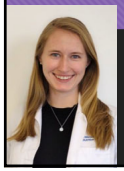
Indirect Calorimetry: Measuring Energy Expenditure in the ICU and Beyond



Laura Van Althuis, RDN, LDN
Clinical Research Coordinator – Registered Dietitian
Duke Office of Clinical Research

1

Disclosures

- Speaking Honorarium and Advisory Board
  - Baxter International

2

Objectives

- To understand the role of indirect calorimetry (IC) in nutrition prescription and delivery in acute and non-acute care settings
- To determine patient populations that would benefit from indirect calorimetry as part of the patient assessment
- To reveal the dynamic nature of resting energy expenditure throughout hospitalization

3

Indirect Calorimetry Basics

4

How do we *predict* energy?

- Mifflin St Jeor
- Harris Benedict
- ASPEN recommendations
  - 12-25 kcal/kg

} Static Variables

- Penn State Equation 2003b and 2010 → Some Dynamic Variables

1. Frankenfield D, Smith JS, Cooney RN. Validation of 2 approaches to predicting resting metabolic rate in critically ill patients. Journal of Parenteral and Enteral Nutrition. 2004 Jul;28(4):259-64.
2. Mifflin MD, St Jeor ST, Hill LA, Scott BJ, Daugherty SA, Koh YO. A new predictive equation for resting energy expenditure in healthy individuals. The American journal of clinical nutrition. 1990 Feb 1;51(2):241-7.
3. Harris JA, Benedict FG. A biometric study of human basal metabolism. Proceedings of the National Academy of Sciences. 1918 Dec;4(12):370-3.

5

Any predictive equation is as reliable as the variables are *accurate*

My soap box

6

How do we *measure* energy?

- Direct Calorimetry
  - Body heat production in whole-room calorimeter
- Indirect Calorimetry
  - Metabolic Cart
    - Measurement of gas exchange (VCO_2, VO_2)

4. Wildman RE, Medeiros DM. Advanced human nutrition. Boca Raton, FL: CRC press; 2000.

7

eat right.

FROM THE ACADEMY

Academy of Nutrition and Dietetics: Revised 2017 Scope of Practice for the Registered Dietitian Nutritionist

The Academy Quality Management Committee

- Recommend, perform, and/or interpret test results related to nutrition status: blood pressure, anthropometrics (eg, height and weight, skinfold thickness, waist circumference, calculation of body mass index with classification for malnutrition and obesity), indirect calorimetry, laboratory tests, and waived point-of-care laboratory testing (eg, blood glucose and cholesterol) (http://wwwn.cdc.gov/dls/waivedtests/ and http://www.cms.gov/Regulations-and-Guidance/Legislation/CLIA/downloads/waivetbl.pdf).

5. Andersen D, Baird S, Bates T, Chapel DL, Cline AD, Ganesh SN, et al. Academy of Nutrition and Dietetics: Revised 2017 Scope of Practice for the Registered Dietitian Nutritionist. Journal of the Academy of Nutrition and Dietetics. 2018;118(1):141-65.

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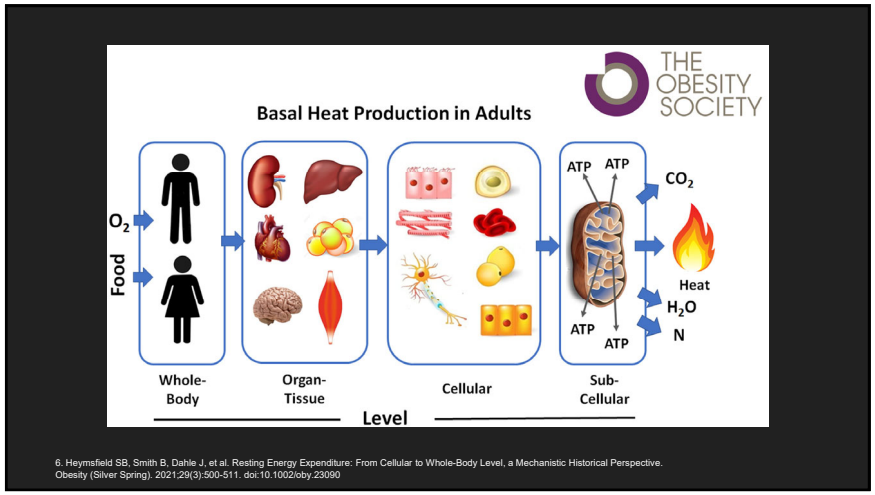

6. Heymsfield SB, Smith B, Dahle J, et al. Resting Energy Expenditure: From Cellular to Whole-Body Level, a Mechanistic Historical Perspective. Obesity (Silver Spring). 2021;29(3):500-511. doi:10.1002/oby.23090

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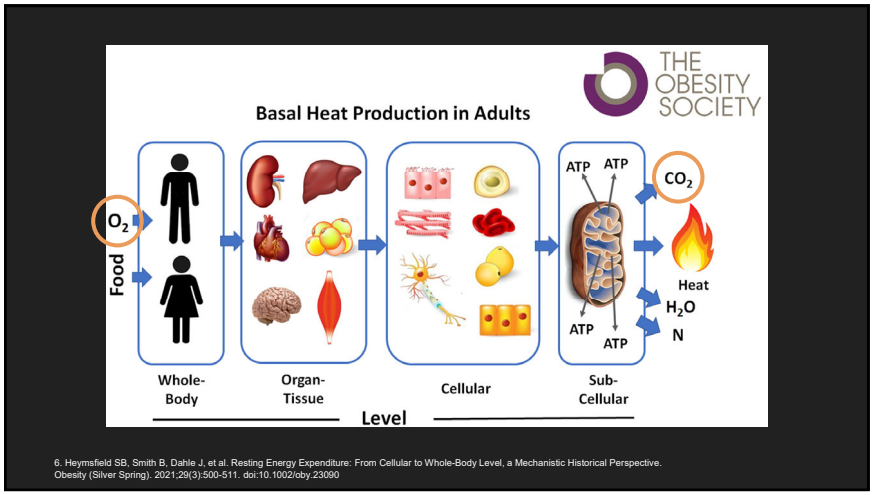

