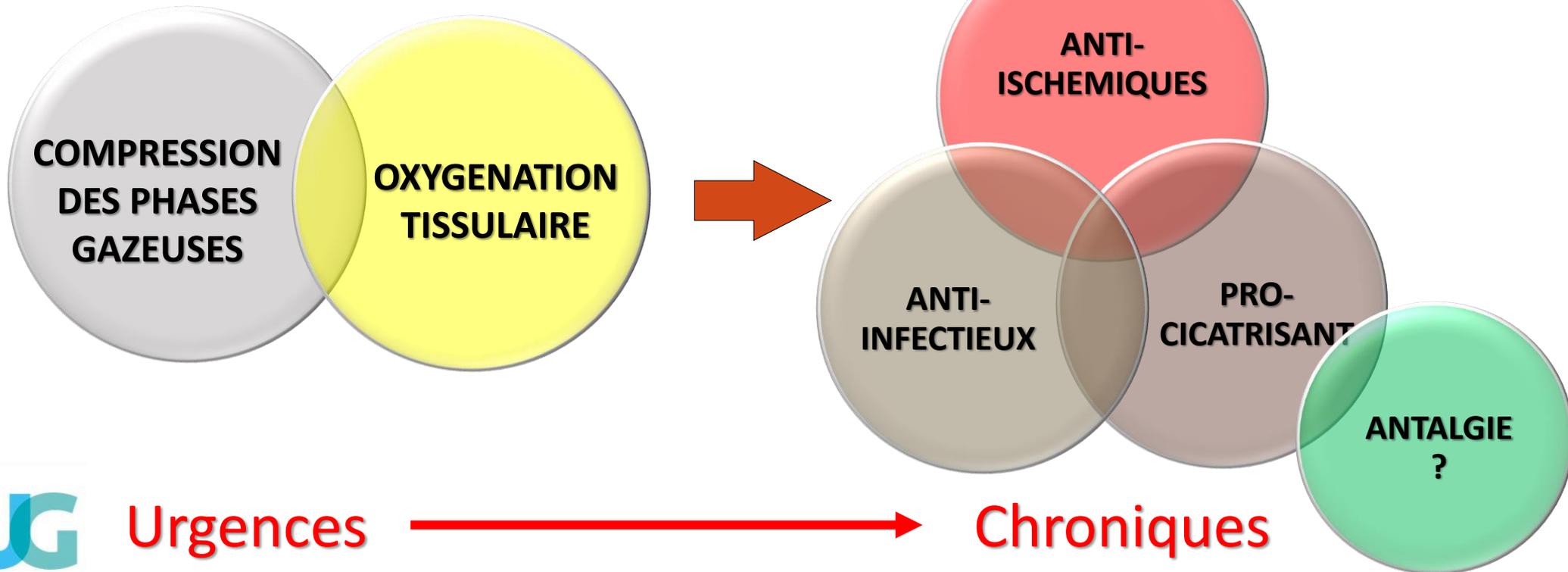
- ✓ Crush syndrom
- ✓ Retards de cicatrisation
- ✓ Ostéomyélites Chroniques

