- Angela L. Bingham, PharmD, BCPS, BCNSP, BCCCP, Associate Professor of Clinical Pharmacy, Philadelphia College of Pharmacy- University of the Sciences
- Basic Skills in Parenteral Nutrition Management: It's All About the Acid-Base, No Trouble: Identification and Treatment of Acid-Base Disorders
- I have no commercial relationships to disclose

Presentation Overview/Summary

- Clinicians require basic nutrition support information in order to safely and effectively deliver parenteral nutrition to patients. This session within the skills lab will focus on identification and treatment of acid-base disorders in patients receiving parenteral nutrition. Participants will engage in a focused, interactive presentation with patient cases to accomplish the learning objectives.

Learning Objectives

- Learning objectives for the presentation:

At the conclusion of the presentation, the learner will be able to:

1. Describe metabolic and respiratory acid-base disorders.
2. Given a nutrition support patient with an acid-base disorder, apply a systematic approach to diagnose and manage the disorder.
3. Given a nutrition support patient with an acid-base disorder, identify the most likely cause(s) for the disorder.

Key Takeaways/Fast Factors

- Assessment of physical exam findings and review of laboratory data are critical to determine the primary acid-base disorder.
- A systematic approach should be used to evaluate acid-base disorders.
- In management of acid-base disorders, it is most important to recognize and treat the underlying etiology. Additional supportive therapies may be warranted depending on severity.

Learning Assessment Questions

1. Question 1: An adult male is hospitalized and receiving parenteral nutrition.
   Patient's current laboratory data:
   pH: 7.46
   pCO_2: 34 mmHg
   pO_2: 100 mmHg
   Serum HCO_3^-: 24 mEq/L

   What is the patient's acid-base disorder at this time?
   A. Respiratory alkalosis
   B. Respiratory acidosis
   C. Metabolic alkalosis
   D. Metabolic acidosis

2. Question 2: In metabolic acidosis, HCO_3^- is decreased below the normal range.
   A. True
   B. False

3. Question 3: An adult female is hospitalized and receiving parenteral nutrition.

   Patient's current laboratory data:
   ABG:
   pH: 7.22
   pCO_2: 38 mmHg
   pO_2: 98 mmHg

   Serum chemistries:
   Sodium: 141 mEq/L
   Chloride: 110 mEq/L
   HCO_3^-: 11 mEq/L

   What is the patient's acid-base disorder at this time?
   A. Metabolic alkalosis
   B. Metabolic acidosis (non-anion gap)
   C. Metabolic acidosis (anion gap)
   D. Respiratory acidosis

4. Question 4: Overfeeding is associated with the development of respiratory acidosis.
   A. True
   B. False

5. Question 5: Upper gastrointestinal hydrogen losses are associated with the development of metabolic acidosis.
   A. True
   B. False

Learning Assessment Answers:

1. Answer = A; Rationale: *The correct answer is respiratory alkalosis. This acid-base disorder is categorized as an alkalosis because the pH is >7.4. This alkalosis is respiratory rather than metabolic because the pCO_2 is <40 mmHg.*
2. Answer = True; Rationale: *In metabolic acidosis, HCO_3^- is decreased below the normal range. By contrast, in metabolic alkalosis, HCO_3^- is increased above the normal range.*
3. Answer = C; Rationale: *The correct answer is metabolic acidosis (anion gap). This acid-base disorder is categorized as an acidosis because the pH is <7.4. This acidosis is metabolic rather than respiratory because the serum HCO_3^- is <24 mEq/L. The anion gap = $[Na^+ – (Cl^- + HCO_3^-)] = [141 – (110+11)] = 20$. Therefore, an anion gap metabolic acidosis is present.*
4. Answer = True; Rationale: *Overfeeding is associated with the development of respiratory acidosis. pCO_2 accumulates resulting in this acid-base disorder.*
5. Answer = False; Rationale: *Upper gastrointestinal hydrogen losses are associated with the development of metabolic alkalosis rather than metabolic acidosis. This may occur due to vomiting or nasogastric losses.*

References

1. Chapter 4. Acid-base disorders. In: Canada T, Tajchman SK, Tucker AM, Ybarra J, eds. ASPEN Fluid, Electrolyte, and Acid-Base Disorders Handbook; 1st ed. Silver Spring, MD: ASPEN; 2015:201-245.
2. Ayers P, Warrington L. Diagnosis and treatment of simple acid-base disorders. *Nutr Clin Pract*. 2008 Apr-May;23(2):122-127.
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Simple Acid-Base Disorders

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Overview

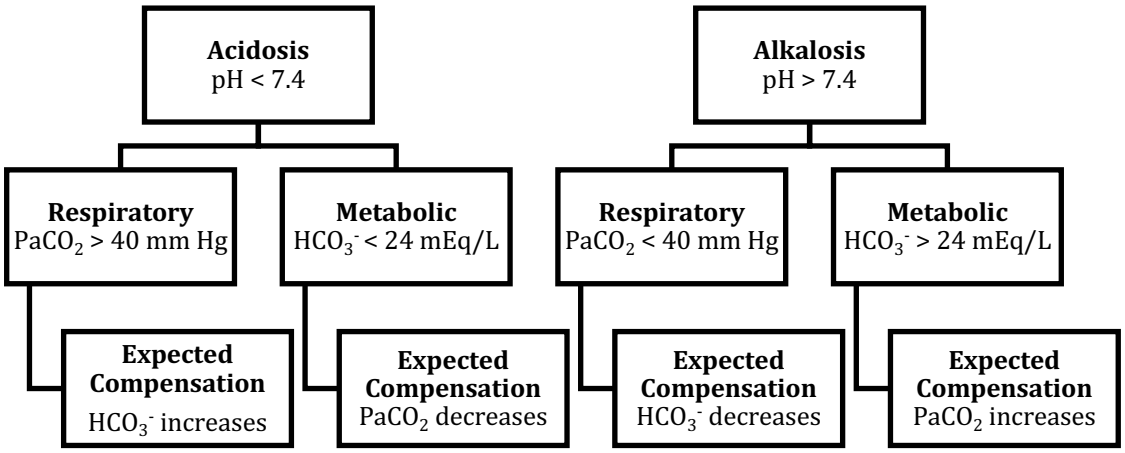
- Physiology
  - Acid: Substance that can donate H^+
  - Base: Substance that can accept H^+
- ABG interpretation:
  - Reported as pH / pCO_2 / pO_2 / HCO_3
  - Normal values:

pH	7.40 (range 7.35-7.45)
pCO_2	35-45 mmHg
pO_2	80-100 mmHg
HCO_3	22-26 mEq/L

- Metabolic disorders (primary disorder)
  - Acidosis = decreased HCO_3
  - Alkalosis = increased HCO_3
- Respiratory disorders (primary disorder)
  - Acidosis = increased PCO_2
  - Alkalosis = decrease PCO_2
- Anion gap (AG)
  - Difference between the measured and unmeasured major extracellular cations and anions
  - Calculate if metabolic acidosis present
  - $AG = Na^+ – (Cl^- + HCO_3^-) = 3\text{-}11$ mEq/L
- Compensation
  - For respiratory disorders
    - Kidneys regulate HCO_3^- by changing HCO_3^- excretion
  - For metabolic disorders
    - Lungs regulate PCO_2 by changing the rate and depth of ventilation