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Organ	Mass (kg)	*Ki* (kcal/kg/d)	Energy Expenditure (kcal/d)	(%REE)
	M/F		M/F	M/F
	1.60/1.43	240	384/343	21/20.0
	0.30/0.27	440	132/119	7.2/6.9
	0.33/0.28	440	145/123	7.9/7.2
	1.68/1.50	200	336/300	18.4/17.5
	30.6/21.3	13	398/277	21.7/12.7
	19.3/29.6	4.5	87/133	4.8/7.6
	87.0/76.5	21.0/19.7	1810/1469	100/100

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12

Learning Assessment Question

Which of the following is the most metabolically active when measured in **kcal/kg**

1. Lean muscle mass
2. Fat mass
3. Cardiac mass
4. Brain mass

13

Learning Assessment Question

Which of the following is the most metabolically active when measured in **kcal/kg**

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3. **Cardiac mass**
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14

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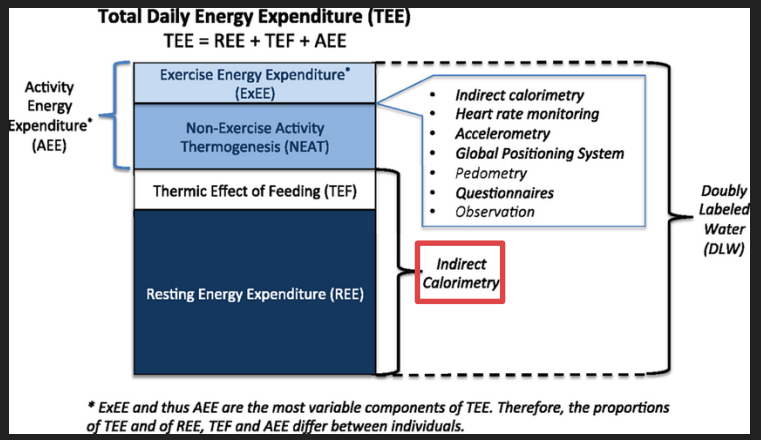

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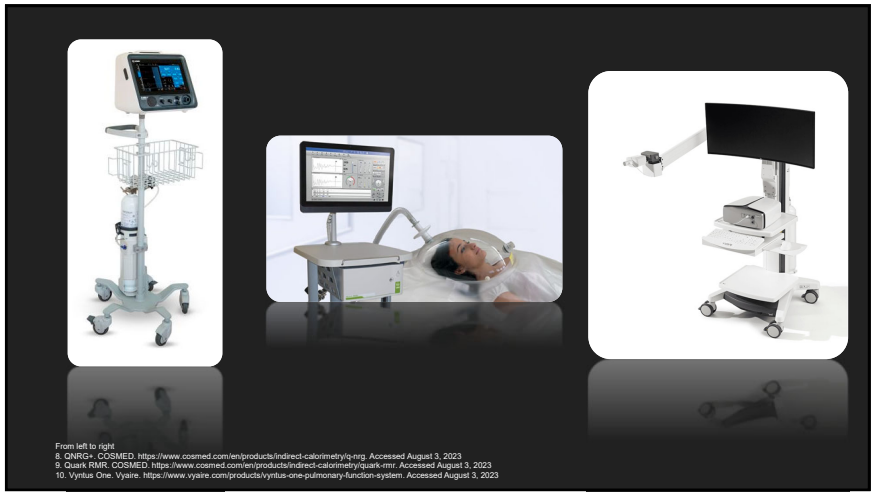

From left to right
8. QNRG+. COSMED. https://www.cosmed.com/en/products/indirect-calorimetry/q-nrg. Accessed August 3, 2023
9. Quark RMR. COSMED. https://www.cosmed.com/en/products/indirect-calorimetry/quark-rmr. Accessed August 3, 2023
10. Vyntus One. Vyaire. https://www.vyaire.com/products/vyntus-one-pulmonary-function-system. Accessed August 3, 2023

17

Common Indirect Calorimetry Modes

Ventilator | Mask | Canopy

From left to right
11. Delsoglio M, Achamrah N, Berger MM, Pichard C. Indirect calorimetry in clinical practice. J of Clin Med. 2019 Sep 5;8(9):1387.
12. Hans Rudolph Mask and Turbine on Child_COSMED. https://www.cosmed.com/media/widgetkit/qnrg_slideshow04-3efc51b08778bcffc1c4198de4b43a78.jpg. Accessed August 4 2023
13. Moonen HP, Beckers KJ, van Zanten AR. Energy expenditure and indirect calorimetry in critical illness and convalescence: current evidence and practical considerations. Journal of Intensive Care. 2021 Dec;9(1):1-3.

18

Common Indirect Calorimetry Modes

Ventilator | Mask | Canopy

Measuring in a closed environment without air leaks

From left to right
11. Delsoglio M, Achamrah N, Berger MM, Pichard C. Indirect calorimetry in clinical practice. J of Clin Med. 2019 Sep 5;8(9):1387.
12. Hans Rudolph Mask and Turbine on Child_COSMED. https://www.cosmed.com/media/widgetkit/qnrg_slideshow04-3efc51b08778bcffc1c4198de4b43a78.jpg. Accessed August 4 2023
13. Moonen HP, Beckers KJ, van Zanten AR. Energy expenditure and indirect calorimetry in critical illness and convalescence: current evidence and practical considerations. Journal of Intensive Care. 2021 Dec;9(1):1-3.

19

The Weir Equation

REE = [(3.94 x VO_{2*}) + (1.1 x VCO_{2*})] x 1440

*Measured in L/min

14. Weir JB. *J Physiol.* 1949;109(1-2):1-9. doi:10.1113/jphysiol.1949.sp004363.

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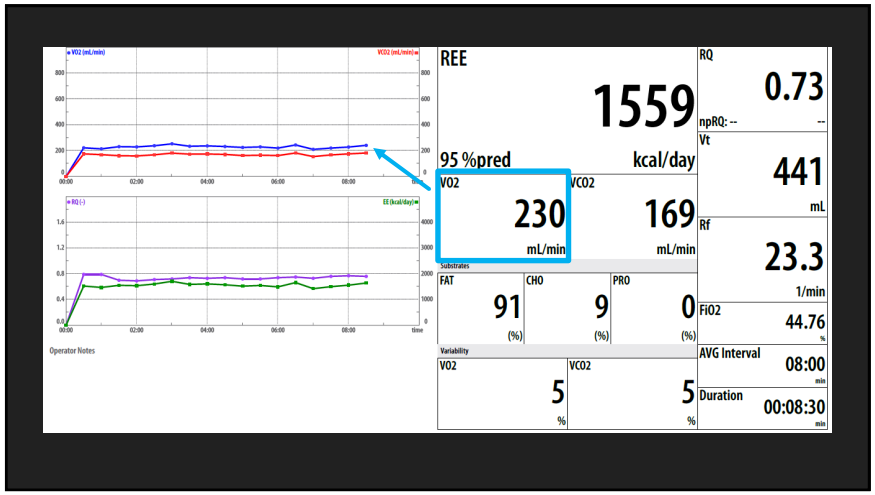