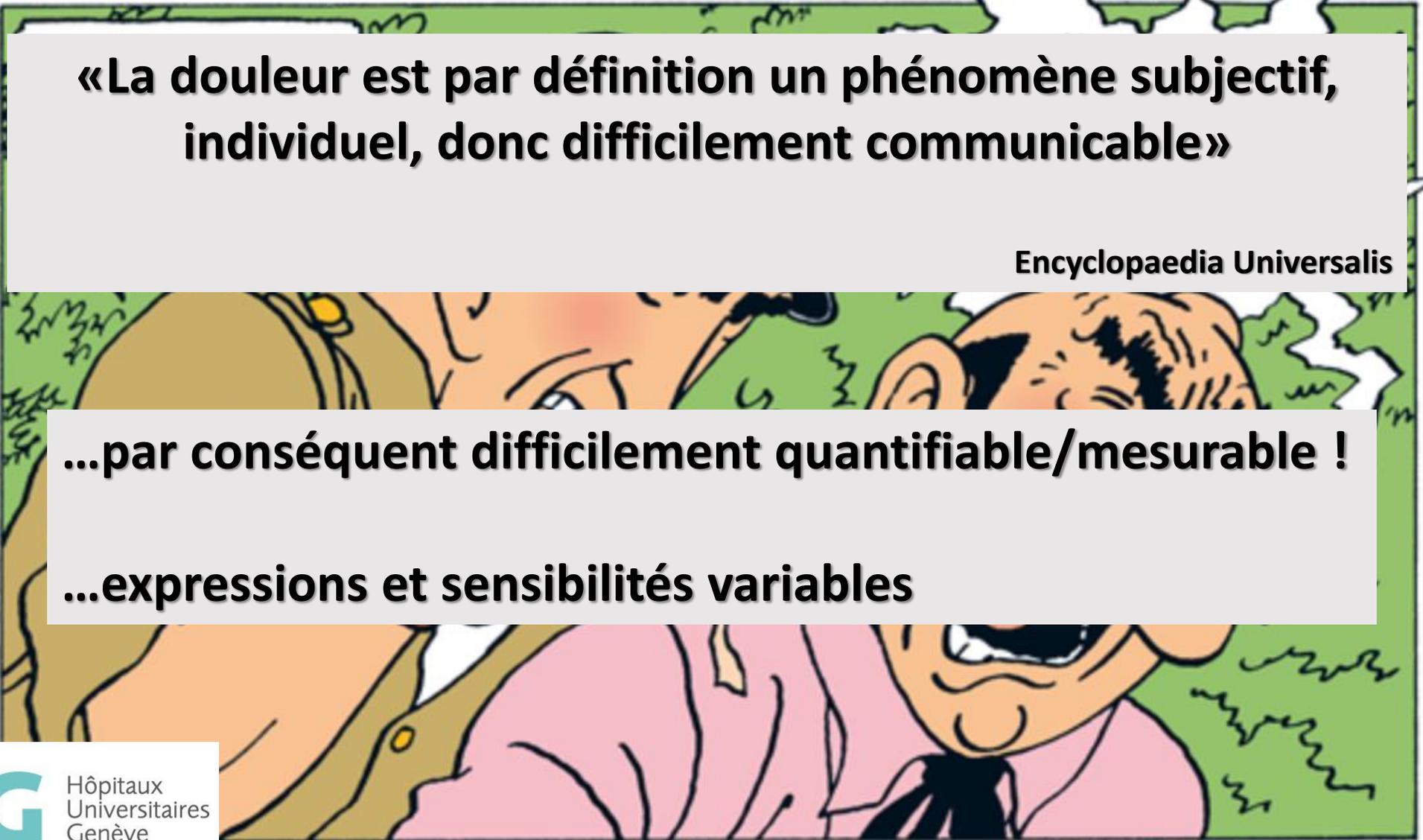
Traumato

- ✓ Greffes et lambeaux compromis

Autres

- ✓ Pieds Diabétiques
- ✓ Surdit  brusque
- ✓ Pneumatose kystique
- ✓ Ulcères artériels (veineux ?)



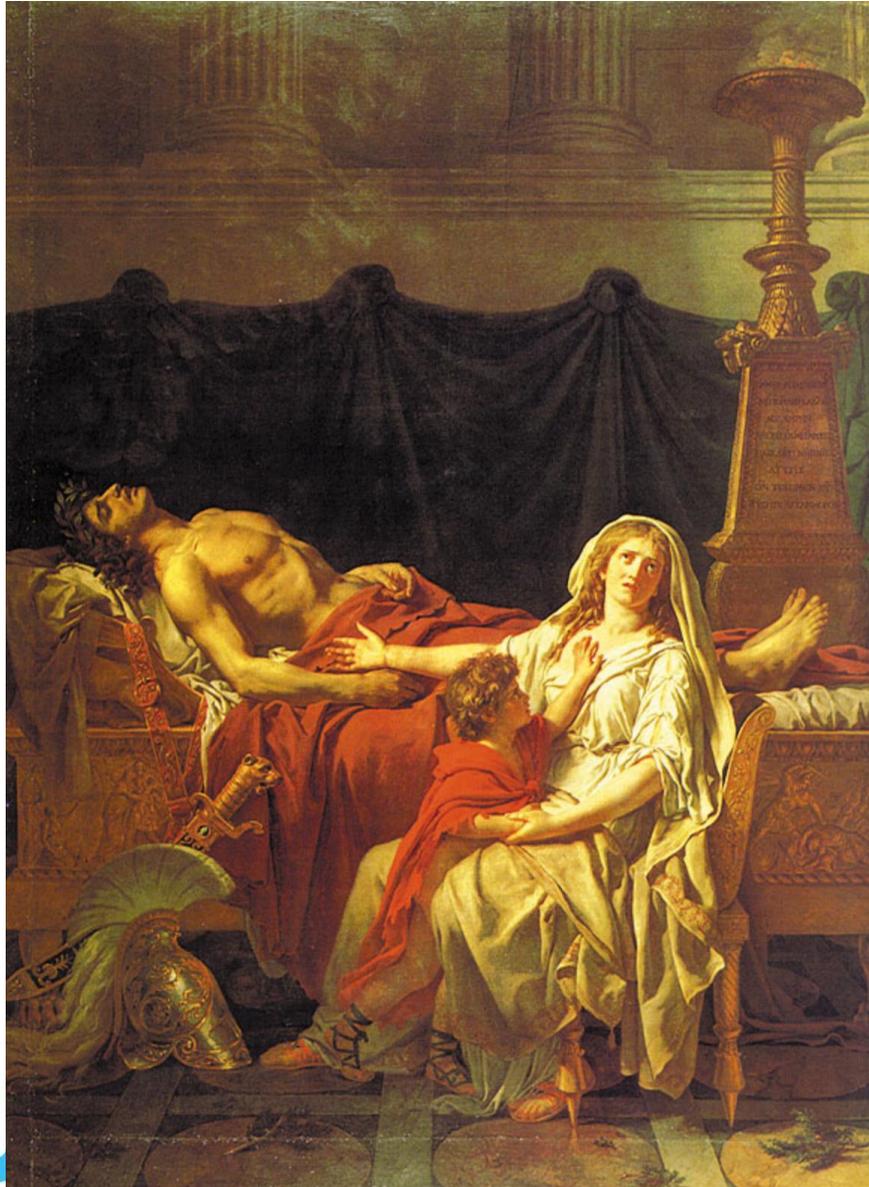


**«La douleur est par définition un phénomène subjectif,
individuel, donc difficilement communicable»**

Encyclopaedia Universalis

...par conséquent difficilement quantifiable/mesurable !