Algorithm to Determine Simple Acid-Base Disorders

- Helpful hints
  - Compare HCO_3^- on ABG and BMP to verify accurate lab values
  - ABG and BMP results should be drawn close to the same time when comparing values
  - Use BMP HCO_3^- value when possible because HCO_3^- on ABG is a calculated value



Angela L. Bingham, PharmD, BCPS, BCNSP, BCCCP, Associate Professor of Clinical Pharmacy, Philadelphia College of Pharmacy

Common Causes for Acid-Base Disorders

<table>
<tr><th>Respiratory Acidosis</th><th colspan="2">Metabolic Acidosis
Anion Gap (AG) = $Na^+ – (Cl^- + HCO_3^-)$</th><th>Respiratory Alkalosis</th><th>Metabolic Alkalosis</th></tr>
<tr><td>Respiratory Depression
Opioids
Benzodiazepines and sedatives
Neuromuscular blockers
Anesthetics
Ventilator underuse
Neuromuscular Disease/Abnormalities
Brain injury or tumor
Stroke
Guillain-Barre
Multiple sclerosis
Amyotrophic lateral sclerosis
Myasthenia gravis
Pulmonary/Airway Abnormalities
Massive pulmonary embolism
Pulmonary edema
Pneumonia
Pneumothorax
ARDS
Smoke inhalation
COPD/emphysema
Sleep apnea
Asthma
Airway obstruction
Metabolic
Overfeeding</td><td>Elevated AG
Lactic Acidosis
Tissue hypoxia (shock, sepsis)
Severe anemia
Propofol (high doses)
Metformin (use in renal failure)
Linezolid
Nucleoside-analog reverse transcriptase inhibitors (NRTIs)
Lorazepam (PEG vehicle)
Isoniazid
Nitroprusside
Decompensated CHF
Seizures
Liver disease
Rhabdomyolysis
Carbon monoxide poisoning
Thiamine deficiency
Ketoacidosis
Diabetic ketoacidosis
Starvation ketoacidosis
Alcohol ketoacidosis
Other Causes
Renal Failure (uremia)
Toxins/Overdoses
Methanol
Ethylene glycol
Propylene glycol
Propyl alcohol
Salicylates</td><td>Normal/Non-AG
Lower GI HCO_3^- Loss
$MgSO_4$ laxatives
Cholestyramine
Small intestinal losses
Diarrhea
Fistula (biliary, pancreatic, small bowel)
Urinary diversion
Renal HCO_3^- Loss
Renal failure (tubular acidosis)
Acetazolamide
Hyperkalemia (Electrolyte Shift)
Hypoactive adrenal disorders
K^+ sparing diuretics
Trimethoprim (Bactrim)
ACE-Is and ARBs
NSAIDs
Heparin
Cyclosporine
Cl^- Addition
Excessive Cl use
Rapid saline administration
Calcium chloride</td><td>Respiratory Stimulation
Theophylline, caffeine
Nicotine
Catecholamines
Salicylate overdose
Brain injury or tumor
Meningitis
Pain
Anxiety
Fever
Pregnancy
Pulmonary embolism
Asthma
Ventilator overuse
Hypoxia
Hyperventilation
Hypoxemia
High altitudes
Pneumonia
Pulmonary edema
Severe anemia
Other Causes
Thyrotoxicosis
Cirrhosis</td><td>Renal H^+ Loss
Loop diuretics
Thiazide diuretics
Steroids
Hyperactive adrenal disorders
Upper GI H^+ Loss
Vomiting
NG or G tube losses
HCO_3^- Addition
Citrate (blood products)
Antacids
Excessive acetate or HCO_3^- use
Others Causes
Profound hypokalemia
Cystic fibrosis
Rapid correction of hypocapnia</td></tr>
</table>

References

1. Chapter 4. Acid-base disorders. In: Canada T, Tajchman SK, Tucker AM, Ybarra J, eds. ASPEN Fluid, Electrolyte, and Acid-Base Disorders Handbook; 1st ed. Silver Spring, MD: ASPEN; 2015:201-245.
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Acknowledgement

Anne M. Tucker, PharmD, BCNSP, Clinical Pharmacy Specialist Critical Care/Nutrition Support, University of Texas MD Anderson Cancer Center

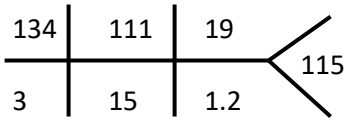
Angela L. Bingham, PharmD, BCPS, BCNSP, BCCCP, Associate Professor of Clinical Pharmacy, Philadelphia College of Pharmacy

Practice Cases

Case 1:

An adult male underwent a partial small bowel resection 3 days ago secondary to Crohn's disease. He remains NPO and is receiving parenteral nutrition.

7.3 / 27 / 98 / 15

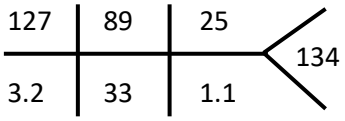


What is the acid-base disorder and possible cause? After adding the appropriate phosphate dose to his parenteral nutrition, which form(s) would you recommend for the anions for his sodium and potassium salts? (all chloride, all acetate, one-half chloride and one-half acetate)

Case 2:

An adult male is intubated for respiratory failure secondary to septic shock 7 days ago. He is now volume overloaded and was started on furosemide continuous infusion yesterday. He is receiving parenteral nutrition due to vasopressor use, high NG output, and abdominal distension.

7.52 / 46 / 94 / 32

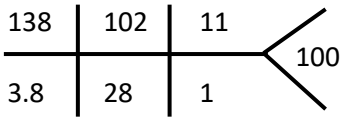


What is the acid-base disorder and possible cause? How should his parenteral nutrition be formulated to ensure that this acid-base disorder is not worsened?

Case 3:

An adult female is admitted for pneumonia requiring intubation. She has experienced a 40 pound weight loss over the past 6 months due to intermittent small bowel obstructions and inability to tolerate significant oral intake. She was initiated on parenteral nutrition and has been at goal nutrition (42 kcal/kg/day and 1.8 g protein/kg/day) for several days. The ICU team is now having trouble weaning her from the ventilator.

7.32 / 52 / 96 / 27



What is the acid-base disorder and possible cause? How should her parenteral nutrition be formulated to ensure that this acid-base disorder is not worsened?

ASPEN EDUCATION PROGRAM OUTLINE TEMPLATE

Anne M. Tucker, PharmD, BCNSP
Clinical Pharmacy Specialist – Critical Care / Nutrition Support
The University of Texas MD Anderson Cancer Center
Houston, Texas

Basic Skills in Parenteral Nutrition Management
Sodium, water, both or none: fluid assessment and sodium homeostasis in parenteral nutrition patients.

Disclosures
"I have no commercial relationships to disclose"

Presentation Overview/Summary
The identification of fluid and sodium disorders and the skills needed to prevent and manage these disorders are important for clinicians who specialize in nutrition support. This presentation will use case studies to demonstrate and reinforce concepts for applying clinical judgment to enhance interpretation of objective monitoring parameters.

Learning Objectives
At the conclusion of the presentation, the learner will be able to:

1. Determine total body water and fluid requirements of parenteral nutrition patients.
2. Identify common fluid and sodium disorders seen in parenteral nutrition patients.
3. Discuss appropriate management of fluid and sodium disorders in parenteral nutrition patients.