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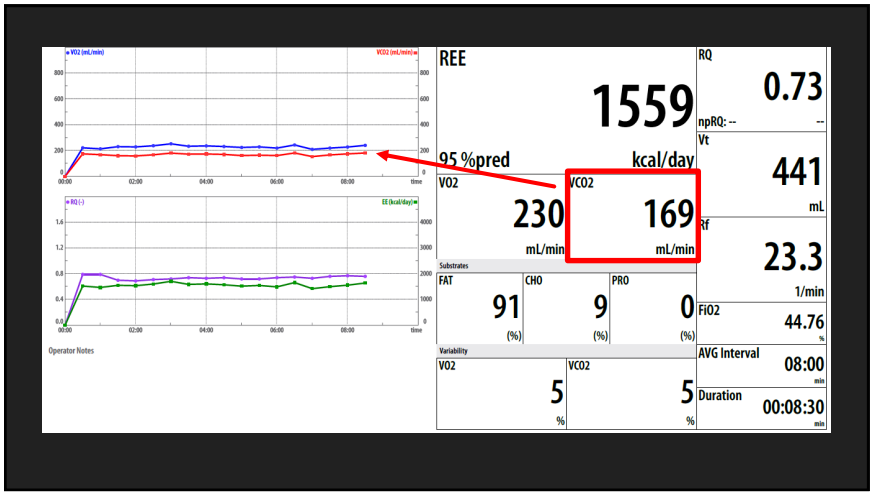

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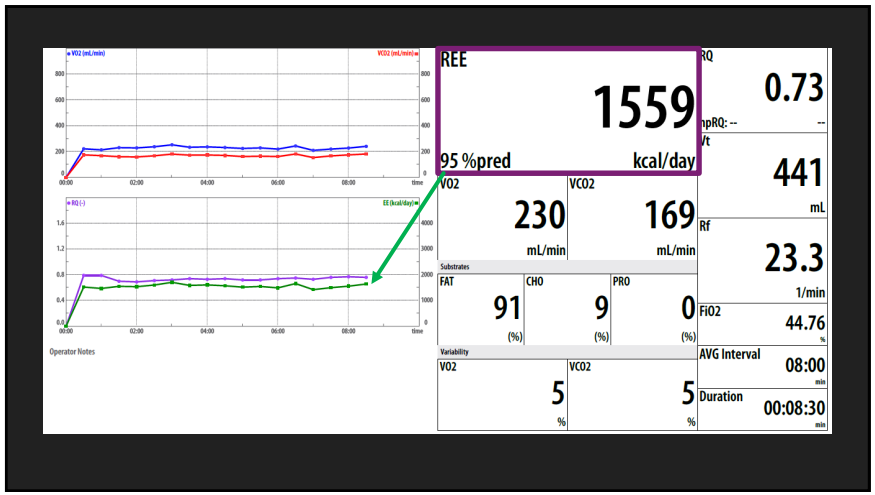

23

The Weir Equation

[(3.94 x .230) + (1.1 x .169)] x 1440

= 1559 kcal/day

14. Weir JB. *J Physiol.* 1949;109(1-2):1-9. doi:10.1113/jphysiol.1949.sp004363.

24

How long do assessments take?

- **20 minutes** at beginning of the day
- **25 minutes** per test from start to finish

25

Using Indirect Calorimetry in Clinical Practice

26

ESPEN 2019– "In critically ill mechanically ventilated patients, EE should be determined by using **indirect calorimetry**."

"Hypocaloric nutrition (not exceeding 70% of EE) should be administered in the **early phase of acute illness."**

"If indirect calorimetry is used, ***isocaloric*** nutrition rather than hypocaloric nutrition can be progressively implemented **after the early phase of acute illness"**

15. Singer P, Blaser AR, Berger MM, Alhazzani W, Calder PC, Casaer MP, Hiesmayr M, Mayer K, Montejo JC, Pichard C, Preiser JC. ESPEN guideline on clinical nutrition in the intensive care unit. Clinical nutrition. 2019 Feb 1;38(1):48-79.

27

ASPEN/SCCM 2016 – "We suggest that **indirect calorimetry (IC)** be used to determine energy requirements [in critically ill patients], when available and in the absence of variables that affect the accuracy of measurement."

Obesity – "65-70% of target energy requirements as measured by IC"

Sepsis – IC is recommended, f/u every 4 days, hypocaloric feeding, >80% over the 1st week

16. McClave SA, Taylor BE, Martindale RG, Warren MM, Johnson DR, Braunschweig C, McCarthy MS, Davanos E, Rice TW, Cresci GA, Gervasio JM. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (ASPEN). JPEN. Journal of parenteral and enteral nutrition. 2016 Feb 1;40(2):159-211.

28

ASPEN 2022 – "…"

Adult Critical Illness – "We suggest feeding between 12 and 25 kcal/kg in the first 7–10 days of ICU stay."

17. Compher C, Bingham AL, McCall M, Patel J, Rice TW, Braunschweig C, McKeever L. Guidelines for the provision of nutrition support therapy in the adult critically ill patient: The American Society for Parenteral and Enteral Nutrition. Journal of Parenteral and Enteral Nutrition. 2022 Jan;46(1):12-41.

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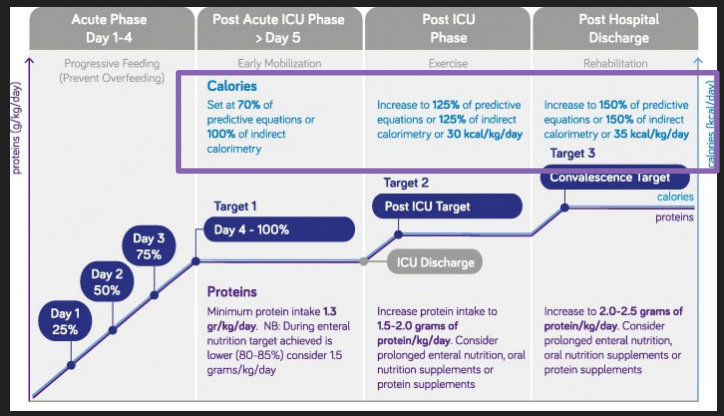

18. van Zanten AR, De Waele E, Wischmeyer PE. Nutrition therapy and critical illness: practical guidance for the ICU, post-ICU, and long-term convalescence phases. Critical Care. 2019 Dec;23(1):1-0.