...expressions et sensibilités variables



«La douleur et les regrets d'Andromaque sur le corps d'Hector» David Jacques-Louis, 1783



Rôle de l'OHB ?

**Nociceptive
Inflammatoire
Neuropathique**

Pubmed: «hyperbaric oxygen therapy + pain» -> 786 results

Opioid Receptors shown to be part of Hyperbaric oxygen's pain-relieving effects

PMID: 24390852



Hyperbaric Therapy reduces pain following nerve injury PMID: 24390961



5 HBOT sessions produced a prolonged reversal effect on on-going inflammatory pain

PMID: 23680474



10 HBOT sessions were successful in producing a quick and long-lasting relief in pain

PMID: 22354664



4 HBOT sessions at very high dosages was able to produce both immediate and long-lasting pain relief PMID: 20418186



Hyperbaric oxygen therapy reduces pain and inflammatory markers PMID: 21596875



Potential use of HBOT for pain-relief when NSAIDS are contraindicated PMID: 16750177



Hyperbaric Oxygen Therapy: A New Treatment for Chronic Pain?

Ainsley M. Sutherland, MD, PhD*; Hance A. Clarke, MD, PhD*;
Joel Katz, PhD*[†]; Rita Katznelson, MD*[‡]

*Department of Anesthesia and Pain Management, Toronto General Hospital, University Health Network, Toronto, ON; [†]Department of Psychology, York University, Toronto, ON; [‡]Hyperbaric Medical Unit, Department of Anesthesia and Pain Management, Toronto General Hospital, Toronto, ON, Canada

Review Article

Mechanistic Rationale and Clinical Efficacy of Hyperbaric Oxygen Therapy in Chronic Neuropathic Pain: An Evidence-Based Narrative Review

Simone Schiavo ¹, Julian DeBacker,¹ Carine Djaiani,¹ Anuj Bhatia,² Marina Englesakis,³ and Rita Katznelson ¹

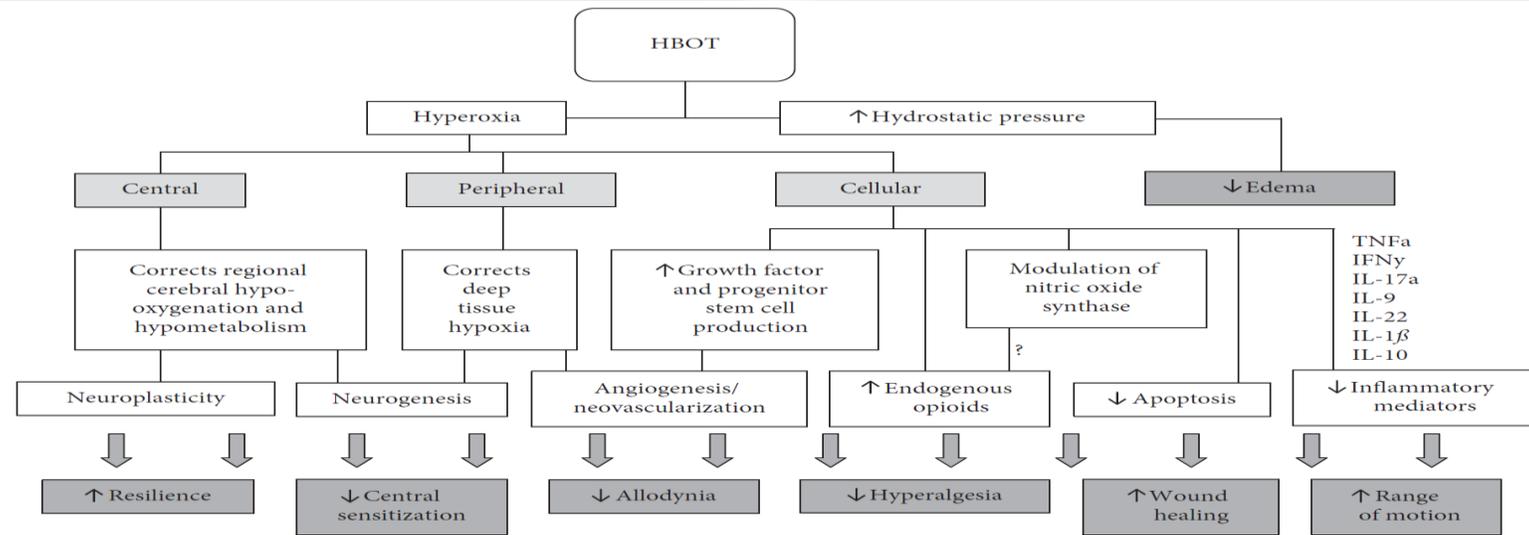


FIGURE 1: HBOT mechanisms and effect on chronic neuropathic pain disorders. HBOT: hyperbaric oxygen therapy; ROS: reactive oxygen species; RNS: reactive nitrogen species; TNFα: tumor necrosis factor-alpha; IFNγ: interferon-gamma; IL: interleukin.