Key Takeaways/Fast Facts

- A thorough history and physical is a key first step in assessment of fluid and sodium disorders.
- Not all hyponatremia cases require an increase in sodium provision.
- When formulating a parenteral nutrition prescription, be aware of medications, inputs/outputs, pertinent labs, and comorbidities to determine fluid and sodium needs of the patient.

Learning Assessment Questions

1. What is the total body water (TBW) for a 45 year old female (170.18 cm and 62 kg)?
    A. 46 L
    B. 37.2 L
    C. 31 L
    D. 27.9 L

2. What would be the maintenance fluid requirements for a 75 year old male with a past medical history of hypertension, atrial fibrillation, and heart failure?
    A. 35-40 mL/kg/day
    B. 30-35 mL/kg/day
    C. 25-30 mL/kg/day
    D. 20-25 mL/kg/day

3. In a hyponatremic patient diagnosed with syndrome of inappropriate antidiuresis (SIAD), which of the following would be the most appropriate management strategy?
    A. Concentrate TPN and sodium provision at 154 mEq/L.
    B. Concentrate TPN and sodium provision at 77 mEq/L.
    C. Addition of free water and sodium provision at 154 mEq/L.
    D. Addition of free water and sodium provision at 38.5 mEq/L.

4. Which of the following sodium concentrations would be appropriate to use when writing a parenteral nutrition order in a patient with nasogastric tube output and stable vital signs?
    A. 513 mEq Na/L
    B. 154 mEq Na/L
    C. 77 mEq Na/L
    D. 38.5 mEq Na/L

5. In a hypernatremia patient due to excessive furosemide administration, which of the following interventions would be most appropriate when formulating a parenteral nutrition order? Of note, the current parenteral nutrition contains 77 mEq Na/L.
    A. Concentrate TPN and continue current sodium provision.
    B. Concentrate TPN and sodium provision at 154 mEq/L.
    C. Addition of free water and sodium provision at 154 mEq/L.
    D. Addition of free water and remove sodium from parenteral nutrition.

Learning Assessment Answers:

1. Answer = C; Rationale: *Total body water (TBW) for adult females less than 70 years of age is weight in kg x 0.5 L/kg (62 kg x 0.5 L/kg = 31 L).*
2. Answer = D; Rationale: *due to this patient's age (> 65 years) and comorbid conditions (specifically heart failure), his fluid requirements would be lower compared to younger patients; recommendations are to begin at 20-25 mL/kg/day and adjust as appropriate for any other current conditions and medications.*
3. Answer = A; Rationale: *in SIAD, management includes restriction of fluid and provision of isotonic sodium (154 mEq/L); treatments initiated at the underlying cause should also be employed.*
4. Answer = B; Rationale: *the sodium content of nasogastric output is ~60 mEq Na/L making use of ½ NS (77 mEq Na/L) the closest fit for maintaining sodium homeostasis.*
5. Answer = D; Rationale: *in a patient with hypernatremia, the most appropriate option of the choices provided is to add free water and remove sodium in the parenteral nutrition.*

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1. Braun MM, Barstow CH, Pyzocha NJ. Diagnosis and Management of Sodium Disorders: Hyponatremia and Hypernatremia. *Am Fam Physician.* 2015;91(5):299-307.
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5. Milionis HJ, Liamis GL, Elisaf MS. The hyponatremic patient: a systemic approach to laboratory diagnosis. *CMAJ* 2002;166(8):1056-62.

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Fluid Assessment and Sodium Homeostasis Guide

Total Body Water (TBW)

The amount of water in the body (Liters)
Percent of lean body mass (LBM)

Affected by percentage of body fat, age, and gender

Percent of TBW (L)
75% for infants
60% males (< 70 years) and children
50% females (< 70 years) & elderly males (> 70 years)
45% elderly females (> 70 years)

Adipose tissue: ~10% water
Muscle: ~75% water
**As age, proportion of adipose tissue to muscle mass increases
**Women have a higher proportion of adipose tissue compared to men

Obesity calculation LBW
LBW (women) = 1.07 * weight (kg) – 148 * [weight (kg) / height (cm)]^2
LBW (men) = 1.1 * weight (kg) – 128 * [weight (kg) / height (cm)]^2

Fluid Requirements

Amount of fluid needed per day to offset losses and maintain hydration

Holliday Segar method (weight-based, used mostly in pediatrics)
≤ 10 kg: 100 mL/kg
11 – 20 kg: 1000 mL + 50 mL/kg over 10 kg
> 20 kg: 1500 mL + 20 mL/kg over 20 kg

Age/condition-based (mL/kg/day)

Active young adult (16-30 years)	35-40 mL/kg/d
Average adults (25-55 years)	30-35 mL/kg/d
Older adults (55-65 years)	25-30 mL/kg/d
Elderly (> 65 years), CHF, CKD, ascites	20-25 mL/kg/d

Per caloric intake
1 mL/kcal ingested

Body surface area
1500 – 1600 mL/m^2/d BSA (m^2) = $\sqrt{[(\text{height in cm} \times \text{weight in kg}) \div 3600]}$

Dietary Reference Intake
Adult female (> 19 years): 2.7 L/d
Adult male (> 19 years): 3.7 L/d

Fluid Balance

Fluid intake = fluid output
Fluids from all sources should be accounted and adjusted to keep net zero
Weight monitoring important (short-term weight changes indicate fluid gains/losses)

Inputs
Oral/enteral fluid intake
Water intake (including water flushes)
Food intake
Water in food
Oxidative metabolism of food (~300 mL water/d)
IV fluid intake
IV fluids and medications (esp. antimicrobial agents)

Outputs
Urine (normal 0.5 – 2 mL/kg/d)
Gastrointestinal (see below); based on amount, increase fluid provision
Vomiting/NG or G-tube losses, diarrhea/ostomy losses, fistula
Insensible losses
Skin - 75% of insensible losses (~600 mL/d)
Sweating, fever, disrupted skin barrier (burns, wounds) increases losses
Lungs - 25% of insensible losses (~300 mL/d)
Hyperventilation, fever and living in dry climates increases losses

Composition of Body Fluids

Body Fluid	Volume (mL/d)	mEq/L			
		Na	Cl	K	HCO_3
Saliva	1000-1500	10	10	26	30
Stomach/NG	1000-9000	60	130	10	0
Duodenum	Variable	140	80	5	0
Ileum	3000	140	104	5	30
Colon	Variable	60	40	30	0
Pancreas	Variable	140	75	5	115
Bile	Variable	145	100	5	35

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Fluid Assessment and Sodium Homeostasis Guide

Composition of Plasma and Crystalloid Fluids

Fluid	Tonicity	mEq/L					
		Na	Cl	K	Ca	Mg	Buffers
Plasma	Isotonic	140	103	4	5	2	Bicarb (25)
D_5W	Hypotonic	-	-	-	-	-	-
0.225% NaCl	Hypotonic	38	38	-	-	-	-
0.45% NaCl	Hypotonic	77	77	-	-	-	-
0.9% NaCl	Isotonic	154	154	-	-	-	-
Lactated Ringer's	Isotonic	130	109	4	3	-	Lactate (28)
Plasma-Lyte	Isotonic	140	98	5	-	3	Acetate (27)
3% NaCl	Hypertonic	513	513	-	-	-	-

Sodium Disorders and Parenteral Nutrition Management

Steps in Na disorder Management
Identify type of Na disorder
Determine cause of Na disorder and start cause-specific/etiology-based treatment
Replace fluid volume loss, if needed (start with NS if hemodynamic compromise)
Adjust TPN Na content (and IV fluids) based on type of losses and patient condition