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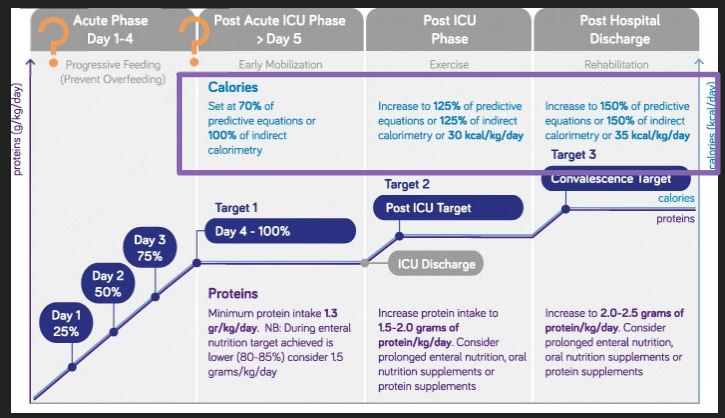

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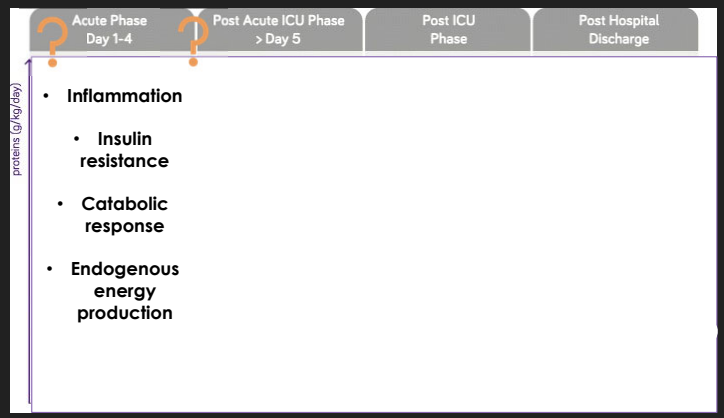

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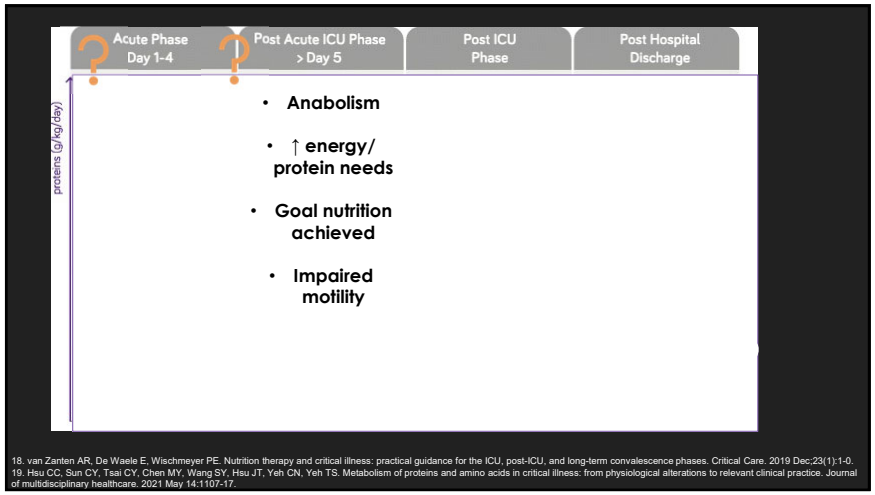
Acute Phase Day 1-4
Post Acute ICU Phase > Day 5
Post ICU Phase
Post Hospital Discharge
proteins (g/kg/day)
• Anabolism
• ↑ energy/ protein needs
• Goal nutrition achieved
• Impaired motility
18. van Zanten AR, De Waele E, Wischmeyer PE. Nutrition therapy and critical illness: practical guidance for the ICU, post-ICU, and long-term convalescence phases. Critical Care. 2019 Dec;23(1):1-0.
19. Hsu CC, Sun CY, Tsai CY, Chen MY, Wang SY, Hsu JT, Yeh CN, Yeh TS. Metabolism of proteins and amino acids in critical illness: from physiological alterations to relevant clinical practice. Journal of multidisciplinary healthcare. 2021 May 14:1107-17.

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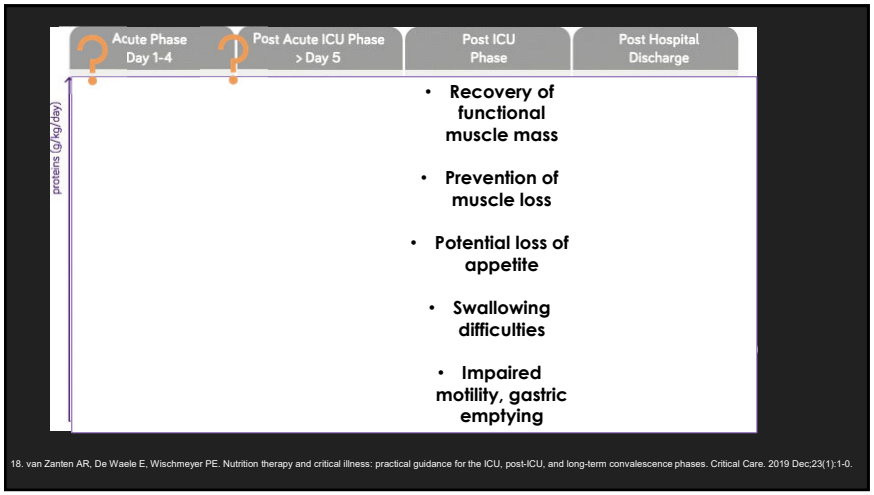
Acute Phase Day 1-4
Post Acute ICU Phase > Day 5
Post ICU Phase
Post Hospital Discharge
proteins (g/kg/day)
• Recovery of functional muscle mass
• Prevention of muscle loss
• Potential loss of appetite
• Swallowing difficulties
• Impaired motility, gastric emptying
18. van Zanten AR, De Waele E, Wischmeyer PE. Nutrition therapy and critical illness: practical guidance for the ICU, post-ICU, and long-term convalescence phases. Critical Care. 2019 Dec;23(1):1-0.

