NUTRITION ET EXERCICE EN REANIMATION : CALORIMETRIE INDIRECTE

JARCA, Bordeaux 14/11/2024

M.Lemaire

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INTRODUCTION

↓↓ mortalité < sepsis/maladies graves

« Survival from Critical illness » X 3

Déficits fonctionnels ou PICS

Wischmeyer P. et al., Curr Opin Crit Care 2017;23(4):269-278

INTRODUCTION: FACTEURS DE RISQUES

SEPSIS / MOF
ALITEMENT / IMMOBILISATION
Hyperglycémie
Insuffisance rénale
Administration de catécholamines
Sexe féminin
Durée VM
Nutrition parentérale, manque d'apports en protéines
Utilisation de corticostéroïdes / agents bloquants neuromusculaires (?)

Lipshutz AKM, Review, Anesthesiology, 2012
Latronico N, Review, The Lancet 2011;10:931-41
Hermans G et al., Cochrane Database Syst Rev 2009;(1):CD006832
Stevens RD et al., A syst rev, Int Care Med 2007;33:1876-91

INTRODUCTION: EFFETS DE L' IMMOBILISATION

Synth. prot. plus lente

Protéolyse accélérée

Apoptose augmentée

Morphologie muscle

Proportion fibres I/II

Contractilité

Capacité aérobic

Catabolisme

Atrophie

Faiblesse

INTRODUCTION: EFFETS DE L'IMMOBILISATION

- Atrophie marquée du diaphragme: 18h après début VM.

Levine S et al, N Engl J Med 2008;358:1327-35

- Corrélation avec durée VM.

Jaber S et al, Am Respir Crit Care Med 2011;183:364-7

- Atrophie muscles squelettiques dès 48h – ICU.

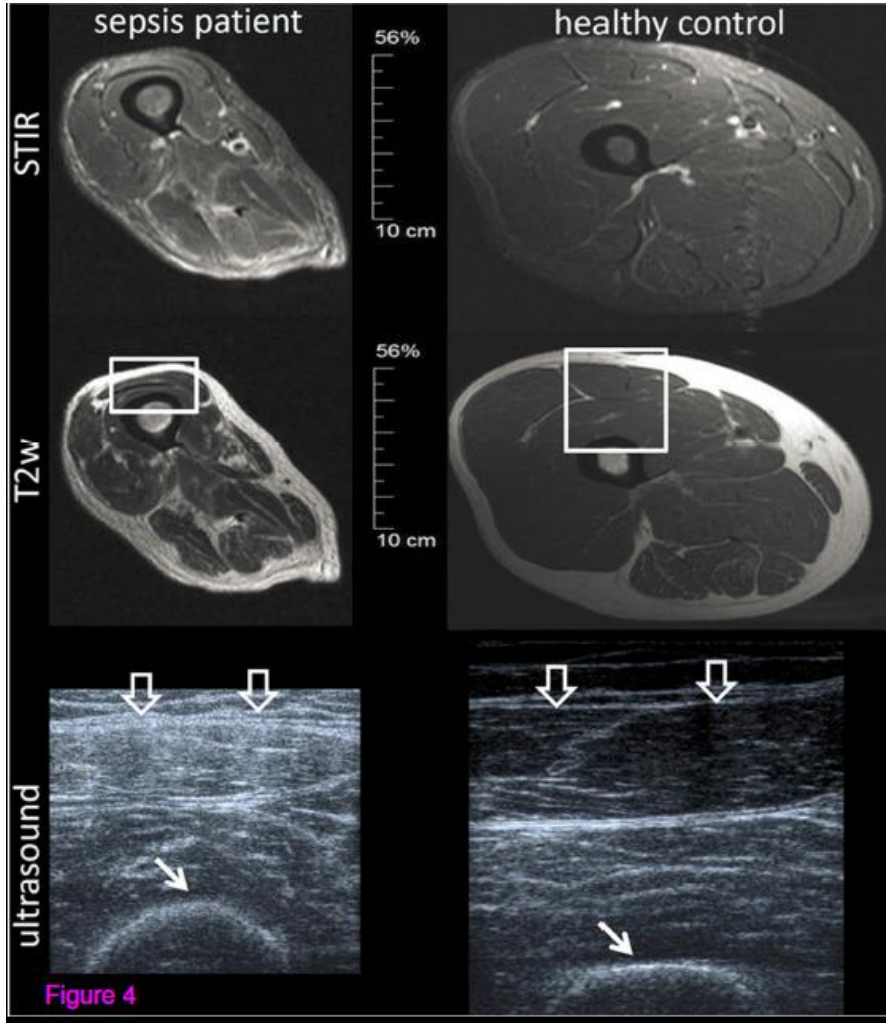
- Plus marquée 2-3 premières semaines séjour ICU.

Tennila A, Int Care Med 2000;26:1360-3

Gruther W. et al , JRM 2008;40:185-9

Cameron S. et al, JJC 2015;30:664-672

EFFETS DE L'IMMOBILISATION



- 40% de perte de force musculaire au cours 1ère semaine:

  ≈ 1% - 6 % / jour d'immobilisation.

Cameron S. et al, JCC 2015

- ↓ 10 % à 14% masse quadriceps au cours 1ère semaine de SI.

Corrélation (+) avec taux élevés de protéine C activée et sévérité dysfonctions organiques.

Gerovasili V. et al, CCM 2009

Puthucheary ZA et al, JAMA 2013

Grimm et al, Crit Care 2013

CONSEQUENCES

1. *Respiratoires* < m. respiratoires (diaphragme ++)

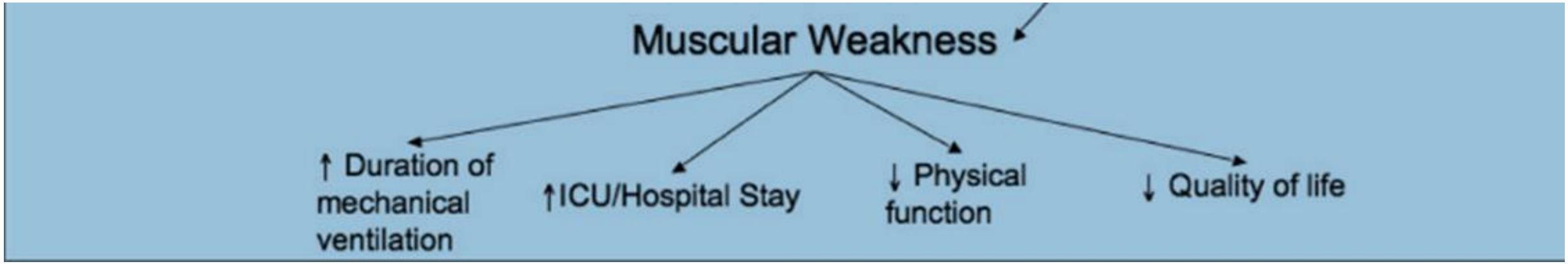
   ⇒ ↑ durée VM et ↑ taux échecs sevrage VM

De Jonghe B et al, Intensive Care Med 2004 ; 30 : 1117-21

Garnacho-Montero J et al, Crit Care Med 2005 ; 33: 349-54

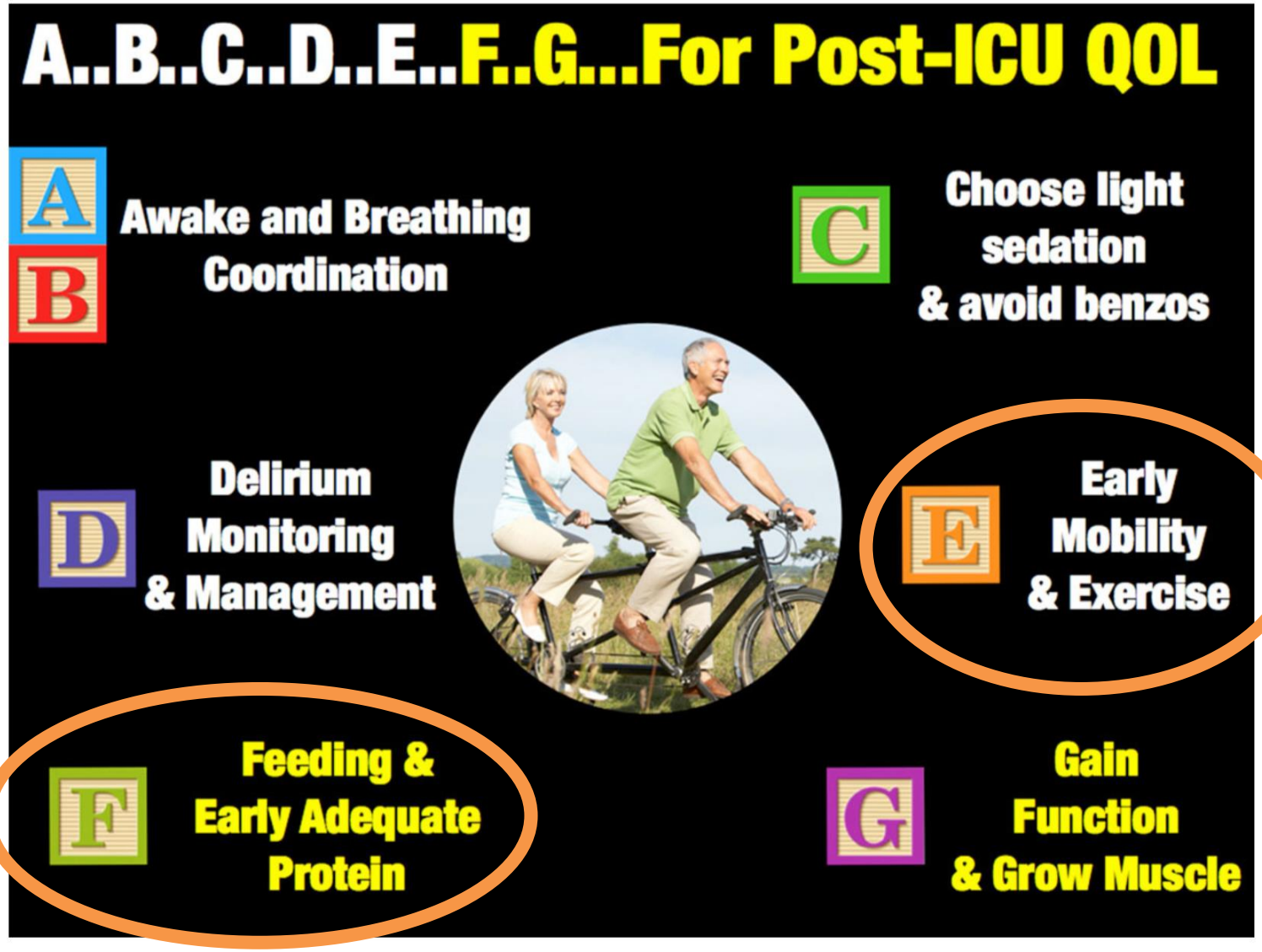
2. *Fonctionnelles* < m. squeletiques

   ⇒ ↓ autonomie du patient, ↑ hospitalisation, transfert en revalidation, retour différé au domicile, reprise du travail limitée…