Small, incremental changes in TPN Na have little to no effect on serum Na

Add Na content to TPN formulations similar to IV fluids
0.9% NaCl (NS) = isotonic = 154 mEq Na/L (SIADH, high output SB fistula)
0.45% NaCl (1/2 NS) = hypotonic = 77 mEq Na/L (maintenance, NG output)
0.225% NaCl (1/4 NS) = hypotonic = 38.5 mEq Na/L (CHF, renal failure, ascites)

Use of NaCl versus NaAcetate
Base choice of Na salt on type of fluid losses and acid-base status

Fluid deficit (hypernatremic patients)
Fluid deficit (L) = TBW * [(serum Na ÷ 140) - 1]
Replace 50% over first day, and remainder over next 2-3 days

Limit change in serum Na to ≤ 8-10 mEq/L in 24 hours or ≤ 18 mEq/L in 48 hours
Correction of hyponatremia too fast → central pontine myelinolysis
Correction of hypernatremia too fast → cerebral edema

Hyponatremia - Fluid and Sodium Adjustments to Parenteral Nutrition

Hyponatremia Type	Adjustment
Hyperglycemia (hypertonic)	Correct hyperglycemia Corrected Na = serum Na + 0.016 * (glucose - 100) No change to TPN Na or volume
Volume depletion (hypotonic hypovolemic)	Replete fluid losses Determine type of fluid loss Adjust TPN Na to reflect type of losses Increase TPN volume/IV fluids based on losses
Syndrome of inappropriate diuresis (SAID) (hypotonic euvolemic)	Identify cause and begin treatment Fluid restriction Concentrate TPN Na repletion → adjust TPN Na to NS
Volume overload (hypotonic hypervolemic)	Fluid restriction ± diuretic therapy Concentrate TPN Na restriction → adjust TPN Na to ¼ or ½ NS

Hypernatremia - Fluid and Sodium Adjustments to Parenteral Nutrition

Hypernatremia Type	Adjustment
Volume depletion (hypertonic hypovolemic)	Replete fluid losses Determine type of fluid loss Adjust TPN Na to reflect type of losses Increase TPN volume/IV fluids based on losses
Diabetes insipidus (hypertonic euvolemic)	Replete fluid losses (as needed) Minimize Na in TPN (consider removal of Na) Increase TPN volume/IV fluids based on losses
Volume overload (hypertonic hypervolemic)	Fluid restriction ± diuretic therapy Concentrate TPN Minimize Na in TPN (consider removal of Na)

References

Langley G and Tajchman S. Fluid, Electrolytes, and Acid-Base Disorders. In:Mueller CM, ed. The A.S.P.E.N. Adult Nutrition Support Core Curriculum; 2nd ed. Silver Spring, MD: A.S.P.E.N.; 2012:98-120.
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Mosteller RD. Simplified calculation of body-surface area. N Engl J Med 1987;317:1098.

Case 1

65 year old male with metastatic lung cancer who is admitted 6 days ago for N/V, abdominal pain, fever, and productive cough. Patient is diagnosed with aspiration pneumonia and small bowel obstruction. IV hydration was provided and a NG tube was placed. Nutrition Support Team is consulted today (1/15/18) to initiate TPN. Past medical history includes hypertension, hypothyroidism, and hyperlipidemia. Medications include: cefepime 2g IV every 8h, metronidazole 500mg IV q8h, linezolid 600mg IV q12h, hydralazine 10mg IV q6h, pantoprazole 40mg IV q24h, levothyroxine 50 mcg IV q24h, ondansetron 8mg IV q8h prn nausea/vomiting, and morphine sulfate 2 mg IV q2h prn pain. IV fluids are D5 1/2NS + 20 mEq KCl/L at 84 mL/hr.

		1/12/18	1/14/18	1/15/18
Inputs / Outputs (mL)		3075 / 2375	3265 / 2414	
Urine output (mL)		1275	1464	
NG output (mL)		1100	950	
Stool		--	--	
Na	(135-147 mEq/L)	127	126	126
K	(3.5-5 mEq/L)	3.5	3.6	3.5
Cl	(98-108 mEq/L)	95	97	96
CO_2	(23-30 mEq/L)	25	27	27
BUN	(8-20 mg/dL)	11	12	11
SCr	(0.6-1.2 mg/dL)	0.8	0.9	0.75
Glucose	(70-99 mg/dL)	135	122	140

Other labs (1/15/18): TSH: 1.33 mcu/mL (normal 0.27-4.2), cortisol: 15 mcg/dL (normal 4.3-22.4), serum Osm: 263 mOsm/kg (275-295), urine Na: 90 mEq/L, urine Osm: 651 mOsm/kg, serum albumin 2.4 g/dL, serum triglycerides 72 mg/dL (normal $\leq$ 150).

Vitals: T 37.2 C, HR 85, BP 126/78, RR 20, SpO_2 96%; height 178 cm, weight 81.6 kg

Physical exam:

HEENT: PERRLA, EOMI intact; moist mucous membranes
CV: regular, rate and rhythm; no murmurs, rubs or gallops, no JVD noted
LUNGS: crackles heard at lung bases bilaterally, no wheezes
ABD: distended, non-tender, hypoactive bowel sounds
EXT: 2+ pulses bilaterally; no edema, cyanosis, or clubbing
Neuro: A & O x 3

Case #1 questions

1. What is his serum osmolality – hypertonic, isotonic, or hypotonic?

2. What is his volume status?

3. What is his sodium disorder?

4. What intervention(s) would you make upon initiation of TPN?

Case 2

51 year old male who is s/p right hemicolectomy 10 days ago admitted with abdominal pain, N/V. Fluid resuscitation was provided using NS and a NG tube was placed. CT abdomen/pelvis was obtained which showed intra-abdominal abscess and partial small bowel obstruction. Patient is s/p IR guided abscess drain placement. It is now hospital day 4 and the Nutrition Support Team is consulted to initiate TPN. Past medical history includes hypertension, GERD, anemia, and colon cancer. Medications include: piperacillin/tazobactam 3.375g IV q6h, pantoprazole 40mg IV q24h, ondansetron 8mg IV q8h prn N/V, and morphine PCA. IV fluids are D5 NS at 84 mL/hr.

		1/12/18	1/14/18	1/15/18
Inputs/Outputs (mL)		2650 / 4170	2540 / 4565	
Urine output (mL)		900	1090	
NG output (mL)		3150	3400	
Abscess drain (mL)		120	75	
Stool		--	x1	
Na	(135-147 mEq/L)	148	151	152
K	(3.5-5 mEq/L)	3.5	3.7	3.9
Cl	(98-108 mEq/L)	114	116	118
CO_2	(23-30 mEq/L)	26	25	26
BUN	(8-20 mg/dL)	45	48	50
SCr	(0.6-1.2 mg/dL)	0.67	0.7	0.68
Glucose	(70-99 mg/dL)	90	98	97

Other labs (1/15/18): Serum Osm: 330 mOsm/kg (275-295), serum albumin 4.6 g/dL.