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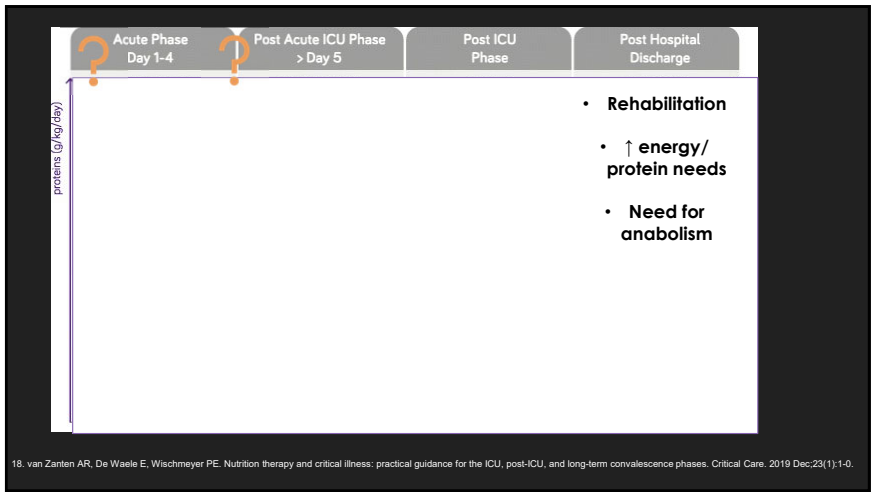
Acute Phase Day 1-4
Post Acute ICU Phase > Day 5
Post ICU Phase
Post Hospital Discharge
proteins (g/kg/day)
• Rehabilitation
• ↑ energy/ protein needs
• Need for anabolism
18. van Zanten AR, De Waele E, Wischmeyer PE. Nutrition therapy and critical illness: practical guidance for the ICU, post-ICU, and long-term convalescence phases. Critical Care. 2019 Dec;23(1):1-0.

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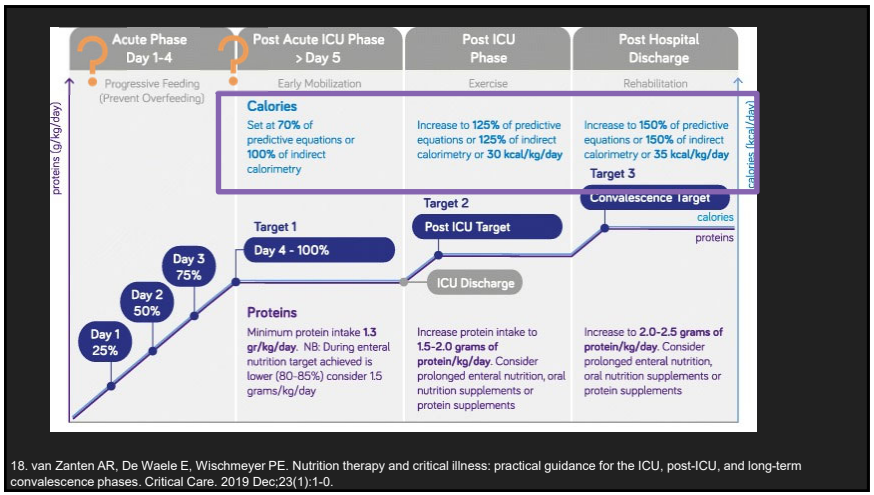
Acute Phase Day 1-4
Post Acute ICU Phase > Day 5
Post ICU Phase
Post Hospital Discharge
proteins (g/kg/day)
calories (kcal/day)
Progressive Feeding (Prevent Overfeeding)
Early Mobilization
Exercise
Rehabilitation
Calories
Set at 70% of predictive equations or 100% of indirect calorimetry
Increase to 125% of predictive equations or 125% of indirect calorimetry or 30 kcal/kg/day
Increase to 150% of predictive equations or 150% of indirect calorimetry or 35 kcal/kg/day
Target 1
Day 4 - 100%
Target 2
Post ICU Target
Target 3
Convalescence Target
calories
proteins
Day 1 25%
Day 2 50%
Day 3 75%
ICU Discharge
Proteins
Minimum protein intake 1.3 gr/kg/day. NB: During enteral nutrition target achieved is lower (80-85%) consider 1.5 grams/kg/day
Increase protein intake to 1.5-2.0 grams of protein/kg/day. Consider prolonged enteral nutrition, oral nutrition supplements or protein supplements
Increase to 2.0-2.5 grams of protein/kg/day. Consider prolonged enteral nutrition, oral nutrition supplements or protein supplements
18. van Zanten AR, De Waele E, Wischmeyer PE. Nutrition therapy and critical illness: practical guidance for the ICU, post-ICU, and long-term convalescence phases. Critical Care. 2019 Dec;23(1):1-0.

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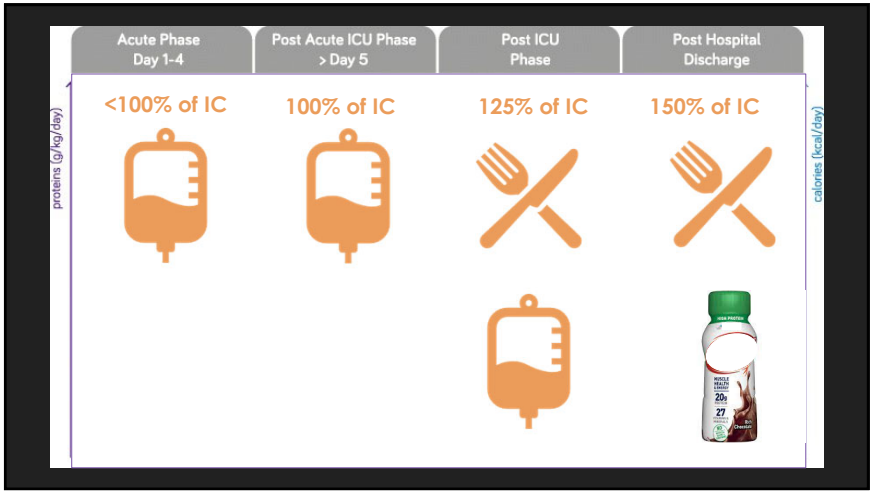