Truong AD et al., CCM 2009;13:216

Prévention: le « E » et le « F »

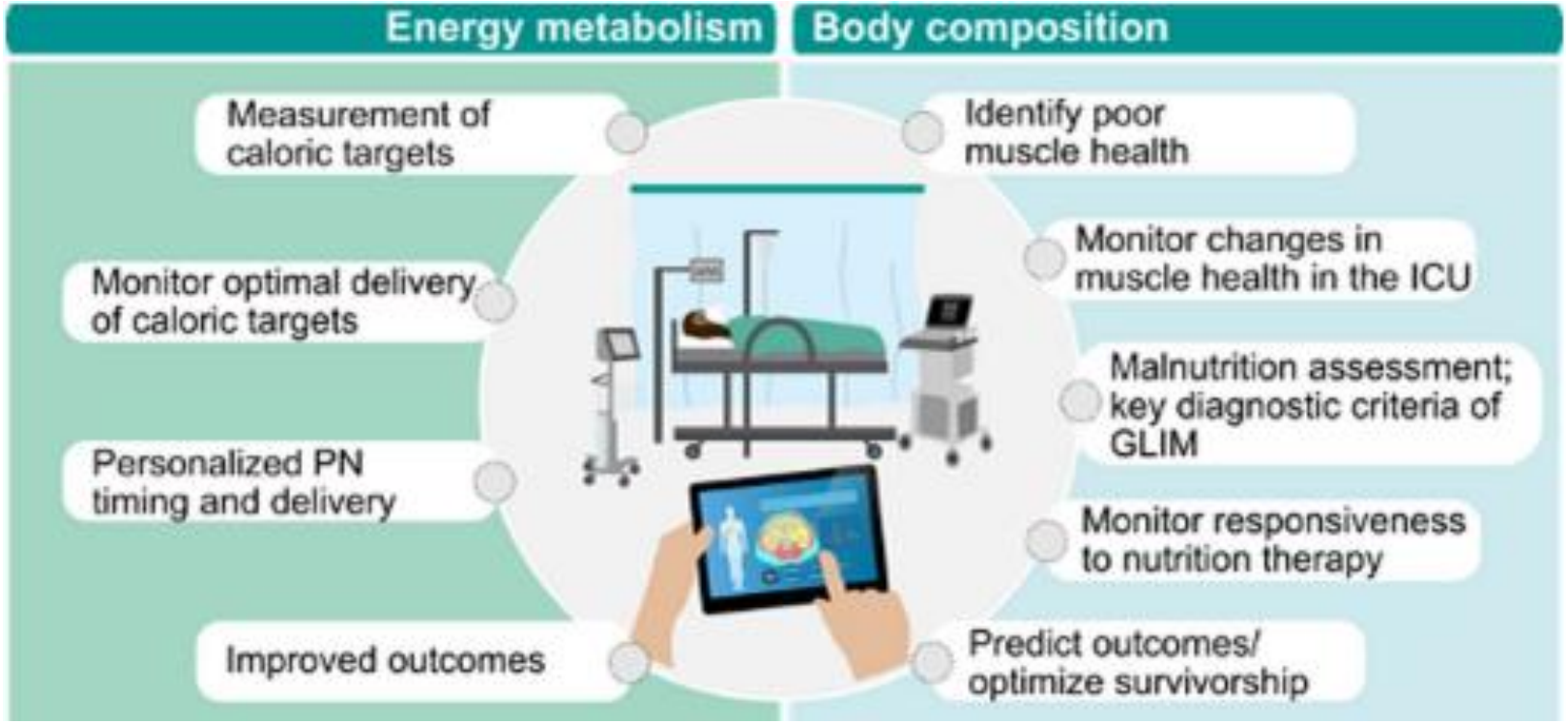


Wischmeyer and San-Millan *Critical Care* 2015, **19**:S6

IMPORTANCE DE L'EVALUATION !

- Masse, force et fonction musculaires mais aussi…

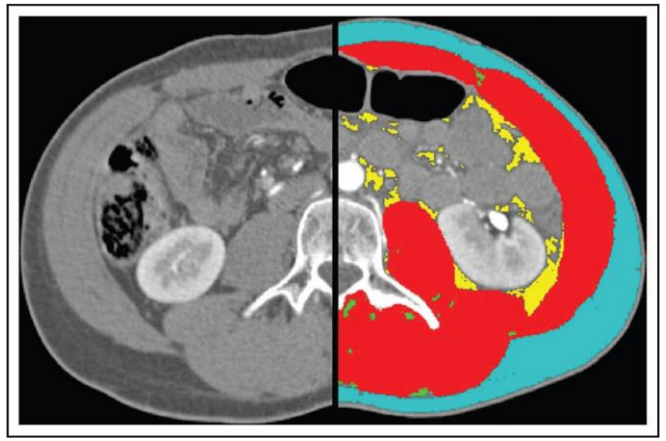
- Dépense énergétique (DE)

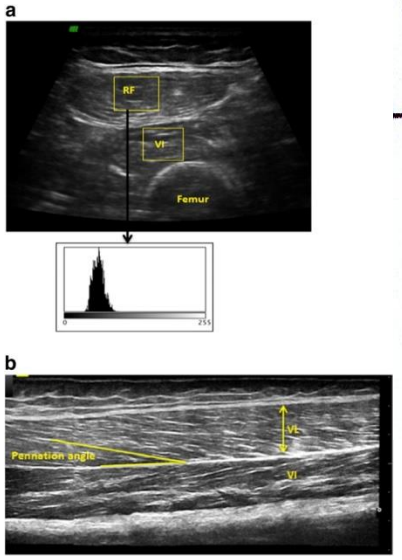


Wischmeyer PE et al., Crit Care 2023:27;261

EVALUATION

Masse, force et fonction musculaires…Outils validés:





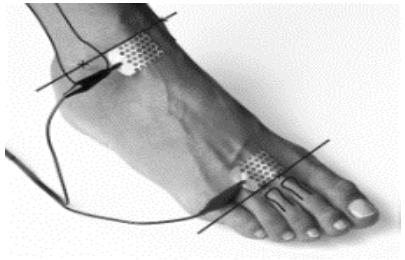


Table 1. Muscle groups (right and left) assessed in the measurement of the MRC-sumscore.

Abduction of the arm
Flexion of the forearm
Extension of the wrist
Flexion of the leg
Extension of the knee
Dorsal flexion of the foot

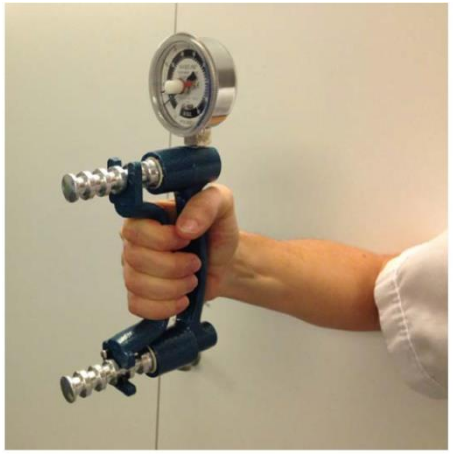
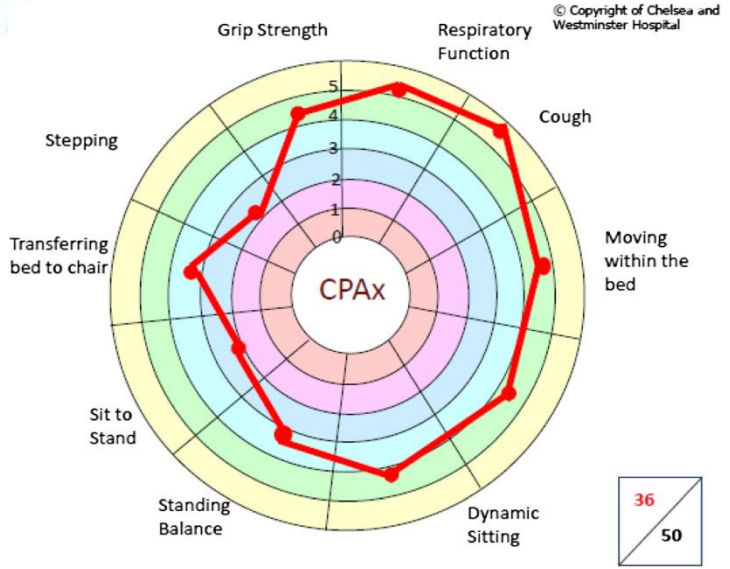


Fig. 1 Dynamomètre à poignée de type "handgrip"

Table 2. MRC-scale with full figures only. The patient is investigated in sitting posture and/or lying supine.

0 = No visible contraction
1 = Visible contraction without movement of the limb (not existent for hip flexion)
2 = Movement of the limb but not against gravity
3 = Movement against gravity over (almost) the full range
4 = Movement against gravity and resistance
5 = Normal



COMMENT EVALUER LA « DE » AU LIT DU PATIENT ?

- Nombre « magique » (25-30 kcal / kg / jour)
- Equations prédictives
- Calorimétrie indirecte
- CO2 exhalé : capnométrie

Nombre magique

- Nombre « magique » : objectif 25-30 Kcal/Kg/jour
- Equation ACCP:

  DE= (25-30 Kcal/J) x poids
- Poids ??
- Pas de modification au cours du temps

Rousting et al., Ann. Intensive Care 2016;6:16
Kreymann et al., ESPEN Guidelines, Clin Nutr 2006;25:210-23
Heyland DK.et al., Canadian Guidelines, JPEN 2003;27(5):355-73

Nombre magique: quel poids?