Vitals: T 37.1 C, HR 110, BP 102/62, RR 20, SpO_2 99% room air; height 190.5 cm, weight 86.3 kg

Physical exam:

HEENT: PERRLA, EOMI intact; dry mucous membranes
CV: regular, rate and rhythm; no murmurs, rubs or gallops, no JVD noted
LUNGS: clear to auscultation bilaterally
ABD: + abdominal tenderness and distension, hypoactive bowel sounds
EXT: 2+ pulses bilaterally; no edema, cyanosis, or clubbing

Case #2 questions

1. What is his total body water?

2. What is his volume status?

3. What is his sodium disorder?

4. What intervention(s) would you make upon initiation of TPN?

My Access is Compromised, Now What!

March 24,2019

Antoinette M. Neal RN, BSN, CRNI, VA-BC, CNSC

Objectives

1. Describe the differences between peripheral parenteral nutrition(PPN) and central parenteral nutrition(CPN)
2. Describe the appropriate vascular access for PPN and CPN
3. Recognize vascular access devices
4. Discuss complications and options available when the access is compromised

Outline

1. Parenteral nutrition formulations
    a. Peripheral Parenteral Nutrition
        i. Peripheral / Midline Catheter
    b. Central Vascular Nutrition
2. Description of vascular accesses
    a. Material
    b. Open or Closed end
    c. Non Power or Power
3. Long Term Vascular Access Placement and Devices
    a. Temporary Non –Tunneled Central Catheter
    b. Peripherally Inserted Central Catheter(PICC)
        i. Locating tip of PICC
    c. Internal Jugular
    d. Tunneled Central Catheters
    e. Implanted Ports
4. Complications and Options

My Access is Compromised, Now What!

Antoinette M. Neal RN, BSN,CRNI,VA-BC,CNSC
Cleveland Clinic Infusion Pharmacy at Home
Center for Connected Care
ASPEN 2018 Nutrition Science & Practice Conference
March 24,2019

Disclosures

- I have nothing to disclose
- Any products mentioned is for general and educational purposes only

Learning Objectives

- Discuss vascular access devices
- Review causes of access malfunctioning and possible complications

Possible Complications

The use of an indwelling central venous catheter provides an important means of venous access for critically ill patients; however, the potential exists for serious complications including the following:

- Air Embolism
- Allergic Reaction to Silver or Collagen (Catheters with VitaCuff® Antimicrobial Cuff only)
- Bleeding
- Brachial Plexus Injury
- Cardiac Arrhythmia
- Cardiac Tamponade
- Catheter or Cuff Erosion Through Skin
- Catheter Embolism
- Catheter or Cuff Occlusion
- Catheter Occlusion, Damage or Breakage due to Compression Between the Clavicle and First Rib
- Catheter-related Sepsis
- Endocarditis
- Exit Site Infection
- Exit Site Necrosis
- Extravasation
- Fibrin Sheath Formation
- Hematoma
- Hemothorax
- Hydrothorax
- Intolerance Reaction to Implanted Device
- Laceration of Vessels or Viscus
- Myocardial Erosion
- Perforation of Vessels or Viscus
- Pneumothorax
- Spontaneous Catheter Tip Malposition or Retraction
- Thoracic Duct Injury
- Thromboembolism
- Venous Thrombosis
- Ventricular Thrombosis
- Vessel Erosion
- Risks Normally Associated with Local and General Anesthesia, Surgery, and Post-Operative Recovery

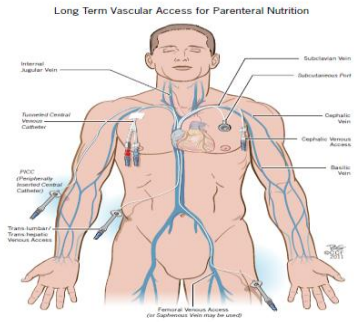
Complications

- Migration or suboptimal tip location
- Pinch Off Syndrome
- Fibrin Sheath -withdrawal occlusion
  - Tissue plasminogen activator
- Damage to catheter
  - Repair kits – Temporary/Permanent repair
- Loss of superior vena vascular access
  - Alternate routes Inferior vena cava
- Catheter related blood stream infection
  - Ethanol lock therapy

Central Parenteral Nutrition(CPN)

- Often referred as total parenteral nutrition (TPN)
- Complete nutrition needs, for a nonfunctioning GI tract
  - Dextrose 15% - 30%
  - Amino acids 4%- 7%
  - (2 N 1)
  - Fat emulsion 10%-20% if be included (3N1)
    - Fat emulsion can be infused separately as a Y infusion
    - SMOF lipid available in United States
  - Electrolytes
  - Trace elements
- 1300-1800 mOsm/L- hyperosmolar
- Formulation must be delivered into a large central vein
-

Adult Nutrition Support Core Curriculum(2nd ed.)



Central Vascular Access

- Access sites SVC
  - Basilic , Cephalic, Jugular, and Subclavian
    - Catheter tip in the distal third of superior vena cava or right atrial junction(RAJ)

Central Vascular Access

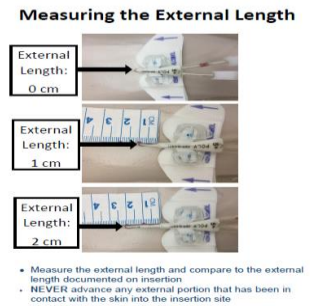
- Superior vena cava (SVC) is the main vessel of venous return from the upper trunk emptying into the right atrium
  - Preferred vessel for central infusion of vesicants and hyperosmolar fluids (TPN)
  - Blood flow 2000ml +/minute

20-30 mm in diameter

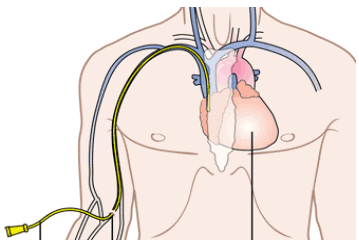
Subclavian 800ml /minute (NOT ENOUGH DILUTION)

SVC 7 cm length

Optimal tip position distal third of the SVC / Cavoatrial Junction



Peripheral Inserted Central Catheter (PICC)



Peripheral Inserted Central Catheter(PICC)

- Inserted into a peripheral vein in the upper arm, catheter tip terminates in the SVC or cavoatrial junction
- Long term ,widely used
- Single, double or triple lumens
- May not be preferred device for long term PN (So who is going to care for my line ?)
- Verify tip with chest x-ray or tip locator

Peripheral Parenteral Nutrition(PPN)

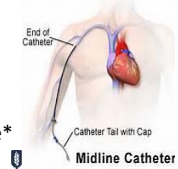
- Mild malnutrition, adjunct to limited or oral intake
- Meet two criteria :
  - *GOOD* peripheral access
    - Phlebitis may occur (potassium is an irritant)
      - 600-900 mOsm/L
      - Requiring frequent site rotations
  - *ABLE* to tolerate larger volumes (2.5- 3 L) of fluids
- Lower concentrations of nutrients
  - Dextrose 150-300g/day , or 5-10 % final concentration
  - Amino acids 50-100g/day, or 3 % final concentration
  - Fat emulsions 10-20 % (isotonic)

Peripheral /Midline Catheter ***FOR PPN ONLY***

- Peripheral
  - Short term 72-96 hours
  - Tip ends in peripheral vessels
- Midline
  - Short term 2-4 weeks
  - 4" - 8" long (10-20 cm.)
  - Tip peripheral, not passed axilla

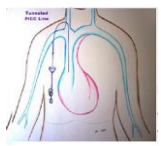
  Brachial /Cephalic 40-95ml/minute

  Basilic 90-150ml/minute



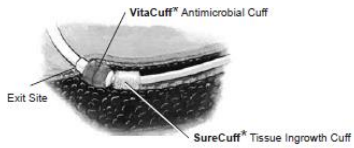
Internal Jugular (IJ)

- Internal jugular catheters utilized in patients with renal disease (Hohn®)
  - Preservation of the peripheral and subclavian veins for arteriovenous fistulae or grafts
  - "Tunneled chest PICC"
- Tunneled or directly inserted
  - into the internal jugular vein
  - tip SVC or RAJ
- Can be cuffed or un-cuffed



CUFF

The **SureCuff** Tissue Ingrowth Cuff, attached to the catheter, is positioned in the tunnel. The cuff helps secure the catheter through fibrous tissue ingrowth and creates a physical barrier to help reduce the potential for infection caused by the migration of bacteria through the subcutaneous tunnel.