37

Learning Assessment Question

ICU Day 2 is always considered acute phase critical illness

1. True
2. False

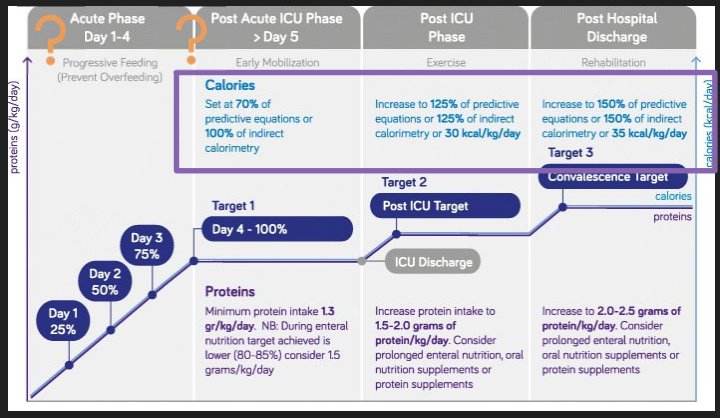
38

Learning Assessment Question

ICU Day 2 is always considered acute phase critical illness

1. True
2. **False**

39



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40

Who Benefits from Indirect Calorimetry?

41

Which patients do I measure?

Which patients are you *least confident* in predicting REE?

42

Which patients do I measure?

EN/PN Access + No Contraindications

20. Oshima T, Berger MM, De Waele E, Guttormsen AB, Heidegger CP, Hiesmayr M, Singer P, Wernerman J, Pichard C. Indirect calorimetry in nutritional therapy. A position paper by the ICALIC study group. Clinical nutrition. 2017 Jun 1;36(3):651-62.
21. Rattanachaiwong S, Singer P. Indirect calorimetry as point of care testing. Clinical nutrition. 2019 Dec 1;38(6):2531-44.

43

Which patients do I measure? - ICU

EN/PN Access + No Contraindications

- ↓ REE — Paralysis
- ↓ REE — Anorexia
- ? REE - ? LBM — Obesity/Fluid
- ↓ REE & ↑ REE — Poly-Trauma
- ↑ REE — COPD / CF

20. Oshima T, Berger MM, De Waele E, Guttormsen AB, Heidegger CP, Hiesmayr M, Singer P, Wernerman J, Pichard C. Indirect calorimetry in nutritional therapy. A position paper by the ICALIC study group. Clinical nutrition. 2017 Jun 1;36(3):651-62.
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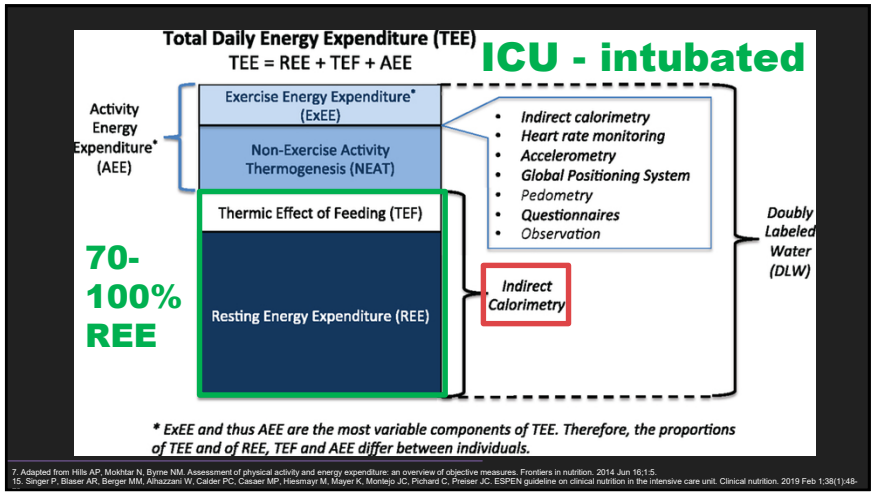

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45

When and how often do I measure?

- Oshima et al. : on ***day 3 or 4*** after ICU admission + **every 2-3** days while in ICU care
- ASPEN/SCCM 2016 : **>1 test / week**
- Also consider… before nutrition assessment due, test should be representative of next few days, next phase of care

20. Oshima T, Berger MM, De Waele E, Guttormsen AB, Heidegger CP, Hiesmayr M, Singer P, Wernerman J, Pichard C. Indirect calorimetry in nutritional therapy. A position paper by the ICALIC study group. Clinical nutrition. 2017 Jun 1;36(3):651-62.
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46

Which patients do I measure? - Floor

EN/PN/Oral Access + No Contraindications

- ↓ REE — Amputee
- REE + More Kcal — Weight Gain
- REE - Kcal — Weigh Loss
- ↓ REE & ↑ REE — HD or PD
- ↑ REE — COPD / CF

20. Oshima T, Berger MM, De Waele E, Guttormsen AB, Heidegger CP, Hiesmayr M, Singer P, Wernerman J, Pichard C. Indirect calorimetry in nutritional therapy. A position paper by the ICALIC study group. Clinical nutrition. 2017 Jun 1;36(3):651-62.
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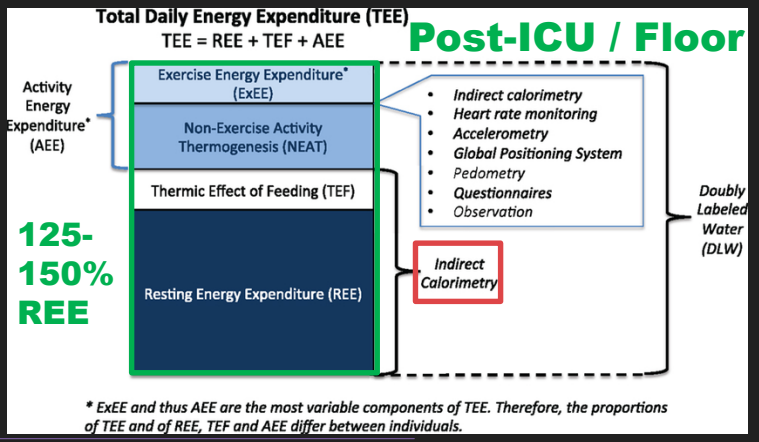

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48

How Dynamic are Energy Needs?