- Poids sec = admission, pesée à l'étage, estimé si œdèmes/ ascite, poids le + bas
- Réel si BMI/IMC < 30 (Espen 2019)
- Poids "ideal" ? ou de forme" si BMI <18.5 après la phase aigue
- Ajusté si BMI ≥ 30 = Poids idéal + 25 % (Poids réel - Poids idéal) (Espen 2019)
- Importance donc de vérifier que la taille soit présente dans le dossier du patient
- Patient, famille, mesure de l'avant bras / talon-genoux

J-C. Preiser

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EQUATIONS PREDICTIVES

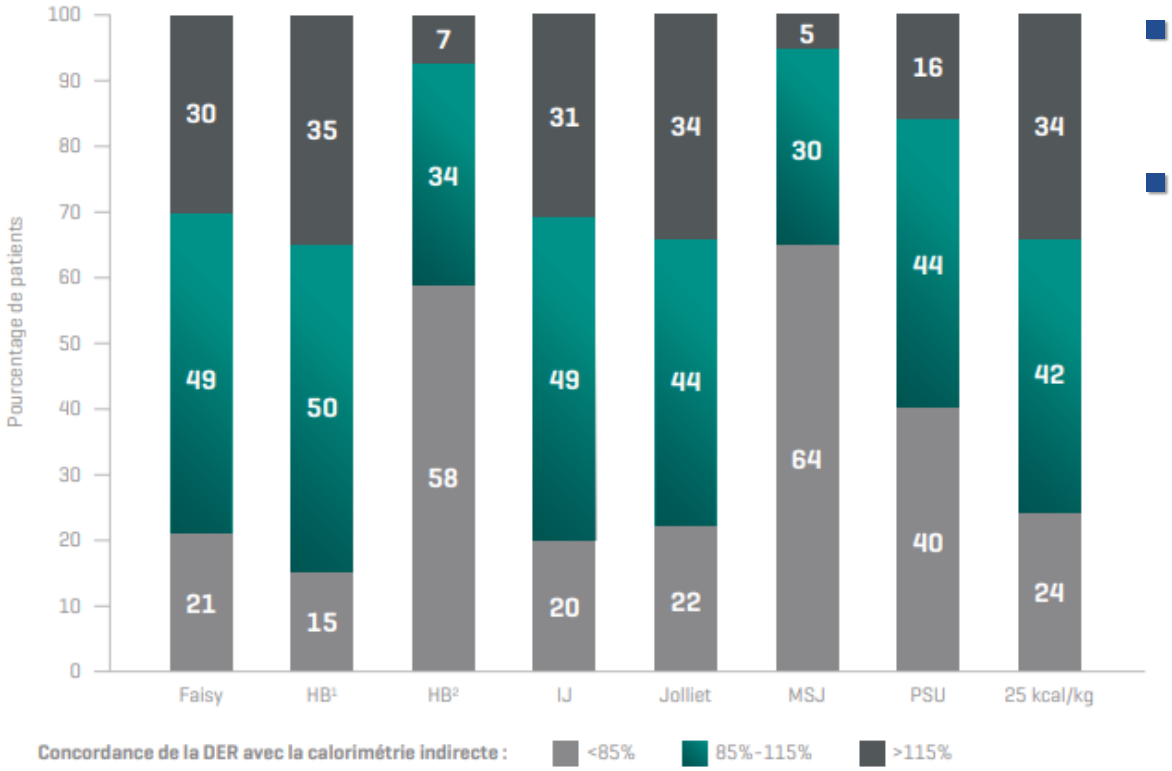
Table 4.7. Selected predictive equations for resting energy expenditure (REE).

Name	Formula
Harris-Benedict	Males: 66.5 + (13.8 × weight) + (5 × height) – (6.8 × age) Females: 655.1 + (9.6 × weight) + (1.9 × height) – (4.7 × age) Correction factors*: • Postoperative: Estimated REE × 1.1 • Multiple fractures: Estimated REE × 1.1 to 1.3 • Severe infection: Estimated REE × 1.3 to 1.6 • Burns: Estimated REE × 1.5 to 2.1 • Fever: Estimated REE × 1.1/°C above 37°C
Frankenfield	–1000 + 100 (minute ventilation) + 1.3 (haemoglobin) + 300 (sepsis)
Swinamer	945 (body surface area) – 6.4 (age) + 108 (temperature) + 24.2 (respiratory rate) + 817 (minute ventilation) – 4349
Fusco	–983 – 4 (age) + 32 (height in inches) + 11 (weight)
Ireton-Jones†	1925 – 10 (age) + 5 (weight) + 281 (sex) + 292 (trauma) + 851 (burn)

Unless otherwise specified, weight is expressed in kilograms, height is expressed in centimetres, body surface area is expressed in square metres and age is expressed in years.
* If required, several correction factors can be used simultaneously
† Sex: 0 for females, 1 for males

- Laquelle choisir ?
- « Niveau » de stress ? (DE X FS)

EQUATIONS PREDICTIVES sont imprécises



[1] Avec un facteur de correction de 1,3.
[2] Sans facteur de correction.
HB = Harris-Benedict, CI = calorimétrie indirecte, IJ = Ireton-Jones, PSU = Penn-State

Adapté de Zusman O, et al. Clin Nutr. 2019;38(3):1206-1210.

- Ne sont exactes que pour < 50% des patients en SI
- Risque sur ou sous alimentation nocive

Etude de validation rétrospective
N= 1440 pat., 3500 mes.

Zusman O. et al., Clin Nutr 2019:38(3);1206-1210

Facteurs affectant DER

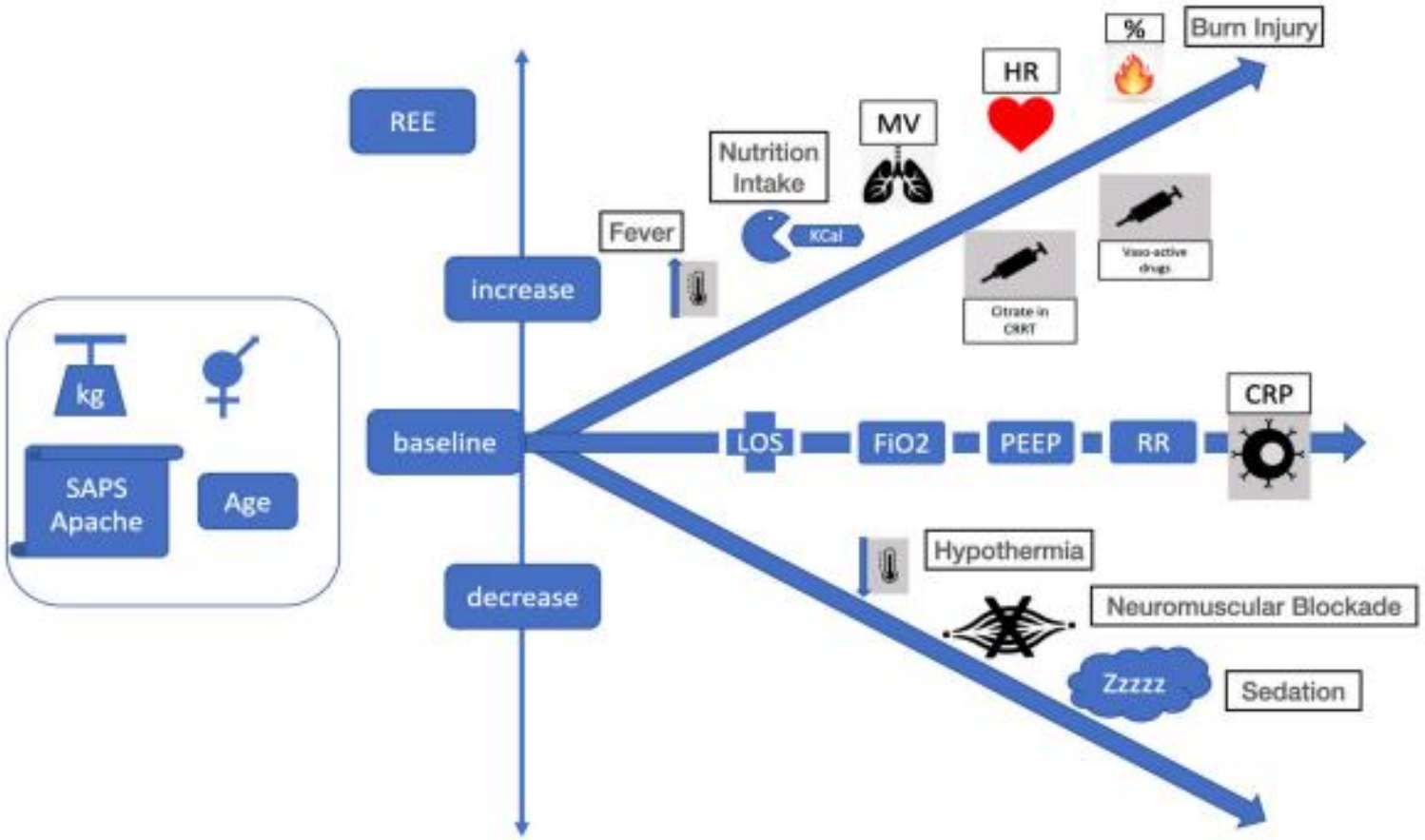


Figure 4. Key factors affecting resting energy expenditure (REE).

+ TEMPS !

DE phase précoce

≠

DE phase tardive

De Waele E. et al., Curr Opin Crit Care 2021;27(4):334-343

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Calorimétrie indirecte

- Mesure de référence de la DE patients ventilés mécaniquement (ESPEN/ASPEN)
- Mesure la quantité d'énergie produite par combustion des nutriments
- Déf. objectifs apports cal. < 70% DE phase aiguë, ↑ = DE plus tard…
- Equation de Weir:

  DER (kcal/j) = 1.44 x (3,94 x V02 (ml/min) + 1.1 x VC02 (ml/min))

- Durée de mesure ≈ 15 minutes, 2-3x/sem.