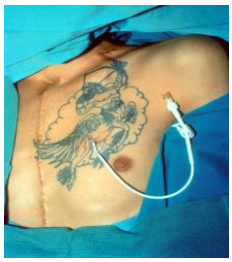


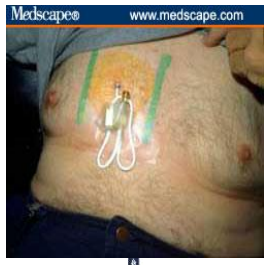
Tunneled Cuffed Central Catheters

- Long term use , surgically placed (common brand names):
- Broviac – Single or double
  - Smaller diameters
  - Geriatric or pediatric population
- Hickman- Single, double or triple
- Leonard- Double
  - Both lumen sizes are equal

Various central tunneled catheters

Single / Double Lumen Tunneled Catheter

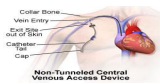




Temporary Non Tunneled Central Catheter

- A quick access device placed in emergency situations or in the intensive care units
- Insertion point under clavicle directly into subclavian vein
- Commonly known as triple lumen subclavian, percutaneous, acute-care catheter
- Short term 7-10 days

Not suitable for home use

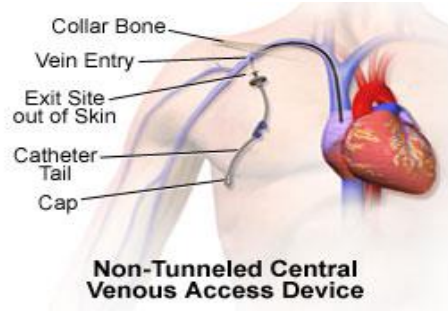


Open or Closed Ended

- Open Ended

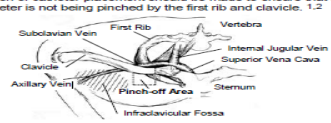
- Closed Ended – Groshong

Pressure sensitive 3 way valve prevents reflux of blood which should decrease rick of occlusion



Pinch Off

- **Pinch-off Prevention:** Catheters placed percutaneously or through a cut-down, into the subclavian vein, should be inserted at the junction of the outer and middle thirds of the clavicle, lateral to the thoracic outlet. The catheter should not be inserted into the subclavian vein medially, because such placement can lead to compression of the catheter between the first rib and the clavicle, which can cause damage and even severance of the catheter. A radiographic confirmation of catheter placement should be made to ensure that the catheter is not being pinched by the first rib and clavicle. [1,2]



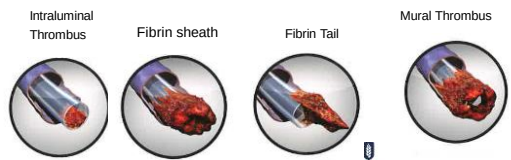
Signs of Pinch-off

Clinical:

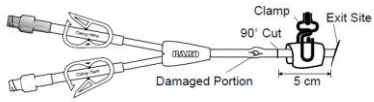
- Difficulty with blood withdrawal.
- Resistance to infusion of fluids.
- Patient position changes required for infusion of fluids or blood withdrawal

Occlusions

- 58 % thrombotic
  - Formation of thrombus within, surrounding or at the tip of the catheter
    - Proper flushing – 10ml Sodium Chloride 0.9%
    - De clotting solutions as a tissue plasminogen activator



Damaged Catheter



Warning: The length of the remaining external segment must be sufficient to permit catheter repair and prevent catheter retraction under the skin line.

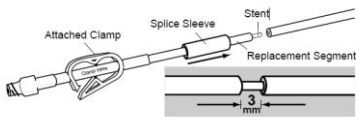
Clamp damaged catheter proximal to skin
Cut to repair external portion of the damaged catheter distal to broken area

Repair

- Temporary Repair Kits
  - No more than 7 days
  - Blunt needles for temporary repair available in various sizes
    - Hickman – 15 ga luer stub adapter
    - Broviac – 18 ga luer stub adapter

Repair

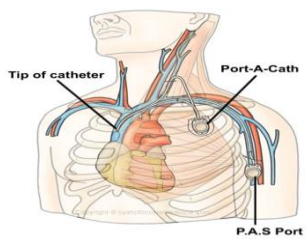
Permanent Repair Kits



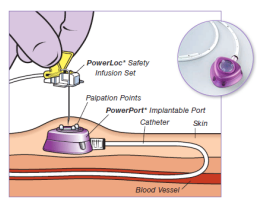
Implanted Ports

- Long Term, minimal alteration in body image
- Lower infection and thrombosis rate
- Silicone catheter attached to a plastic or titanium disk with a self sealing septum
- Surgically placed in subcutaneous pocket common anterior chest , or arm (peripheral vascular access system (PAS)
- Access only with a non coring needle
- Can be accessed 1000-2000 times
- Various port sizes , single or double lumen

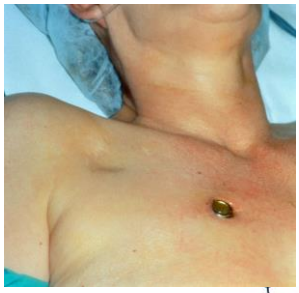
Implanted Port



Implanted port- Non Power and Power

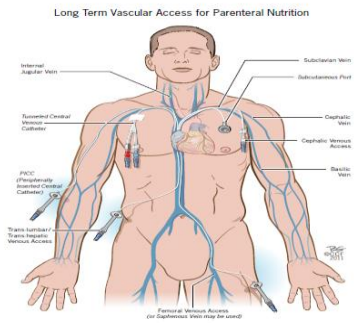


Exposed Port – “Easy Access”

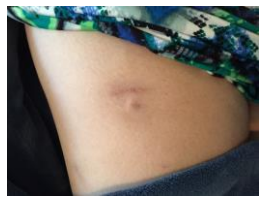


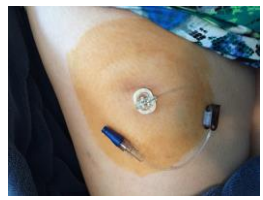
Central Vascular Access

- Access to the Inferior Vena Cava (IVC)
  - Trans lumbar, Trans hepatic and Femoral
    - Distal catheter tip in the IVC above the level of the diaphragm at the right atrium
      - Femoral area higher prone infection



Femoral Thigh Port





Types of Catheter Material CRBSI

- Silicone
  - Pliable, less traumatic to veins
  - Able to instill ethanol lock solution
- Polyurethane
  - Thinner wall
  - Debate over ethanol dwelling in catheters
    - “Alcohol should not be used to lock , soak or declot polyurethane as alcohol is known to degrade polyurethane catheters over time with repeated prolonged exposure” Bard Access Systems, 2012