TABLE 6: HBOT and neuropathic pain–human studies characteristics.

First author, year	Article title	Pain model	Study design, n patients	Inclusion criteria	Intervention (pressure, duration, sessions)		
Kiralp, 2004 [33]	Effectiveness of hyperbaric oxygen therapy in the treatment of complex regional pain syndrome	CRPS	RCT, n = 71 (37 intervention, 34 placebo)	Clinical CRPS, type I or II	2.4 ATA, 90 min x 15	RCT, n = 71 (37 intervention, 34 placebo)	Placebo: 2.4 ATA breathing air, 90 min x 15, once daily
Peach, 1995 [35]	Hyperbaric oxygen and the reflex sympathetic dystrophy syndrome: a case report	CRPS	Observational case reports, n = 1	Clinical CRPS, type I	2.8 ATA, 46 min x1 + 2.0 ATA, 90 min x 1 + 2.4 ATA, 90 min x 1		Observational case reports, n = 1
Williams, 2009 [36]	Chronic regional pain syndrome after subtalar arthrodesis is not prevented by early hyperbaric oxygen	CRPS	Observational case reports, n = 1	Clinical CRPS type I, Norman Harden and Bruhl diagnostic criteria	2.2 ATA, 90 min x 1	Observational case reports, n = 1	None
Katznelson, 2016 [37]	Successful treatment of lower limb complex regional pain syndrome following three weeks of hyperbaric oxygen therapy	CRPS	Observational case reports, n = 1	Clinical CRPS, type I	2.4 ATA, 90 min x 1		Observational case reports, n = 1
Binkley, 2019 [38]	Successful treatment of long standing complex regional pain syndrome with hyperbaric oxygen therapy	CRPS	Observational case reports, n = 1	Clinical CRPS, type I	2.4 ATA, 90 min x 1 Second course 7 months later, 2.0 ATA, 90 min x 3	Observational case reports, n = 1	None
van Ophoven, 2004 [39]	Hyperbaric oxygen for the treatment of interstitial cystitis: long-term results of a prospective pilot study	IC	Observational prospective case series, n = 6	Symptom criteria of the National Institute of Diabetes, Digestive and Kidney Diseases for IC	2.4 ATA, 90 min x 15		Observational case reports, n = 1
van Ophoven, 2006 [40]	Safety and efficacy of hyperbaric oxygen therapy for the treatment of interstitial cystitis: A randomized, sham controlled, double-blind trial	IC	RCT, double-blind, sham controlled, n = 21 (14 intervention, 7 placebo)	Diagnostic criteria of the National Institute of Diabetes and Digestive and Kidney Diseases for IC	2.4, 90 min x 15	Observational case reports, n = 1	None
Tanaka, 2011 [41]	Hyperbaric oxygen therapy for painful bladder syndrome/ interstitial cystitis resistant to conventional treatments: long-term results of a case series in Japan	IC	Observational prospective case series, n = 11	Diagnostic criteria of the National Institute of Diabetes and Digestive and Kidney Diseases for IC	2.0 ATA, 60 min (pts) or x 20		Observational case reports, n = 1
Wenzler, 2017 [42]	Treatment of ulcerative compared to nonulcerative interstitial cystitis with hyperbaric oxygen: a pilot study	IC	Observational prospective pilot case series, n = 9	Diagnostic criteria of the National Institute of Diabetes and Digestive and Kidney Diseases for IC	2.2 ATA, 90 min x 15	Observational prospective case series, n = 6	None

2015

REVIEW ARTICLE

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Hindawi
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Volume 2021, Article ID 8817504, 20 pages
<https://doi.org/10.1155/2021/8817504>



Review Article

Mechanistic Rationale and Clinical Efficacy of Hyperbaric Oxygen Therapy in Chronic Neuropathic Pain: An Evidence-Based Narrative Review

Simone Schiavo ¹, Julian DeBacker,¹ Carine Djaiani,¹ Anuj Bhatia,² Marina Englesakis,³ and Rita Katznelson ¹

Rongeur:

- Indices en faveur d'une diminution de l'inflammation (TNF α ,...) et de la perception de la douleur
- Rôle du NO et modulation de la douleurs via dynorphin et récepteurs opiacés
- Diminution œdème
- Pas d'effet de l'O₂ seul ou compression seul

Humain:

- Effet clinique observé dans certaines pathologies, mais faible niveau d'évidence (observational) avec méthodologie variable et petits collectifs de patients

Hyperbaric oxygen therapy for delayed onset muscle soreness and closed soft tissue injury (Review)

Bennett MH, Best TM, Babul-Wellar S, Taunton JE

Nine small trials involving 219 participants were included. Two trials compared HBOT versus sham therapy on acute closed soft tissue injuries (ankle sprain and medial collateral knee ligament injury respectively). The other seven trials examined the effect of HBOT on DOMS following eccentric exercise in unconditioned volunteers.