Preiser J-C. et al., Crit Care 2015;19(1):35
Wischmeyer et al., Crit Care 2023;27:261

Calorimétrie indirecte

COSMED
Rome - ITALY
www.cosmed.com

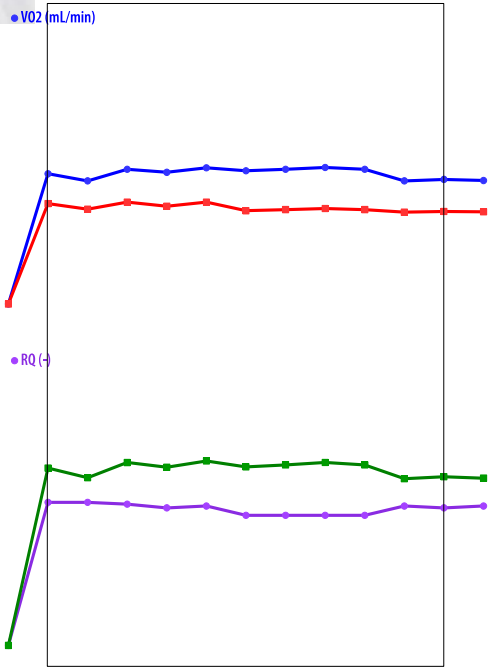
Respirateur | Masque | Canopy

Test date	Time
04/28/2020	11:45

Subject	ID	Gender	Age	D.O.B.	Weight	Height	BMI (kg/m2)
Waongwango Bokungu	--	Male	21	03/31/1999	142.0 Kg	186.0 cm	41.0
Predicted Set	**Test Position**	**Agitation**	**Sedation**	**Body Temp (°C)**	**Resting period**	**Fasting period**	**UN (g/day)**
ESPEN(25kcal/kg/day)	Undefined	N/A	N/A	37	N/A	N/A	0

Indirect Calorimetry Report - Ventilator Test

- VO2
- VCO2
- DER
- QR



REE		RQ
2383 Kcal/day		0.73
67 %pred		npRQ: -- --
VO2	VCO2	Vt
352 mL/min	258 mL/min	857 mL
Substrates		Rf
FAT	CHO	PRO
91 (%)	9 (%)	0 (%)
		FiO2
		29.71 %

Calorimétrie indirecte: erreurs de mesures dynamiques

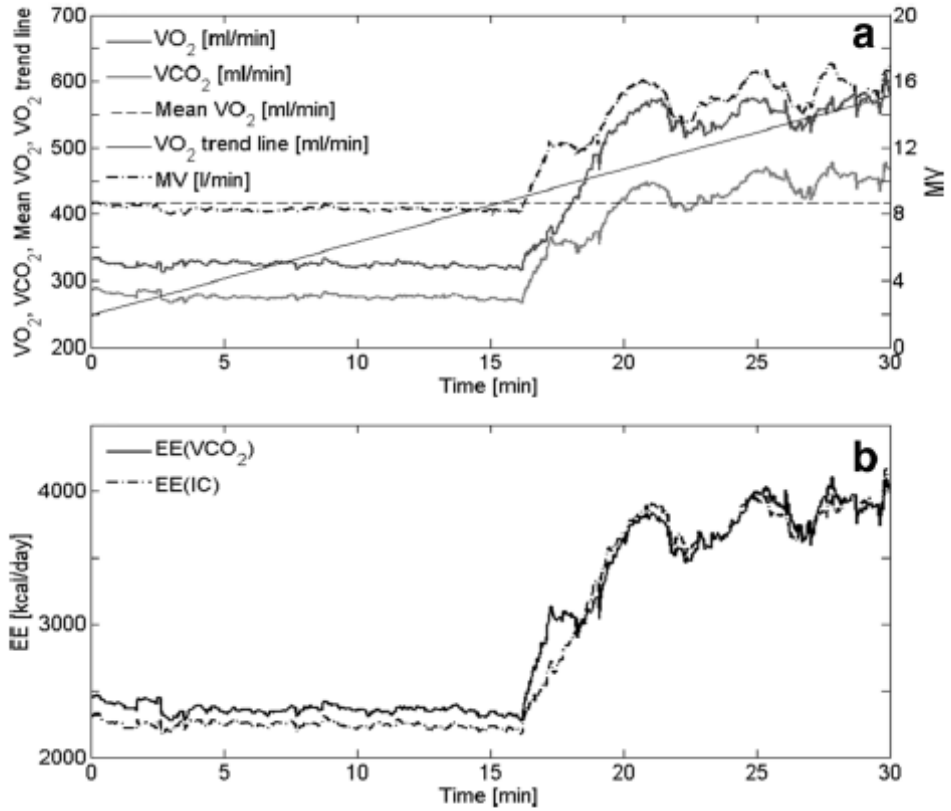


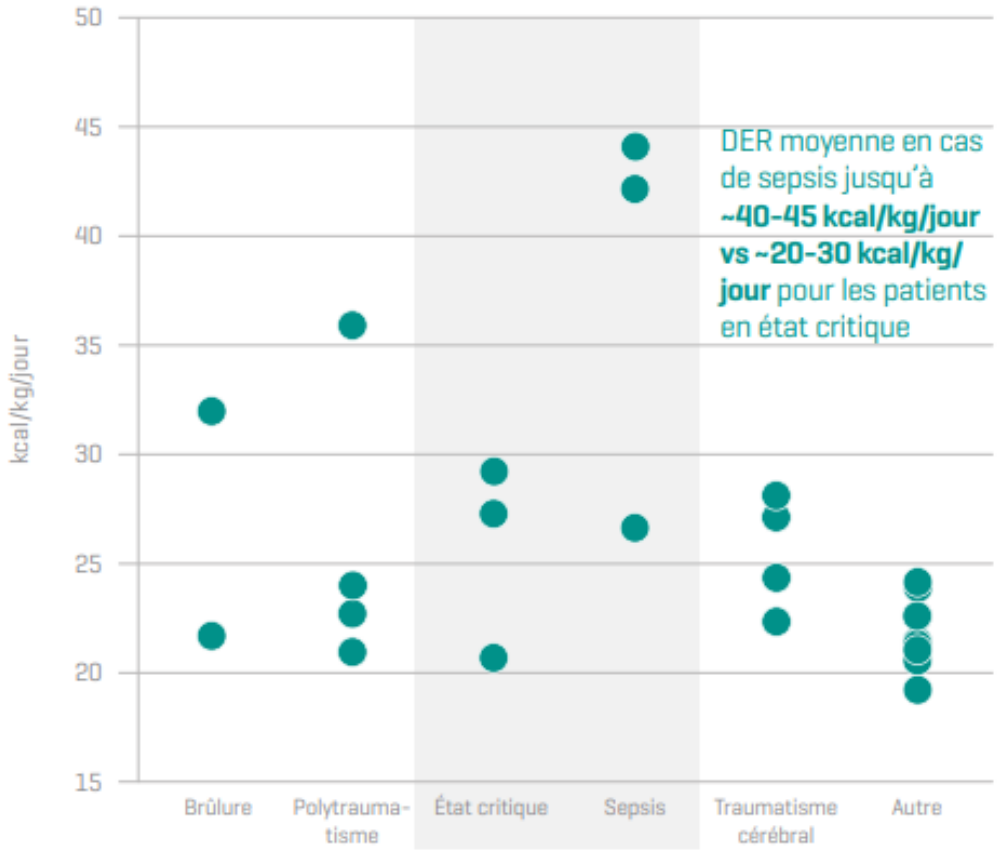
Fig. 2 **a** Recorded VO_2, VCO_2 and MV from Patient 18. The mean and trend line of VO_2 are also displayed. **b** EE(VCO_2) and EE(IC) were calculated from recorded VO_2 and VCO_2

Rousing et al., Ann. Intensive Care 2016;6:16

Mesures sensibles aux variations de ventilation et aux changements rapides du métabolisme !

Ivanov S. et al., Respir Physiol 1968.5(2):243-9
Andreassen S. et al., Crit Rev Biomed Eng 2005;33(3):265-98
Chiumello D. et al., Intensive Care Med 2013;39(8):1377-85

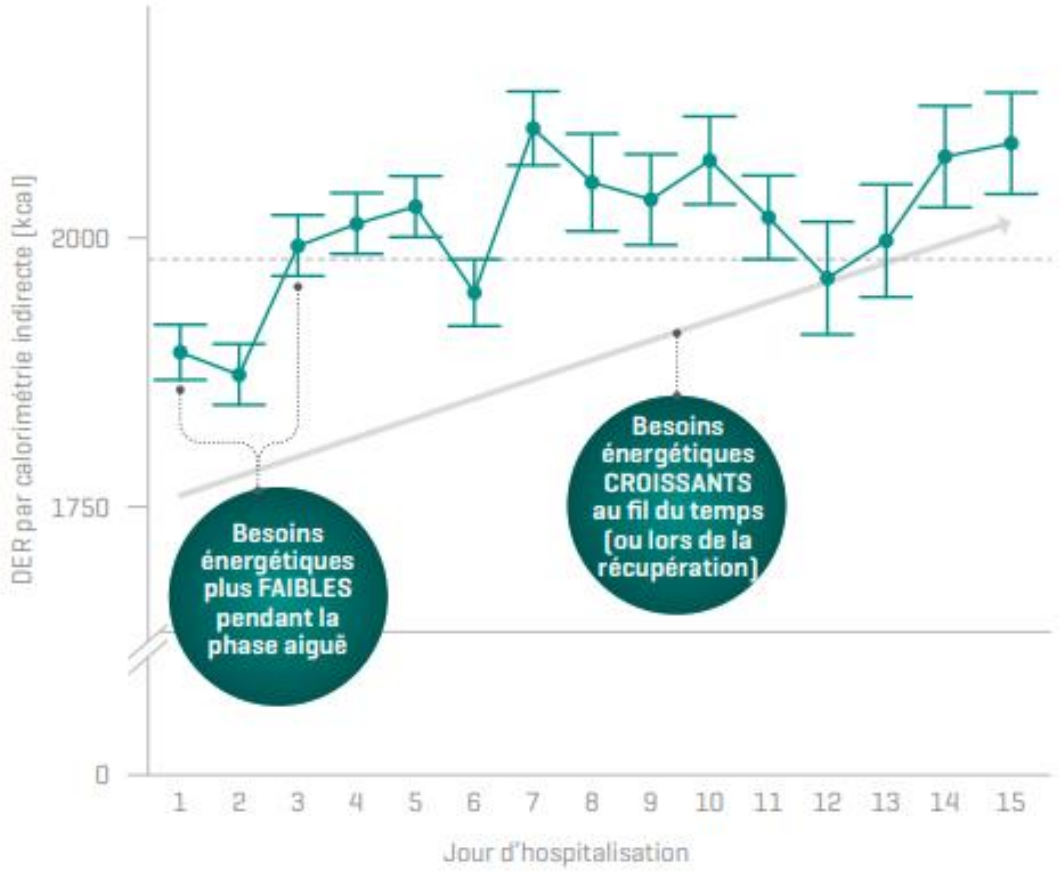
Besoins énergétiques « dynamiques »



Chaque point représente la moyenne des DER mesurées de chaque groupe dans les études.

MT = polytraumatisme, TBI = traumatisme cérébral

Adapté de Rattanachaiwong S, et al. Clin Nutr 2018, doi.org/10.1016/j.clnu.2018.12.035.



DER moyenne des patients en état critique par jour d'hospitalisation.
DER = dépense énergétique au repos
USI = unité soins intensifs

Adapté de Rattanachaiwong S, et al. Clin Nutr 2018, doi.org/10.1016/j.clnu.2018.12.035.