Thank You

- Questions?????
- Contact information :
  - May request slides
  - neala@ccf.org

Jacob W. Hall, PharmD, BCNSP
Clinical Pharmacy Specialist - Nutrition Support/Critical Care
The University of Texas MD Anderson Cancer Center

ASPEN 2019 Nutrition Science & Practice Conference

jhall1@mdanderson.org

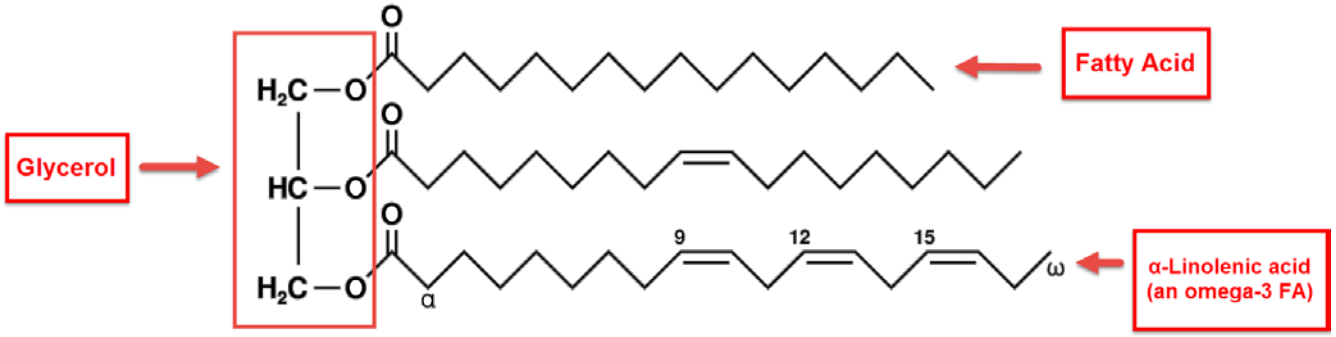
Navigating the Intravenous Lipid Emulsion Literature: Understanding the Types and Uses of Lipid Therapy

Disclosures: I have nothing to disclose. I will be discussing off-label use.

Background:

I. Nomenclature[1]

a. Triglycerides versus Fatty Acids



b. Polyunsaturated Fatty Acids: PUFA's
   i. Carbon length > 12
   ii. Multiple double bonds (see image above)

c. Omega-What?
   i. Named for number of carbons from the end of the molecule to the first double bond

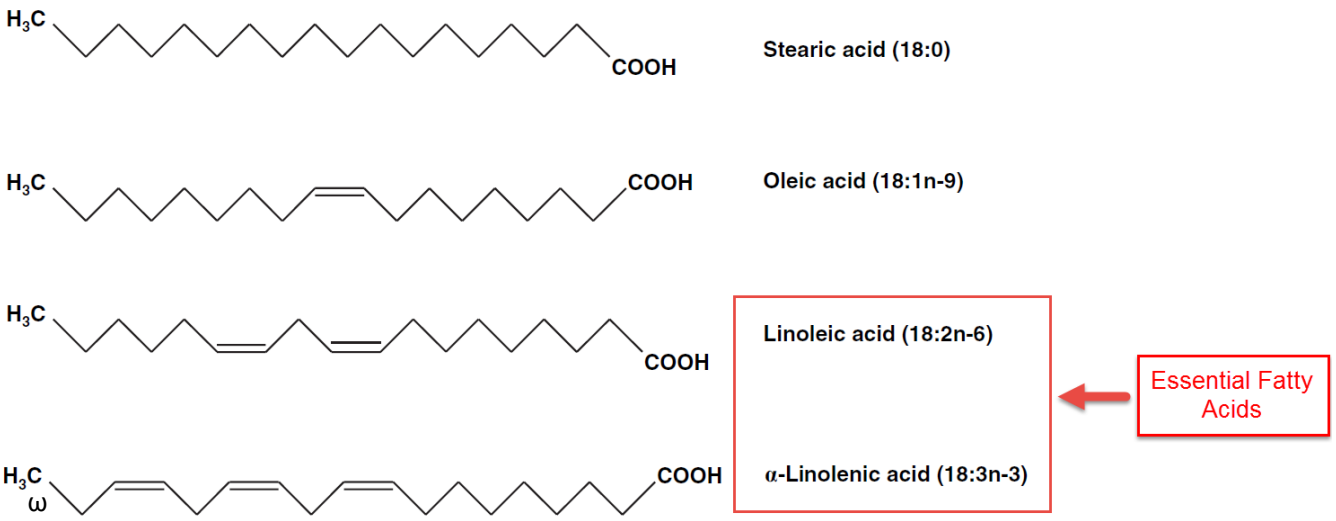


FIGURE 2. Structure and naming of selected 18-carbon fatty acids.

Wanten & Calder. *Am J Clin Nutr*. 2007; 1171-84

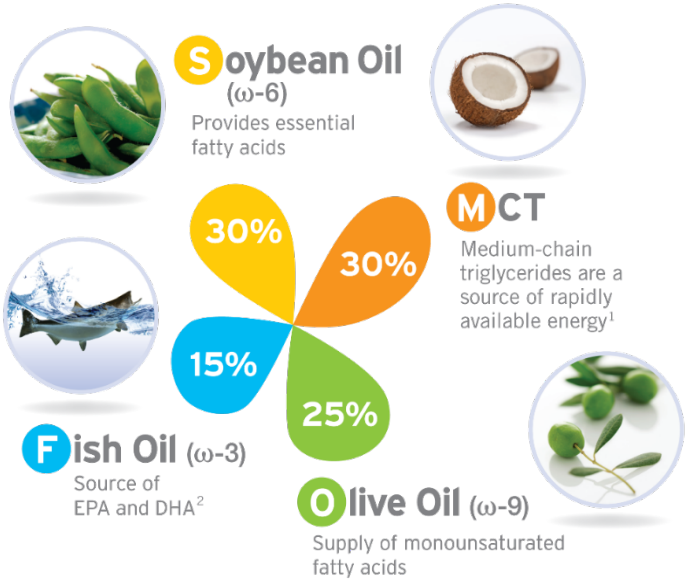
II. Sources
   a. Soybean oil
   b. Coconut oil - MCT
   c. Olive oil
   d. Fish oil

III. What is available in US

<u>Intralipid® – 100% soybean oil</u>

Source: Baxter Healthcare

<u>Smoflipid® – 30% Soybean, 30% MCT (Coconut), 25% Olive, 15% Fish</u>



Source: Fresenius Kabi

<u>Omegaven® – 100% fish oil</u> (Recent FDA Approval!)