There was insufficient evidence from comparisons tested within randomised controlled trials to establish the effects of HBOT on ankle sprain or acute knee ligament injury, or on experimentally induced DOMS. There was some evidence that HBOT may increase interim pain in DOMS. Any future use of HBOT for these injuries would need to have been preceded by carefully conducted randomised controlled trials which have demonstrated effectiveness.

9 études, 219 participants
 Protocoles OHB hétérogènes
 Pas de preuve suffisante en faveur ou contre OHB

Hyperbaric oxygen in the treatment of migraine with aura

J R Wilson ¹, B H Foresman, R G Gamber, T Wright

8 participantes
 100% O2 à 1 ATA vs. 100% O2 à 2,4 ATA
 Diminution subjective de la douleur par OHB

Hyperbaric oxygen therapy in cluster headache

Francesco Di Sabato ¹, Bruno M Fusco, Paolo Pelaia, Mario Giacobozzo

13 participants
 100% O2 à 2,5 ATA vs. Placebo
 Diminution de la durée des symptômes

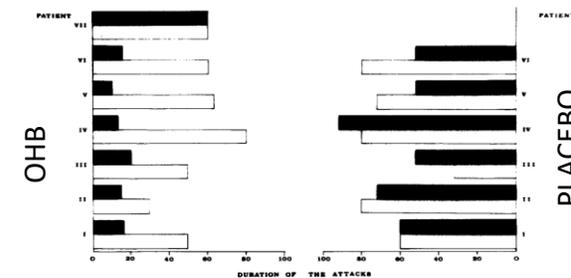


Fig. 1. Duration of cluster headache attacks in each patient before (empty bars) and during (filled bars) exposure to the hyperbaric chamber. The value before treatment is an arithmetical mean of the duration of the 3 attacks preceding the test. Patients receiving hyperbaric oxygen are represented on the left; patients not receiving the effective treatment (placebo procedure) are represented on the right.

Hyperbaric Oxygen Therapy Can Diminish Fibromyalgia Syndrome – Prospective Clinical Trial