Calorimétrie indirecte

- CI recommandée (ESPEN/ASPEN) pour mesurer avec précision la DE
- Permet de détecter la variabilité de la DER au cours du temps
- Guider/Optimiser apports en énergie
- ↓ ICU-AW

Fetterplace K. et al., J Hum Nutr Diet 2019 ;32(6):702-712

- ↓ catabolisme et dégradation protéines

(≈ préservation masse m. et récupération fonction)

Sundstrom et al., PLoS One 2020;15(10):e0240045

Intensive Care Med
https://doi.org/10.1007/s00134-024-07458-9

NARRATIVE REVIEW

Nutrition in the intensive care unit: from the acute phase to beyond

Angelique M. E. de Man[1,2*], Jan Gunst[3,4] and Annika Reintam Blaser[5,6]

Maximum
70% REE (20-25 kcal/kg/d)
Protein loss

Minimum
100% REE (25-35 kcal/kg/d)
1,3 g proteins

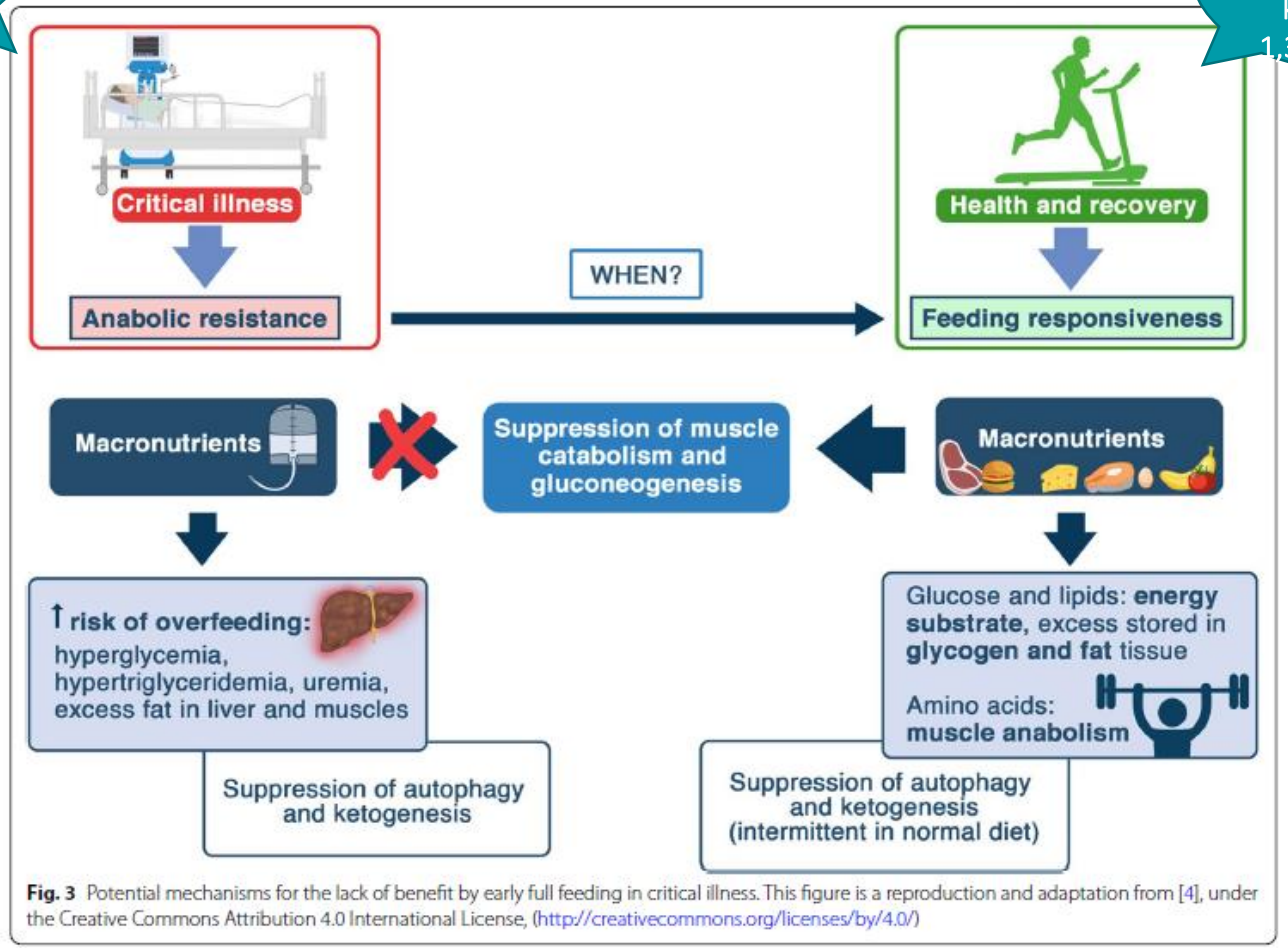
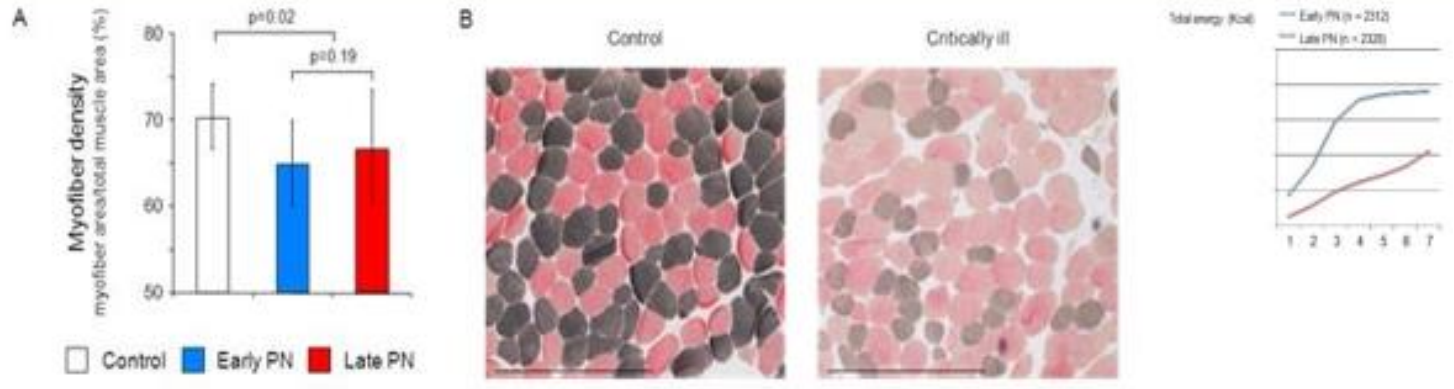
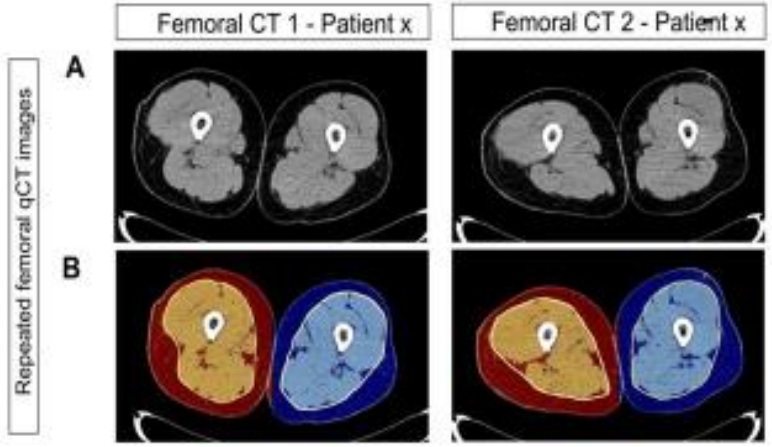


Fig. 3 Potential mechanisms for the lack of benefit by early full feeding in critical illness. This figure is a reproduction and adaptation from [4], under the Creative Commons Attribution 4.0 International License, (http://creativecommons.org/licenses/by/4.0/)

Impact of Early Parenteral Nutrition on Muscle and Adipose Tissue Compartments During Critical Illness*





Trop d'apports en NRJ en phase précoce:
+ dépôt graisse
+ faiblesse m.

Casaer Crit Care Med 2013

Intensive Care Med
https://doi.org/10.1007/s00134-024-07458-9

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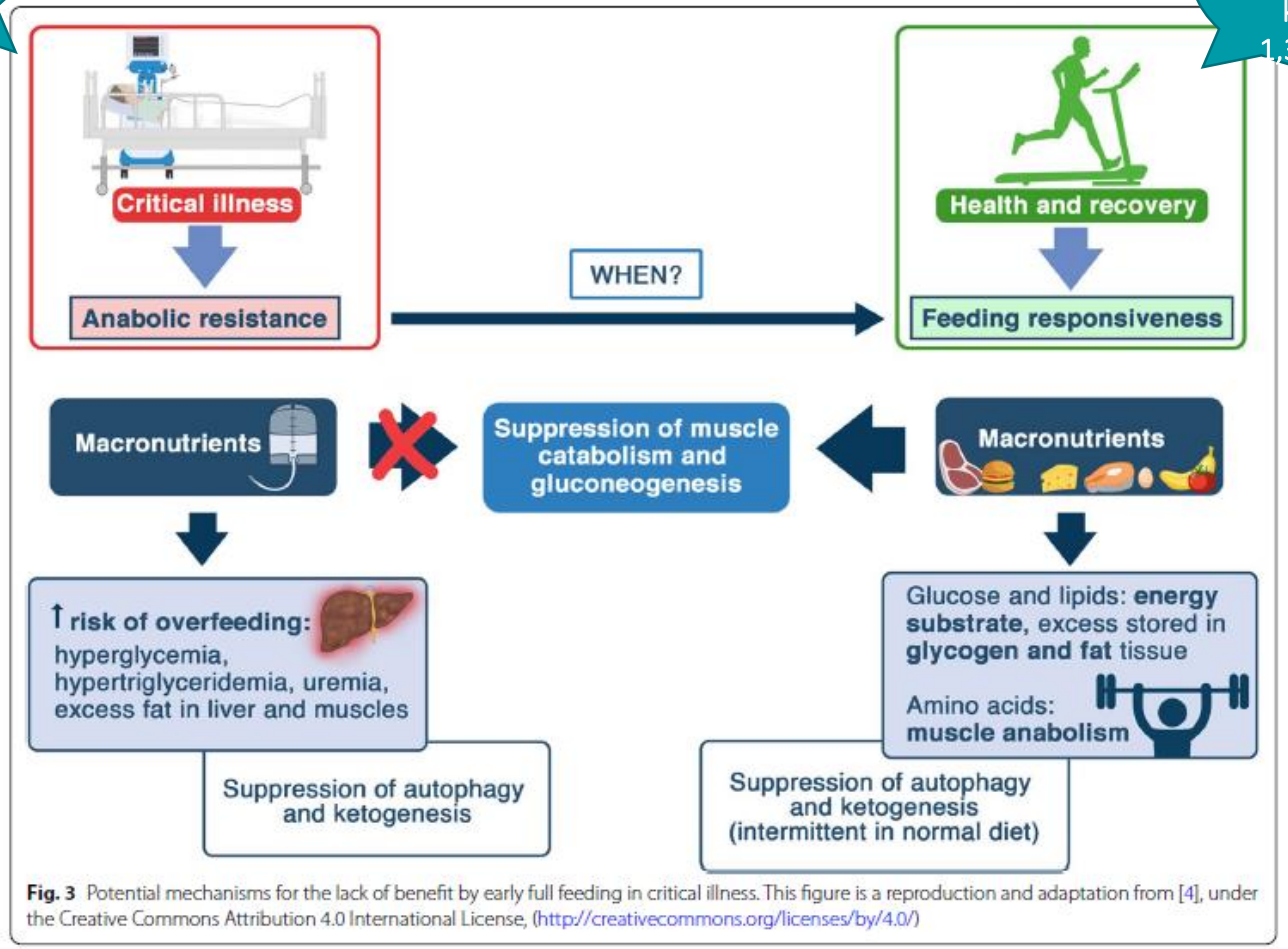