49

Case Study

Calorie Needs in Post-ICU Care

50

EB is a 42 y.o. F admitted for abdominal pain

s/p emergent small bowel resection for ischemia

PMHx

- Hyperthyroidism
- Substance use disorder
- T2DM

Anthropometrics upon Admission

Height – 168.4 cm

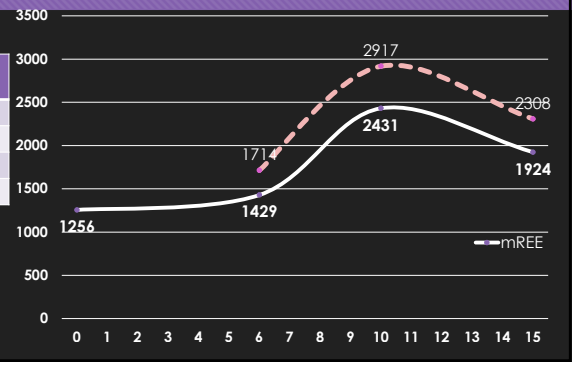
Weight – 100 kg

BMI 35.3 kg/m^2

51

EB's Measured REE in ICU

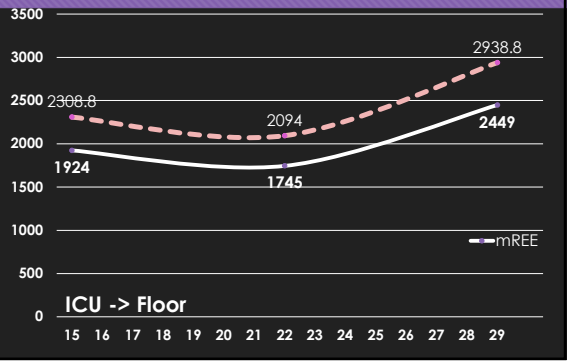
ICU Day	Measured REE	Respiratory Status
0	1,256 kcal	Ventilator
6	1,429 kcal	Room Air
10	2,431 kcal	Room Air
15	1,924 kcal	Room Air



52

EB's Measured REE in post-ICU

Day	Measured REE	Clinical Notes
22	1,745 kcal	WBC WNL, afebrile
29	2,449 kcal	Tachycardic, elevated WBC, afebrile



53

7 days after the last measurement… EB refuses for N/V/abd pain

Current Nutrition: TPN + full liquid diet, ONS ordered
Current Weight – 86.8 kg
Hospital Day – 36
Declines PT, afebrile, normal WBC count, no C-RP available

At this point, we must use a predictive equation

54

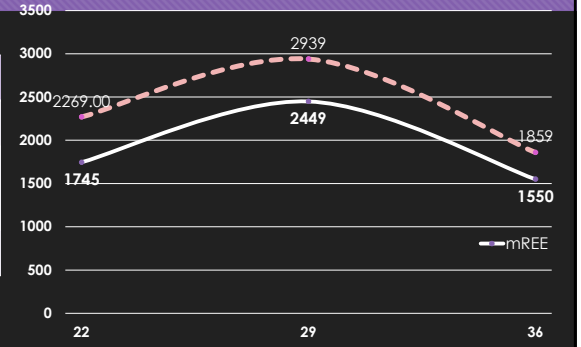
Predictive Energy Equations

Equation	Estimated REE	x 1.2 Activity Factor
Mifflin St Jeor	1,550 kcal	1,859 kcal
Harris Benedict	1,600 kcal	1,920 kcal
ASPEN 15 kcal/kg	1,302 kcal	1,562 kcal
ASPEN 20 kcal/kg	1,736 kcal	2,083 kcal
Other?		

55

EB's Measured REE in post-ICU

Day	Measured REE	Clinical Notes
22	1,745 kcal	WBC WNL, afebrile
29	2,449 kcal	Tachycardic, elevated WBC, afebrile
36	1,859 kcal **MSJ x 1.2**	N/V, abd pain



56

7 days after the last visit… EB refuses *again* for N/V/abd pain

Current Nutrition: TPN + full liquid diet, ONS ordered
Current Weight – 86.6 kg *(0.2 kg wt loss x 1 week)*
Hospital Day – 45
Declines PT, afebrile, normal WBC count, no C-RP available

Once again, a predictive equation must be used

57

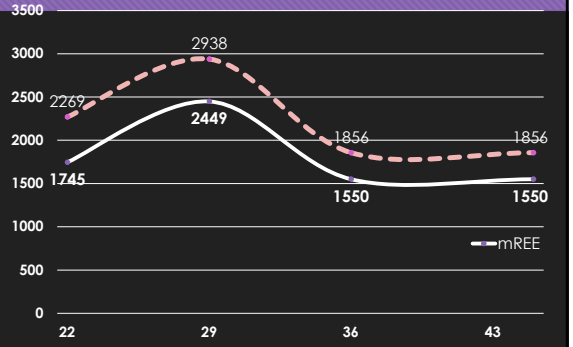
Predictive Energy Equations

Equation	Estimated REE	x 1.2 Activity Factor
Mifflin St Jeor	1,550 kcal	1,859 kcal
Harris Benedict	1,600 kcal	1,920 kcal
ASPEN 15 kcal/kg	1,302 kcal	1,562 kcal
ASPEN 20 kcal/kg	1,736 kcal	2,083 kcal
Other?		