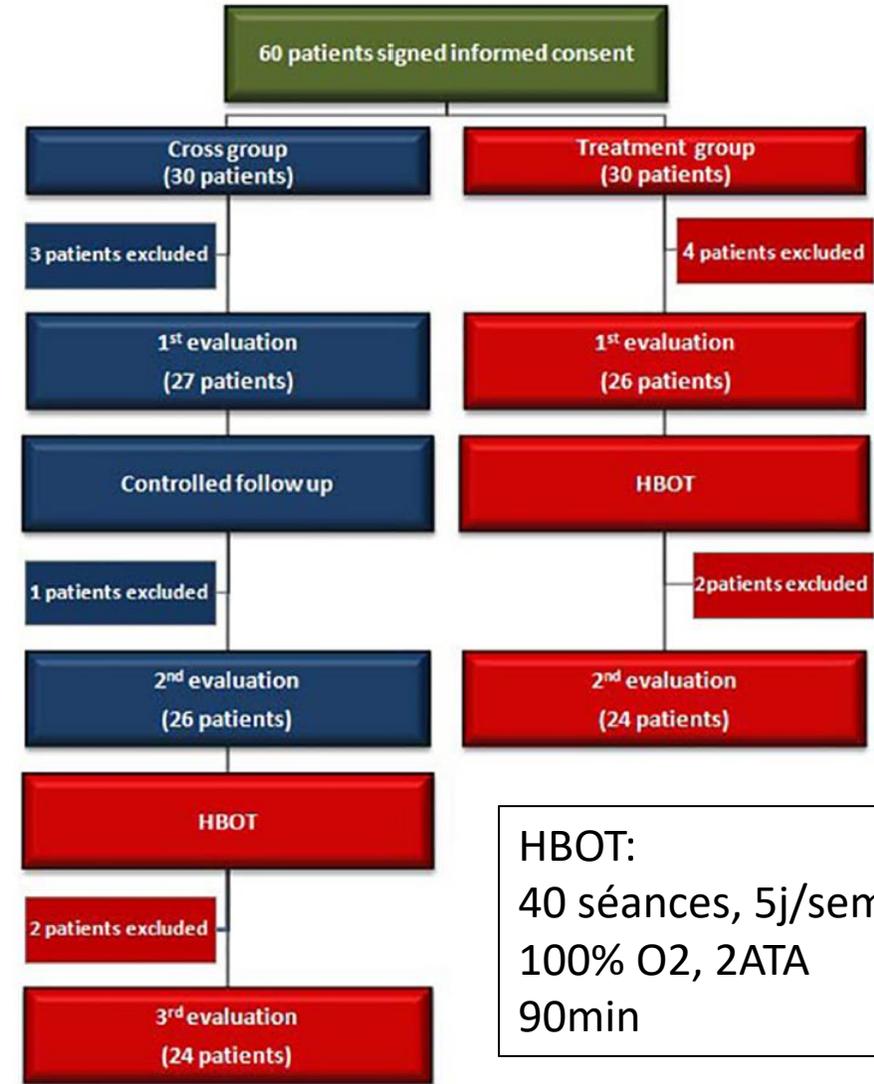
2014

Shai Efrati^{1,2,3,4*}, Haim Golan^{3,5}, Yair Bechor², Yifat Faran⁶, Shir Daphna-Tekoah^{6,7}, Gal Sekler⁸, Gregori Fishlev^{2,3}, Jacob N. Ablin^{9,3}, Jacob Bergan^{2,3}, Olga Volkov^{3,5}, Mony Friedman^{2,3}, Eshel Ben-Jacob^{1,4,8,10*}, Dan Buskila¹¹

Table 1. Demographic of patients' characteristics.

	Treated Group (n = 24)	Crossover Group (n = 26)	p Value
Age (years)	50.4±10.9	48.1±11.1	0.677
Years of education	17.1±3.5	14.8±3.0	0.019
Duration of fibromyalgia (years)	6.75±5.9	6.2±5.1	0.735
Number of children	2.38±1.21	2.95±1.43	0.156
Marital status: Married	21 (87.5%)	18 (69.2%)	0.239
Single	1 (4.1%)	5 (19.2%)	
Divorce	2 (8.3%)	1 (3.8%)	
Widow	0 (0%)	1 (3.8%)	
Life style: Secular	19 (79.2%)	17 (65.3%)	0.662
Traditional	4 (16.6%)	6 (23.1%)	
Religious	1 (4.1%)	2 (7.6%)	
Place of born: Israel	20 (83.3%)	18 (69.2%)	0.297
USSR	0 (0%)	2 (7.6%)	
else	4 (8.3%)	6 (23%)	
Economic status: Very bad	0 (0%)	1 (3.8%)	0.77
Bad	2 (8.3%)	2 (7.6%)	
Medium	16 (66.7%)	18 (69.2%)	
Very good	6 (25%)	5 (19.2%)	
Work	16 (66.7%)	17 (77.3%)	0.425
Body Mass Index (kg/m ²)	26.9±5.8	27.2±4.7	0.849
Diabetes Mellitus	1 (4.1%)	2 (7.6%)	0.55
Dyslipidemia	9 (37.5%)	10 (38.5%)	0.859
Hypertension	6 (25%)	5 (19.2%)	0.671

doi:10.1371/journal.pone.0127012.t001



HBOT:
40 séances, 5j/sem
100% O₂, 2ATA
90min

Fig 1. Flow chart of the patients in the study.

Hyperbaric Oxygen Therapy Can Diminish Fibromyalgia Syndrome – Prospective Clinical Trial

2014

Shai Efrati^{1,2,3,4*}, Haim Golan^{3,5}, Yair Bechor², Yifat Faran⁶, Shir Daphna-Tekoah^{6,7}, Gal Sekler⁸, Gregori Fishlev^{2,3}, Jacob N. Ablin^{9,3}, Jacob Bergan^{2,3}, Olga Volkov^{3,5}, Mony Friedman^{2,3}, Eshel Ben-Jacob^{1,4,8,10*}, Dan Buskila¹¹