Fig. 3 Potential mechanisms for the lack of benefit by early full feeding in critical illness. This figure is a reproduction and adaptation from [4], under the Creative Commons Attribution 4.0 International License, (http://creativecommons.org/licenses/by/4.0/)

Calorimétrie indirecte

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- ↓ catabolisme et dégradation protéines

(≈ préservation masse m. et récupération fonction)

Sundstrom et al., PLoS One 2020;15(10):e0240045

Calorimétrie indirecte: méta-analyse

8 RTCs
N=991 pat.

Study or Subgroup	IC Events	IC Total	Predictive equation Events	Predictive equation Total	Weight	Risk Ratio M-H, Fixed, 95% CI	Year
Singer 2011	21	65	31	65	28.4%	0.68 [0.44, 1.05]	2011
Yang 2016	1	30	7	30	6.4%	0.14 [0.02, 1.09]	2016
Allingstrup 2017	30	100	32	99	29.5%	0.93 [0.61, 1.40]	2017
Gonzalez-Granda 2018	5	20	3	20	2.7%	1.67 [0.46, 6.06]	2018
Zhao 2019	5	29	7	29	6.4%	0.71 [0.26, 1.99]	2019
Singer 2020	22	200	29	200	26.6%	0.76 [0.45, 1.27]	2020
Total (95% CI)		**444**		**443**	**100.0%**	**0.77 [0.60, 0.98]**	
Total events	84		109				

Heterogeneity: Chi² = 5.16, df = 5 (P = 0.40); I² = 3%
Test for overall effect: Z = 2.11 (P = 0.03)

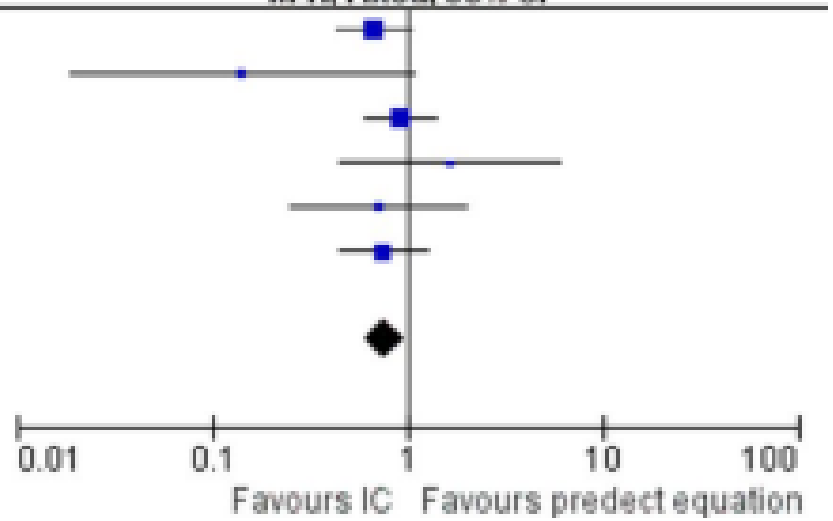

Fig. 2 Forest plot showing the effects of energy delivery guided by indirect calorimetry on short-term mortality rate in critically ill patients

Duan et al., Crit Care 2021;25(1):88

Indirect calorimetry

New generation metabolic cart

ADVANTAGES

- Precise
- Accurate
- Simple
- Respiratory quotient to identify underfeeding or overfeeding
- Rapid assessment
- Parts are disposable

DISADVANTAGES

- Need for IC-trained staff
- Patient stability
- Supplemental oxygen
- Patient cooperation
- Interference from medical interventions
- Uncertain accuracy on ECMO

/!\ variations ventilation et métabolisme

Wischmeyer PE et al., Crit Care 2023:27;261

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- Equations prédictives
- Calorimétrie indirecte
- CO2 exhalé : capnométrie

CAPNOMETRIE: CO2 exhalé

- Alternative basée uniquement sur la VCO2

- Equation de Weir modifiée:

$$DE(VCO_2) = ((5{,}5\ min/ml.QR - 1 + 1{,}76\ min/ml).VCO_2 - 26))\ kcal/J$$

$$VO_2 = VCO_2/QR$$

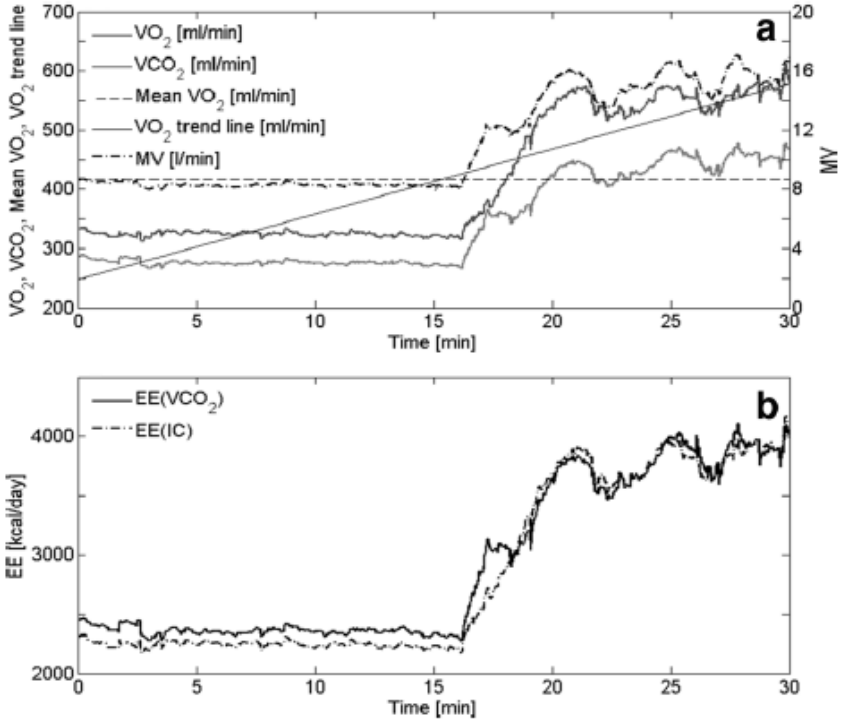
- QR ? Valeur fixe ≈ 0,86

Rousing et al., Ann. Intensive Care 2016;6:16

RESEARCH Open Access

Energy expenditure in critically ill patients estimated by population-based equations, indirect calorimetry and CO_2-based indirect calorimetry

Mark Lillelund Rousing[1*], Mie Hviid Hahn-Pedersen[1], Steen Andreassen[1], Ulrike Pielmeier[1] and Jean-Charles Preiser[2]



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N= 18 pat.

Calorimétrie basée sur VCO2 estime DE avec précision

Meilleure corrélation que éq.prédictives

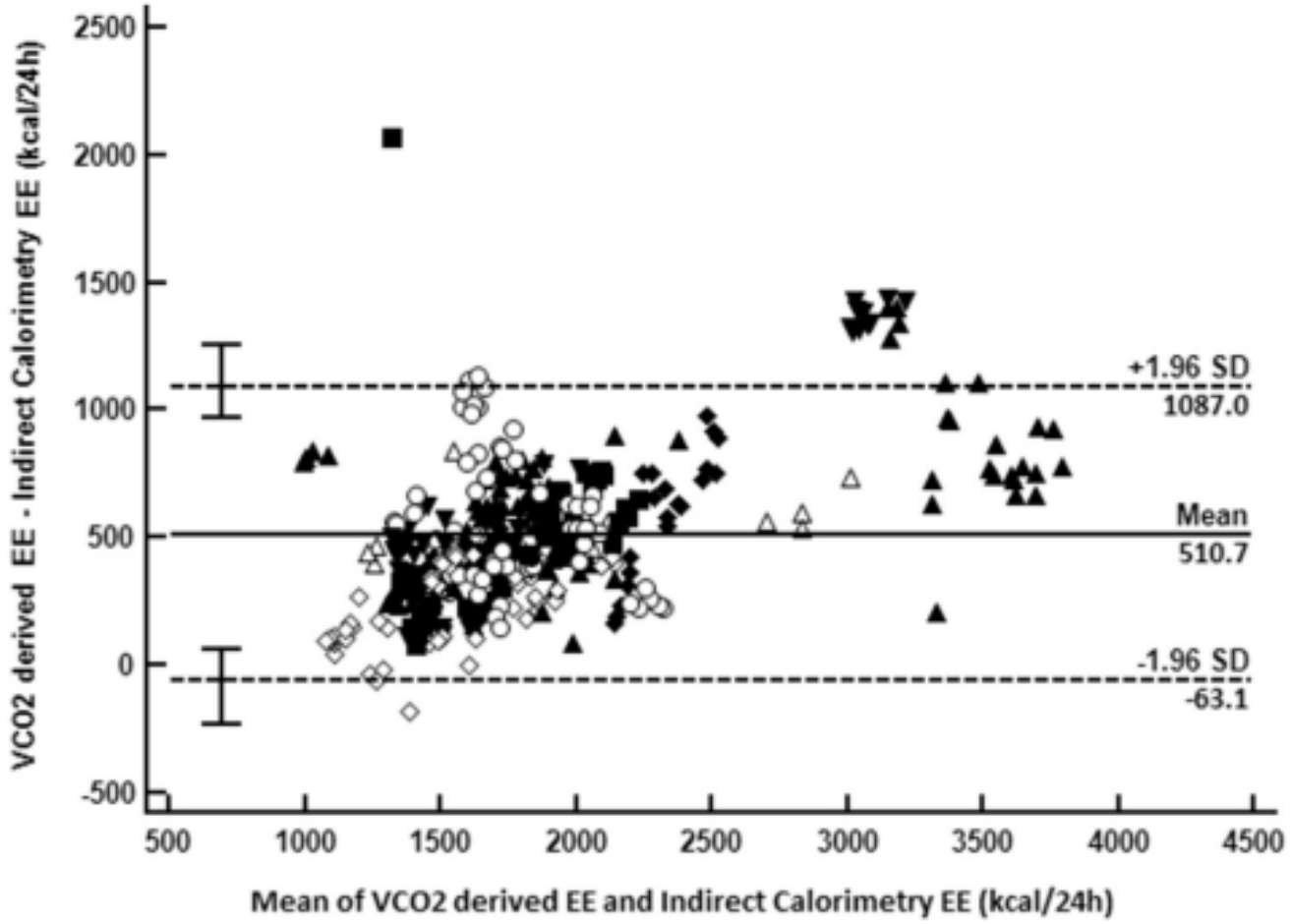
Sensible variations VM et métaboliques

QR arbitraire?