58

EB's Measured REE in post-ICU

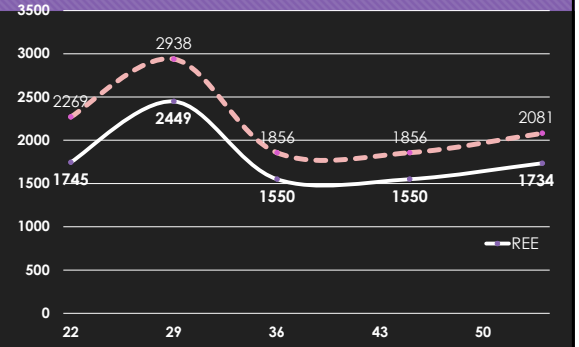
Day	REE	Clinical Notes
22	1,745 kcal **IC mREE**	WBC WNL, afebrile
29	2,449 kcal **IC mREE**	Tachycardic, elevated WBC, afebrile
36	1,550 kcal **MSJ**	N/V, abd pain
45	1,550 kcal **MSJ**	N/V, abd pain



59

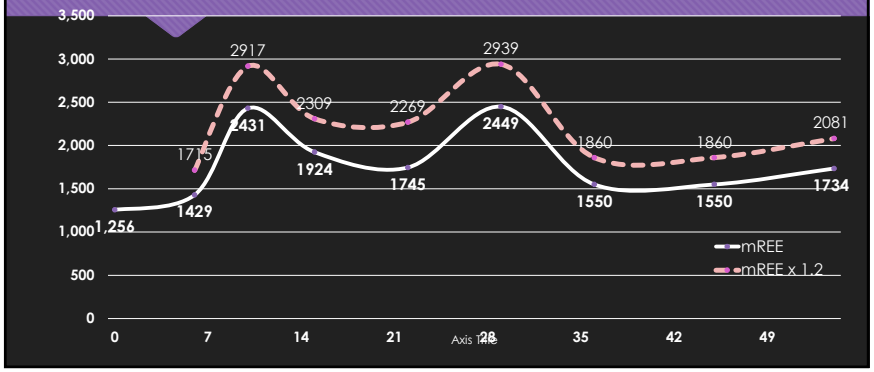
EB agrees to a measurement!

Day	REE	Clinical Notes
22	1,745 kcal **IC mREE**	WBC WNL, afebrile
29	2,449 kcal **IC mREE**	Tachycardic, elevated WBC, afebrile
36	1,550 kcal **MSJ**	N/V, abd pain
45	1,550 kcal **MSJ**	N/V, abd pain
54	1,734 kcal **IC mREE**	WBC WNL, afebrile



60

The Dynamic Nature of Energy Requirements



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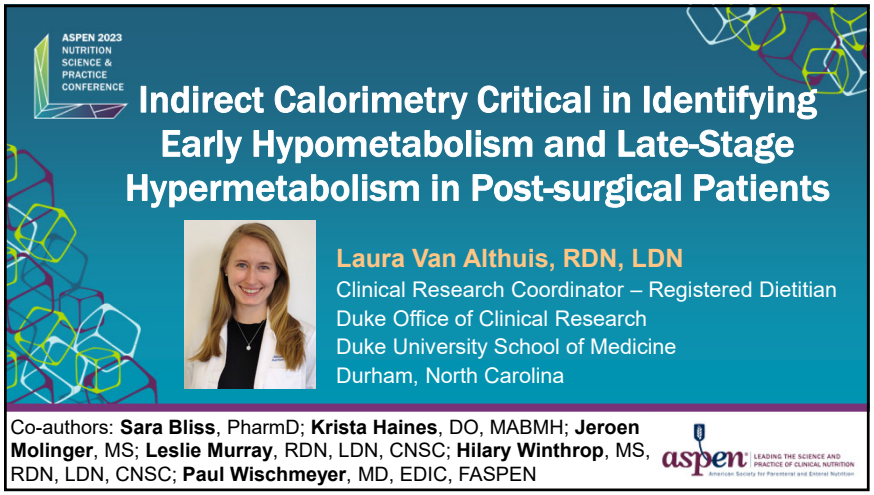
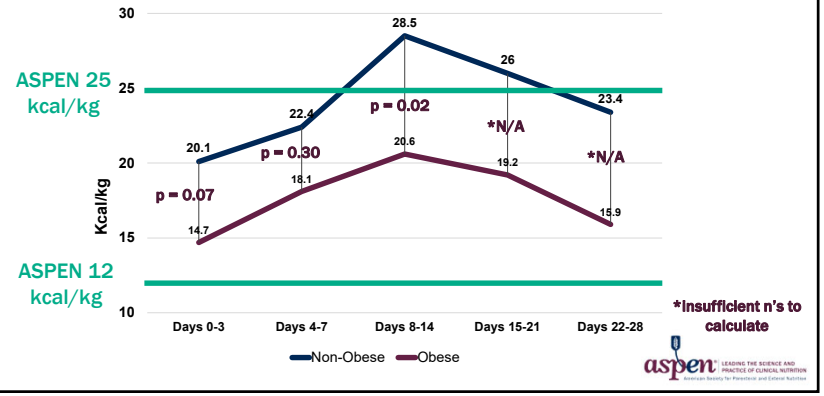


62

Higher caloric needs among non-obese patients consistent with literature



63

Conclusion

- Any predictive equation is as reliable as the variables are *accurate*
- Energy needs are dynamic throughout hospitalization – how are you accounting for that?
- Be persistent with your pursuit to perform at the top of your license

64

Learning Assessment Question

Which functions of Indirect Calorimetry are within an RD's scope of practice

1. Interpret test results
2. Recommend and interpret test results
3. Perform and interpret test results
4. Recommend, perform, and/or interpret test results

65

Learning Assessment Question

Which functions of Indirect Calorimetry are within an RD's scope of practice

1. Interpret test results
2. Recommend and interpret test results
3. Perform and interpret test results
4. **Recommend, perform, and/or interpret test results**

66

eat right.

FROM THE ACADEMY

Academy of Nutrition and Dietetics: Revised 2017 Scope of Practice for the Registered Dietitian Nutritionist

The Academy Quality Management Committee

- Recommend, perform, and/or interpret test results related to nutrition status: blood pressure, anthropometrics (eg, height and weight, skinfold thickness, waist circumference, calculation of body mass index with classification for malnutrition and obesity), indirect calorimetry, laboratory tests, and waived point-of-care laboratory testing (eg, blood glucose and cholesterol) (http://wwwn.cdc.gov/dls/waivedtests/ and http://www.cms.gov/Regulations-and-Guidance/Legislation/CLIA/downloads/waivetbl.pdf).

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68

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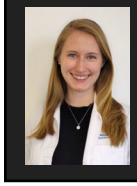
69

Thank you! Questions?

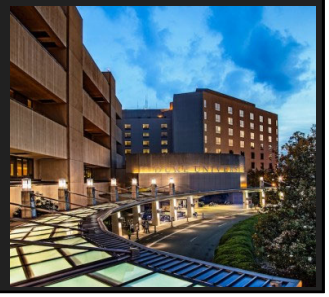
Laura Van Althuis, RDN, LDN

Clinical Research Coordinator and Registered Dietitian

Email: laura.vanalthuis@duke.edu



Email me for an Indirect Calorimetry SBAR



70