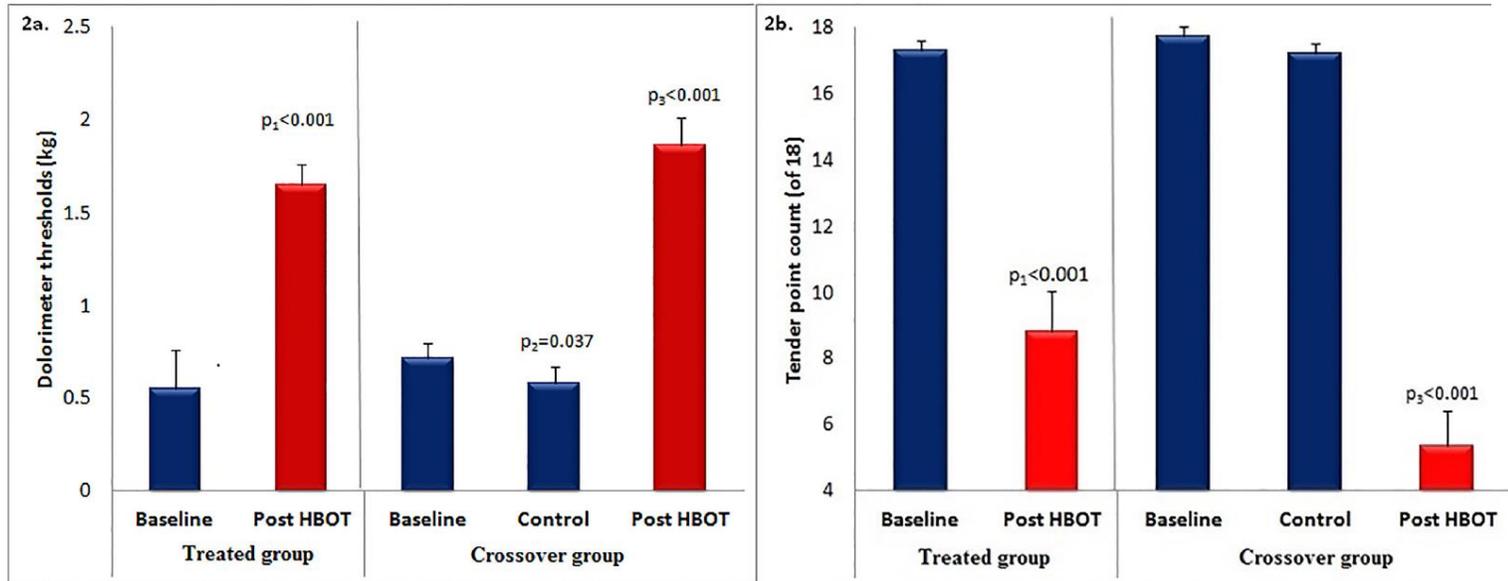
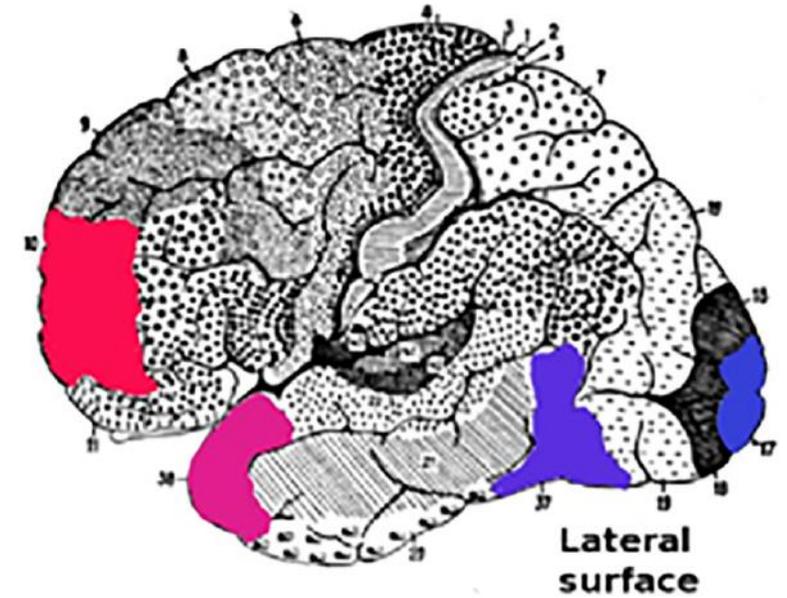


Fig 2. The HBOT effects on tender points. A) The effect on dolorimeter threshold. For both groups, the threshold level tripled after treatment (about 1.5, red bars, vs. about 0.5, blue bars). B) The effect on the number of tender points. The treatment led to significant reduction in the number of tender points in both groups: by a factor of 2 in the treated group and by a factor of 3 in the crossover group.

Hyperbaric Oxygen Therapy Can Diminish Fibromyalgia Syndrome – Prospective Clinical Trial

2014

Shai Efrati^{1,2,3,4*}, Haim Golan^{3,5}, Yair Bechor², Yifat Faran⁶, Shir Daphna-Tekoah^{6,7}, Gal Sekler⁸, Gregori Fishlev^{2,3}, Jacob N. Ablin^{9,3}, Jacob Bergan^{2,3}, Olga Volkov^{3,5}, Mony Friedman^{2,3}, Eshel Ben-Jacob^{1,4,8,10*}, Dan Buskila¹¹