Rousing et al., Ann. Intensive Care 2016;6:16

Resting energy expenditure by indirect calorimetry versus the ventilator-VCO_2 derived method in critically ill patients: The DREAM-VCO_2 prospective comparative study

W.A.C. Koekkoek [a], G. Xiaochen [a], D. van Dijk [b], A.R.H. van Zanten [c, d, *]



Etude cohorte prospective
N= 31 pat., 414 mes

EEVCO2 surestime DE réelle
≈ Biais de 511 Kcal

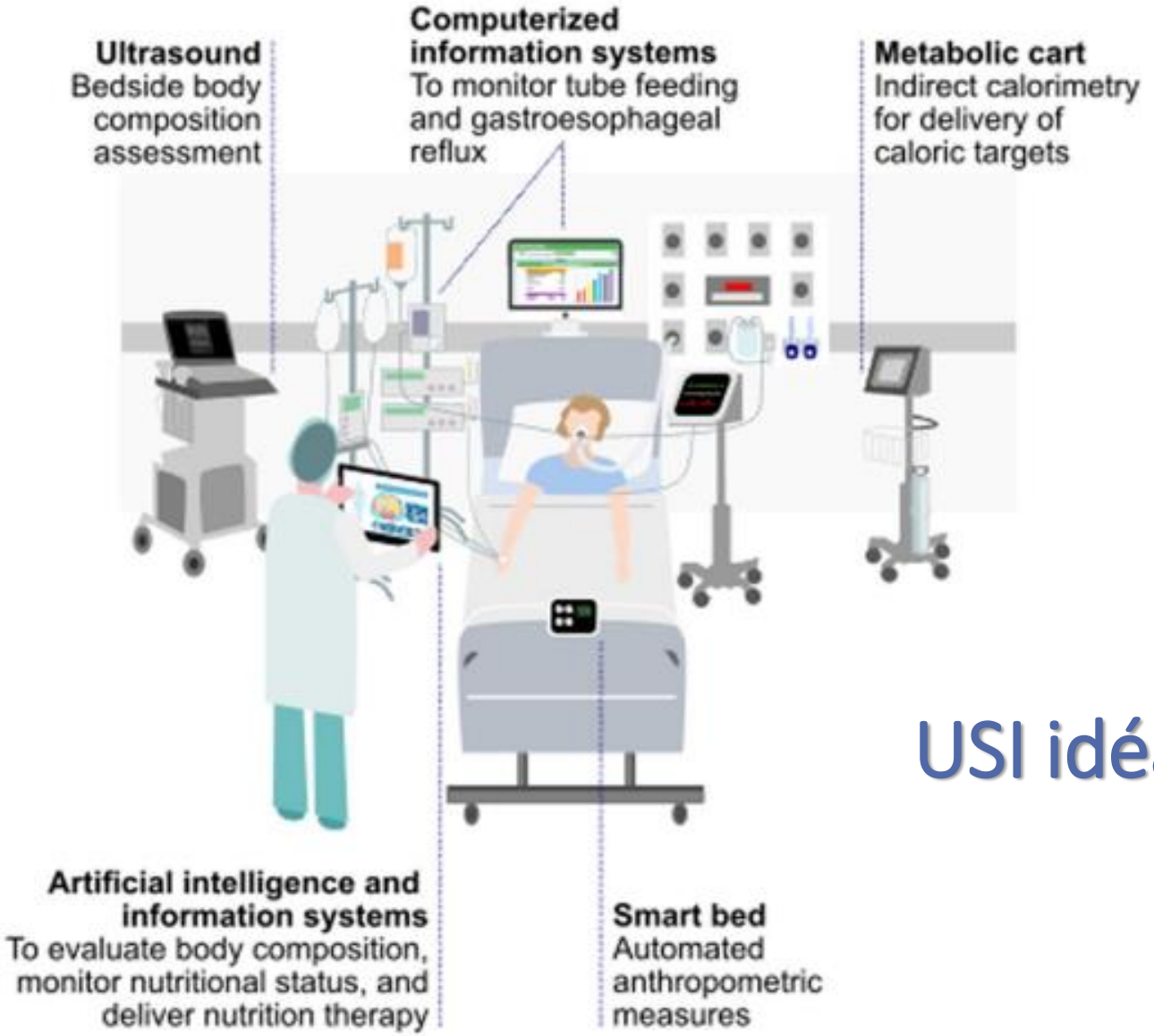
Fiabilité mes. « acceptable », meilleure que éq. prédictives

EEVCO2 peut-être alternative

Clin Nutr ESPEN 2020 ;(39): 137-143

Pré-conclusion

- CI recommandée (ESPEN/ASPEN) pour mesurer avec précision la DE
- Permet de détecter la variabilité de la DER au cours du temps
- Guider/Optimiser apports en énergie (pas trop début/assez ensuite)
- ↓ ICU-AW, préservation masse m. et récupération fonction ?
- Alternatives: éq. prédictives et capnométrie ?



USI idéale…Des soins sur mesures !

Wischmeyer PE et al., Crit Care 2023:27;261

Nutrition/Exercice: Algorithme proposé

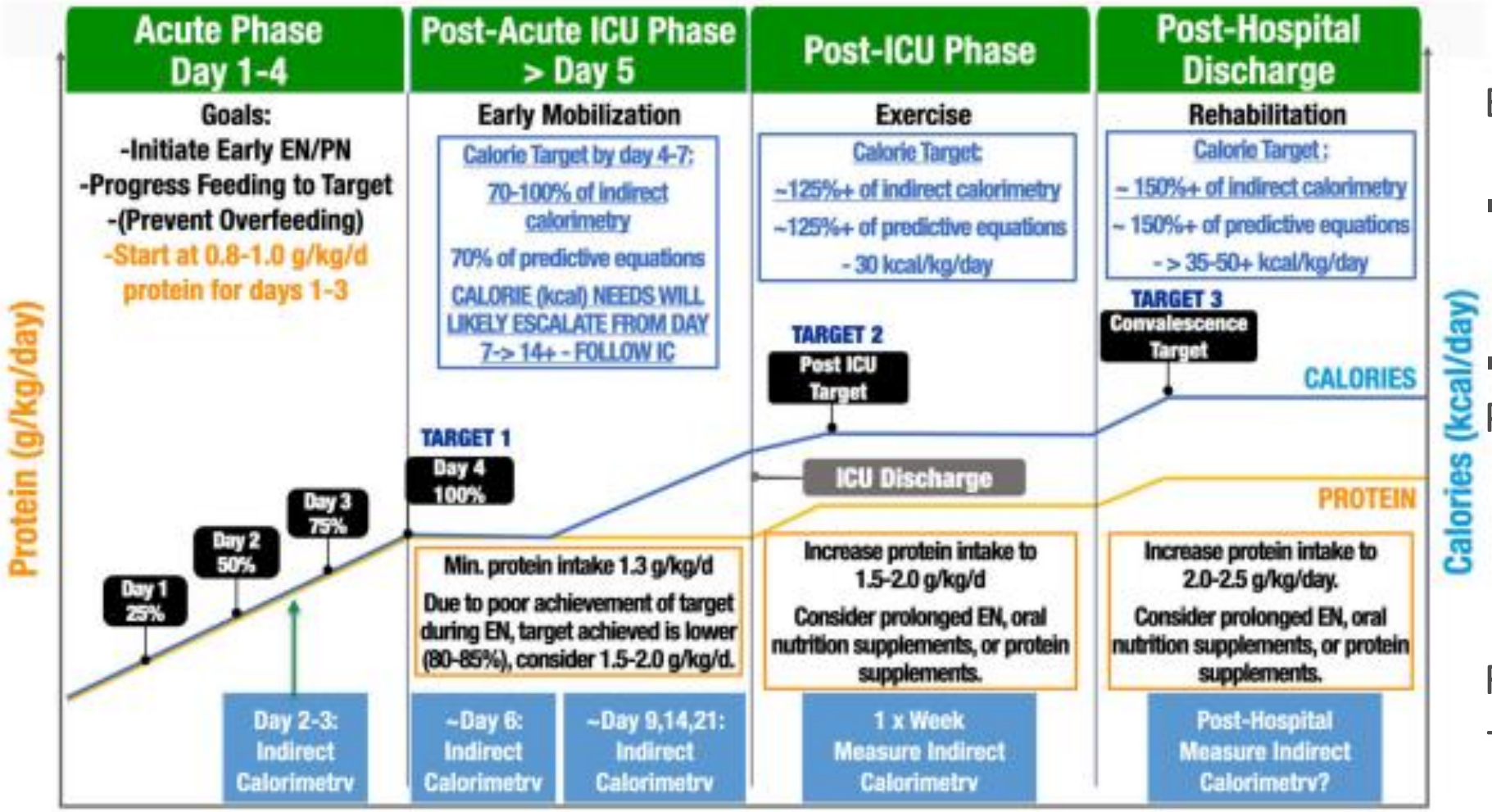


Figure 5. Personalized Indirect Calorimetry-Guided Critical Care Nutrition Algorithm

Exercice ↑ DER :

- ↑ Kcal

70% DER >> 100% >>> 125%

- ↑ protéines ?

Pas trop en phase aiguë

< ne sert à rien

< nocif: - ↑ urée toxique (IRA)
- ↓ anabolisme
- « autocanibalisme »

Favorise production glucagon

→ protéolyse !

De Waele E. et al., Curr Opin Crit Care 2021;27(4):334-343

RESEARCH ARTICLE Open Access

High-protein intake and early exercise in adult intensive care patients: a prospective, randomized controlled trial to evaluate the impact on functional outcomes

José Raimundo Araujo de Azevedo*, Hugo César Martins Lima, Pedro Henrique Dias Brasiliense Frota, Ivna Raquel Olimpio Moreira Nogueira, Suellen Christine de Souza, Erika Arana Arraes Fernandes and Adlyene Muniz Cruz

RCT prospective

N= 186 pat. ventilés > 4 jours, randomisation J3

87 pat. gr. HP (1,48g/Kg/J) + 2 séances 15 min. ergocycle/J (avec ↑ progressive R)

vs

94 pat. gr. témoin (1,19g/Kg/J) + physiothérapie routine (mob. passive/active au lit 2x/J)

BMC Anesthesiol 2021:21;283

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- **Méthode:**

DER mesurée quotidiennement par CI ds les 2 gr. (même cible apports en Kcal)

- J3: apports NRJ ≈ 50% DER et apports prot. 0,8-1g/Kg/J pour les 2 gr.
- J5: apports NRJ≈ 80% DER et apports prot. 2-2,2g/Kg/J vs 1,4-1,5g/Kg/J

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- **Résultats:**

Table 3 Primary and secondary outcomes

Variable	HPE group n = 87	Control group n = 94	*P* value
PCS score, Median (IQR)			
3 months	24.40 (0.00–49.12)	0.00 (0.00–37.0)	0,01
6 months	33.63 (0.00–71.61)	0.00 (0.00–55.1)	0,01
ICU-acquired weakness n (%)	16 (29.1)	26 (46.4%)	0.05
Length of stay, days			
Median (IQR)			
ICU	18 (12–36)	23 (16–36)	0,11
Hospital	38 (18–70)	40 (21–60)	0,96
Duration of MV, days			
Median (IQR)	10 (5–19)	12 (7–21)	0,09
Mortality			
n (%)			
ICU	23 (26.4)	41 (43.6)	0,01
Hospital	25 (31.2)	47 (53.4)	0,002
6-months follow-up	29 (33.3)	51 (54.2)	0.005

PCS physical component summary

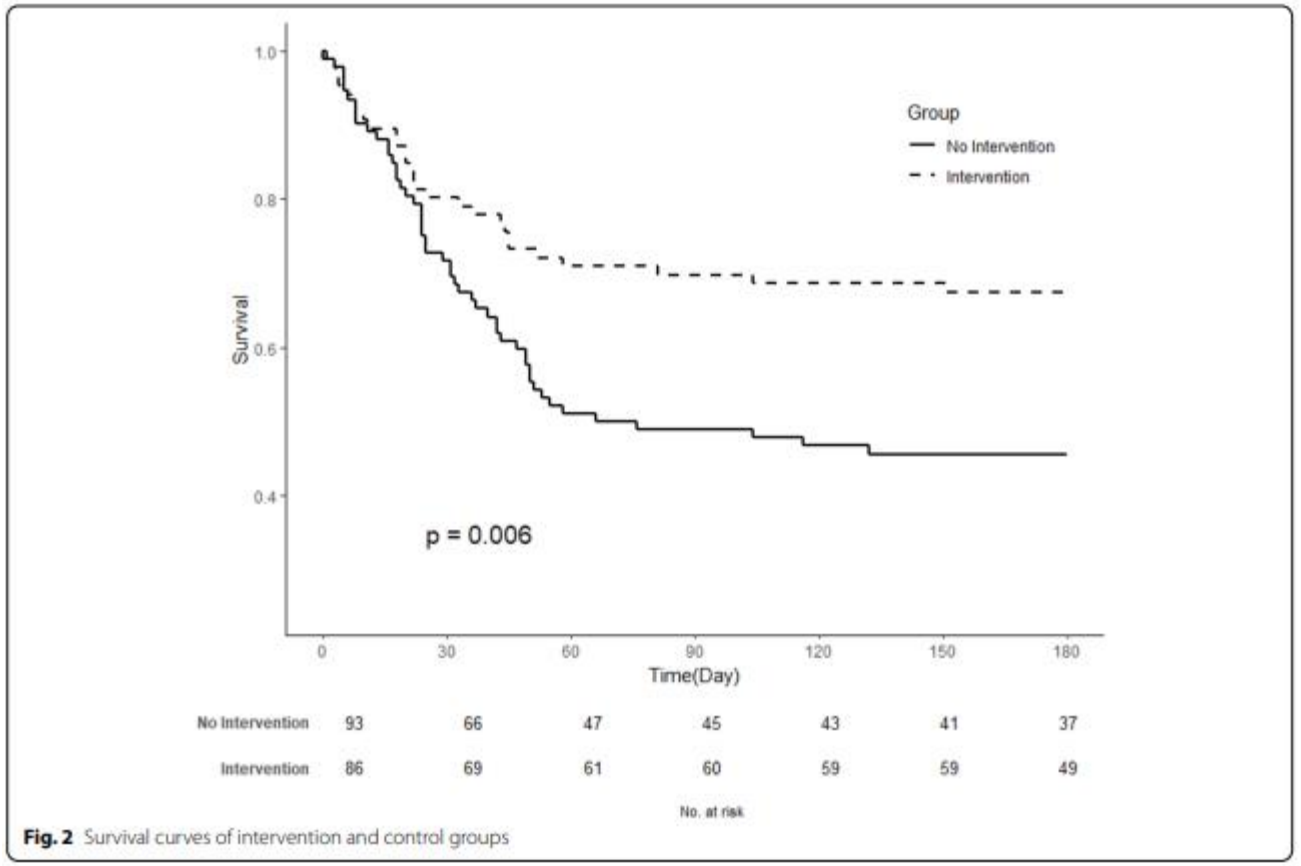

Fig. 2 Survival curves of intervention and control groups

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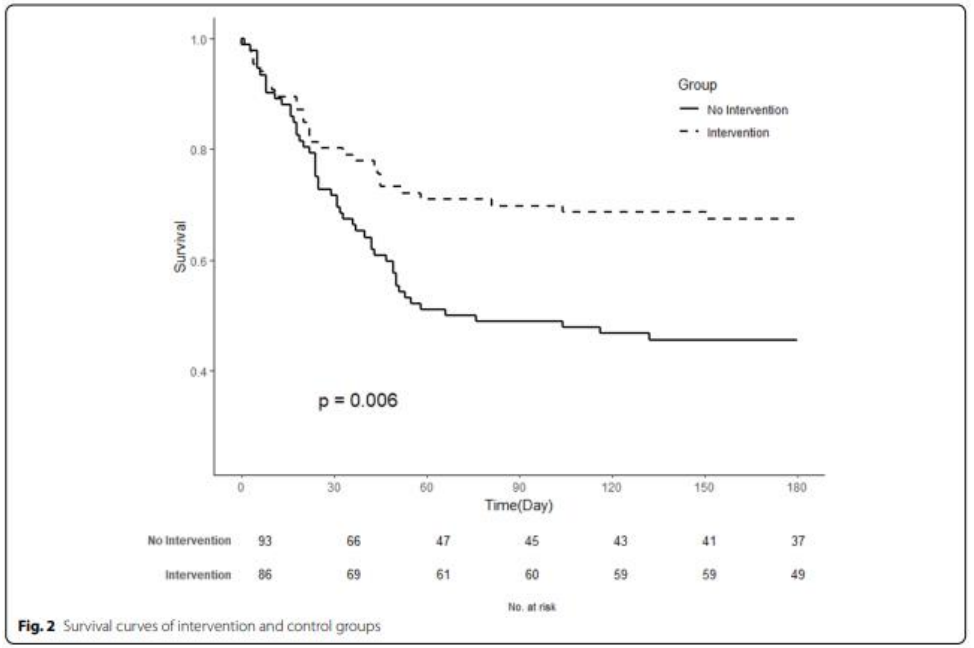

Fig. 2 Survival curves of intervention and control groups

Conclusion: This study showed that a high-protein intake and resistance exercise improved the physical quality of life and survival of critically ill patients.

BMJ Open

Nutrition and Exercise in Critical Illness Trial (NEXIS Trial): a protocol of a multicentred, randomised controlled trial of combined cycle ergometry and amino acid supplementation commenced early during critical illness

Daren K Heyland,[1] Andrew Day,[2] G John Clarke,[3] Catherine (Terri) Hough,[4] D Clark Files,[5] Marina Mourtzakis,[6] Nicolaas Deutz,[7] Dale M Needham,[8] Renee Stapleton[9]

Table 4 Primary and secondary outcomes—all performed by blinded assessors*

	Instrument	Assessment timing
Primary outcome		
Physical functioning	6 min walk distance (6MWD)	Hospital discharge
Secondary outcomes		
Overall strength-upper and lower extremity	MRC sum-score	Hospital discharge
Quadriceps force-lower extremity strength	Hand-held dynamometry	Hospital discharge
Distal strength-hand grip strength	Hand grip dynamometry	ICU and hospital discharge
Overall Physical Functional status	SPPB and FSS-ICU	ICU and hospital discharge
Physical functioning (ADL)	Katz ADL	Hospital discharge
Mortality	Chart review	ICU and hospital discharge
Length of ventilation, ICU and hospital stay	Chart review	ICU and hospital discharge
ICU readmission and reintubation	Chart review	Hospital discharge
Hospital-acquired infections	Chart review	Hospital discharge
Discharge location (eg, home vs rehab)	Chart review	Hospital discharge
Body composition	Ultrasound of rectus femoris, vastus intermedius, tibialis anterior	Enrolment, ICU and hospital discharge
Body composition (when clinically available)	Chest CT scan (above the aortic arch)	Only when clinically available
Body composition (when clinically available)	Abdominal CT scan at third lumbar vertebra	Only when clinically available
Health-related quality of life	SF-36 and EQ-5D-5L	Telephone survey at 6 months
Physical functioning	Katz ADL; Lawton IADL	Telephone survey at 6 months
Physical functioning	Return to baseline work/activity	Telephone survey at 6 months
Physical functioning	Living location	Telephone survey at 6 months
Mental and cognitive functioning	MoCA-BLIND, HADS and IES-R	Telephone survey at 6 months
Healthcare resource utilisation	Admission to ICU, hospital, rehabilitation and nursing facility	Telephone survey at 6 months

ADL, activities of daily living; IADL, instrumental activities of daily living; FSS-ICU, Functional Status Score for ICU; ICU, intensive care unit; MRC, Medical Research Council; SPPB, Short Physical Performance Battery.

RCT multicentrique en cours…

Strengths and limitations of this study

- This is the first randomised controlled trial (RCT) evaluating the combination of exercise and protein supplementation started in the early phase of critical illness.
- We have developed a rigorous framework to evaluate the effect of the study intervention on the patient's functional recovery and outcomes.
- As a phase II RCT, the study has a relatively small sample size recruited from four participating centres.
- This study evaluates a combined intervention and will not be able to independently evaluate the effect of the nutrition versus exercise on study outcomes.

- Cyclo ergomètre + supplément en AA (2-2,5g/Kg/J en IV)

- Effets sur M, F et fction musc.

(6MWT sortie hôpital, MRC, test handrip, dynamométrie quadriceps, score fonctionnel USI, US quadriceps, CT scan pour masse corporelle maigre,…)

Conclusion

- CI recommandée (ESPEN/ASPEN) pour mesu… DE
- Permet de détecter la …
- C… …nsuite)
- Evaluer DE et masse musculaire
- Guider, optimiser nutrition et exercice
- Personnaliser prise en charge
- …m. et récupération fonction ?

Alternatives: éq. prédictives et capnométrie ?

MERCI pour votre attention !

Merci à Jean-charles Preiser
et Coralie Snidero (Baxter)