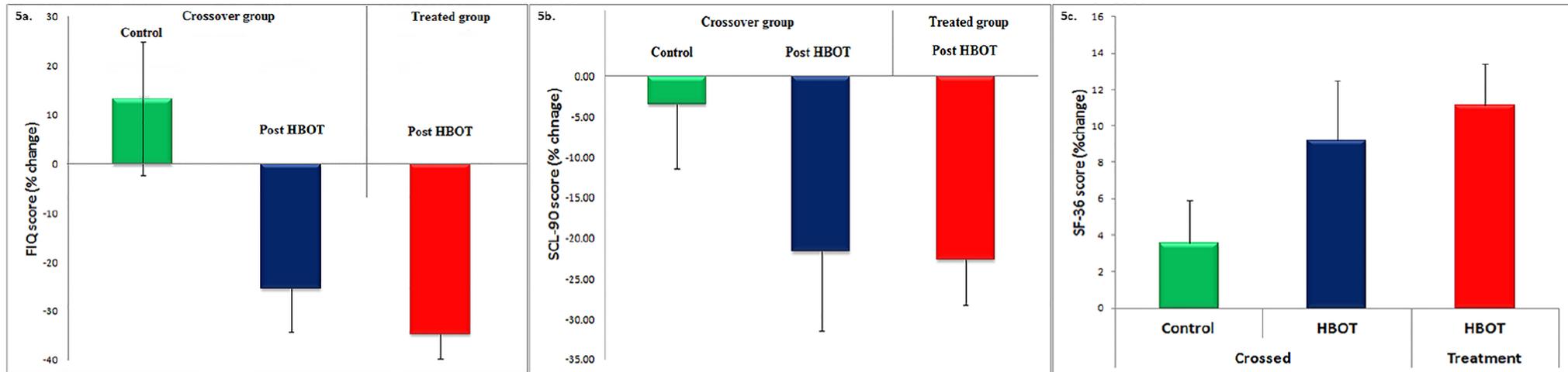
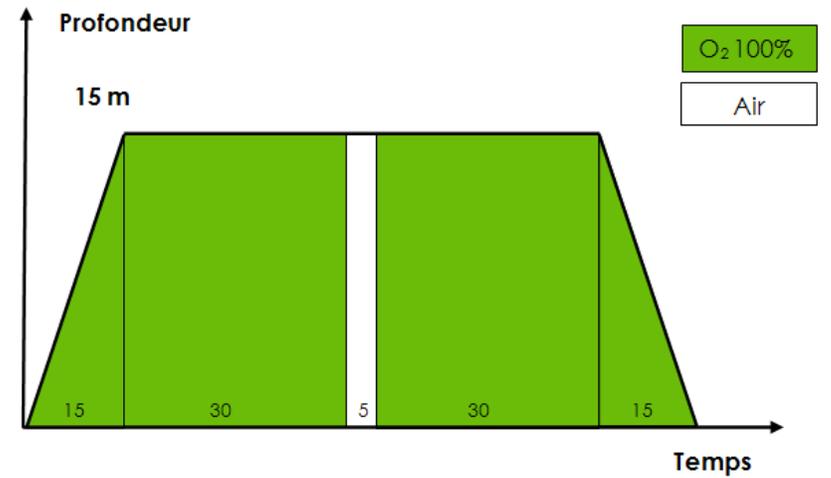


Fig 5. Assessments of the mean relative changes in the FIQ, SCL-90 and the SF-36 scores. The figures show the mean relative changes and standard errors in the three measures for the crossover group following the control period (green) and following HBOT (blue), and for the treated group following HBOT (red). A) Mean relative changes and standard errors in physical function assessed by the FIQ score. B) Mean relative changes in and standard errors in the psychological distress assessed by the SCL-90 score. c) Mean relative changes and standard errors in the quality of life assessed by the SF-36 score.

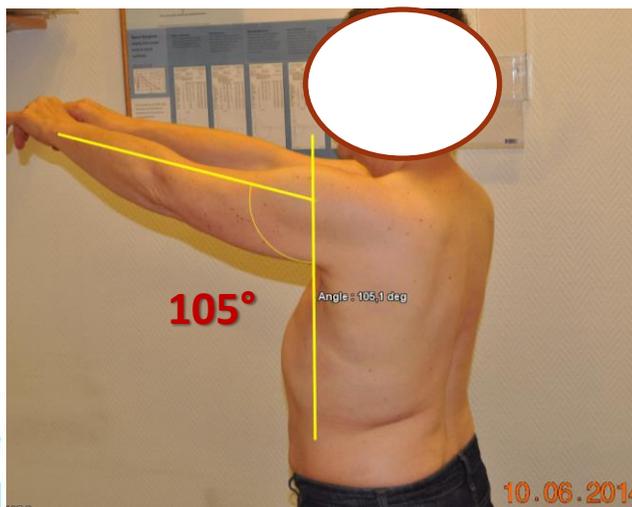
doi:10.1371/journal.pone.0127012.g005

Et en pratique, ça donne quoi ?





Expérience aux HUG



douleur et impotence fonctionnelle suite a une radiothérapie

➤ 30 séances d'oxygénothérapie hyperbare.

Aucun traitement adjuvant n'est prescrit.





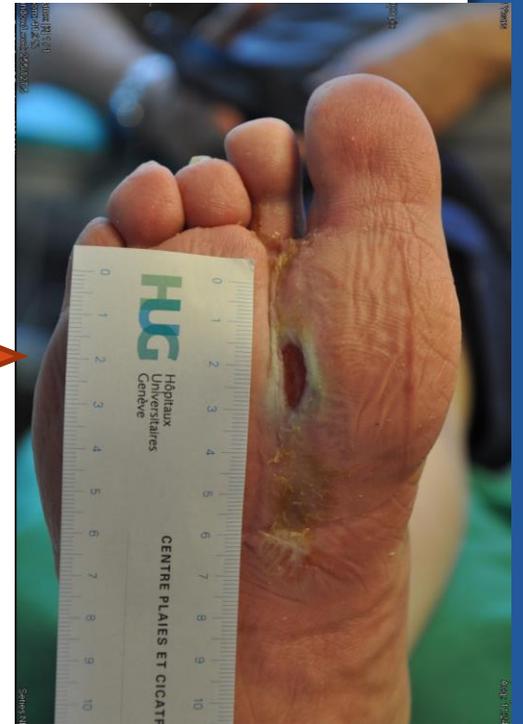
01/2019

12 séances



02/2019

50 séances



06/2019

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