Source: Fresenius Kabi

Why we care about lipid type:

I. Essential Fatty Acids[2]
   a. Linoleic & α-linolenic
   b. Linoleic needs minimum 1% of calories per day, optimally 3-4% of daily calories

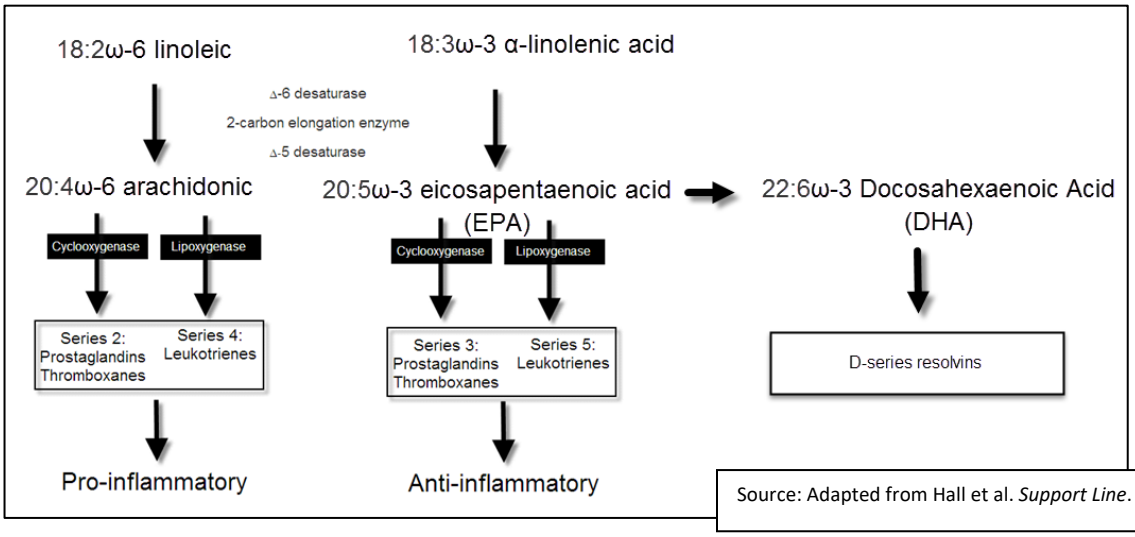
IVFE needs based on EFA content (amounts per day)*								
Kcal	1000-1250	1250-1500	1500-1750	1750-2000	2000-2250	2250-2500	2500-2750	2750-3000
Intralipid® 20%	22 mL (4.4 g)	26 mL (5.2 g)	31 mL (6.2 g)	36 mL (7.2 g)	41 mL (8.2 g)	46 mL (9.2 g)	50 mL (10 g)	55 mL (11 g)
SMOFlipid® 20%	34 mL (6.8 g)	47 mL (9.4 g)	56 mL (11.2 g)	65 mL (13 g)	73 mL (14.6 g)	82 mL (16.4 g)	91 mL (18.2 g)	99 mL (19.8 g)
*Amounts based on 2% of daily kcal provided at linoleic acid, Intralipid linoleic acid content of 52%, SMOFLipid linoleic acid content of 29%.								

Simplified formulas to meet EFA needs*:

Intralipid: $g\ IL\ per\ day = kcal/day \times 0.0038$ Smoflipid®: $g\ SMOF\ per\ day = kcal/day \times 0.0069$

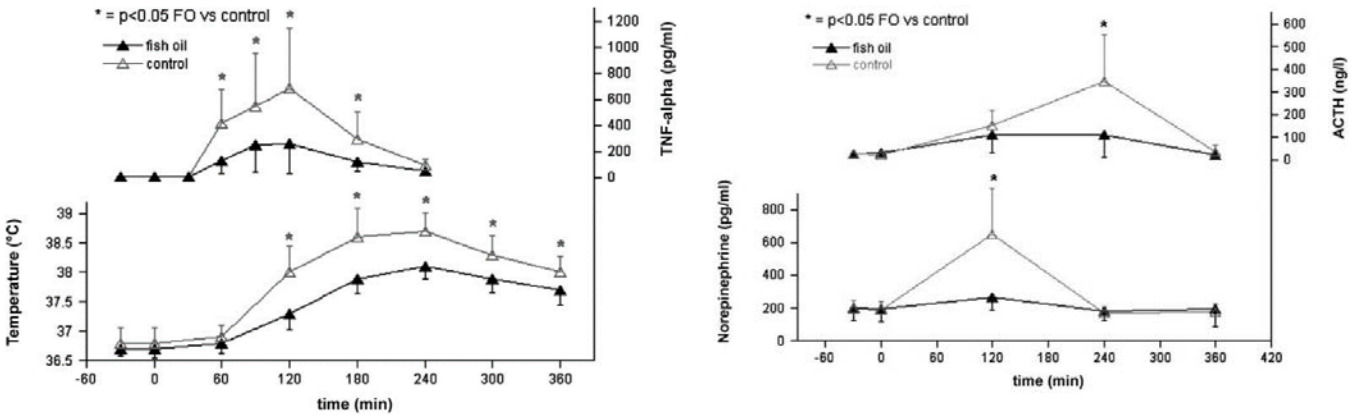
   c. Omegaven® contains very low amounts of Linoleic acid (4.5% versus 52% of intralipid®)
      i. Max dose of 1 g/kg/day – insufficient to obtain 2% of kcal as linoleic
      ii. However, arachidonic acid, EPA and DHA content have been shown to be sufficient to prevent EFAD in infants[3]

II. Problems of soy only
   a. Inflammatory[4]



Source: Adapted from Hall et al. *Support Line*. 2014; 1-10

   b. Fish oil in healthy volunteers[5]



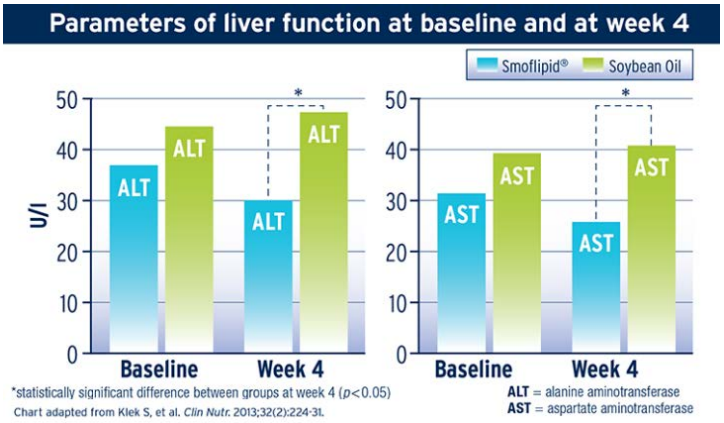
c. Liver[6]

i. Soybean oil fat emulsions have high levels of phytosterols

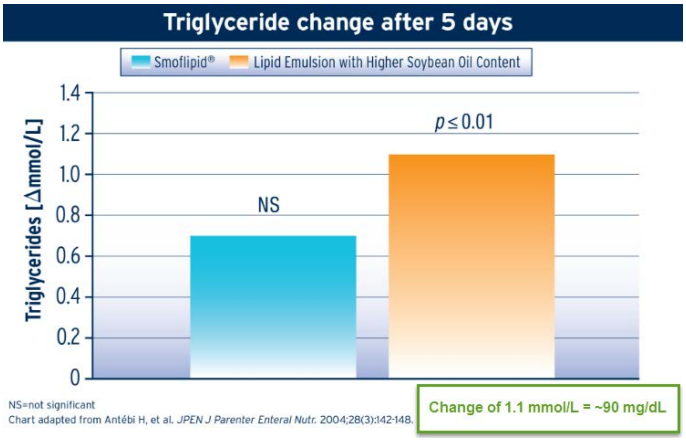
1. Blocks cholesterol enterally, but potentially harmful via parenteral route
2. High levels can result in cholestasis

ii. Soybean oil lacks α-tocopherol, potent antioxidant

1. Relieves oxidative stress related to abnormal lipid accumulation

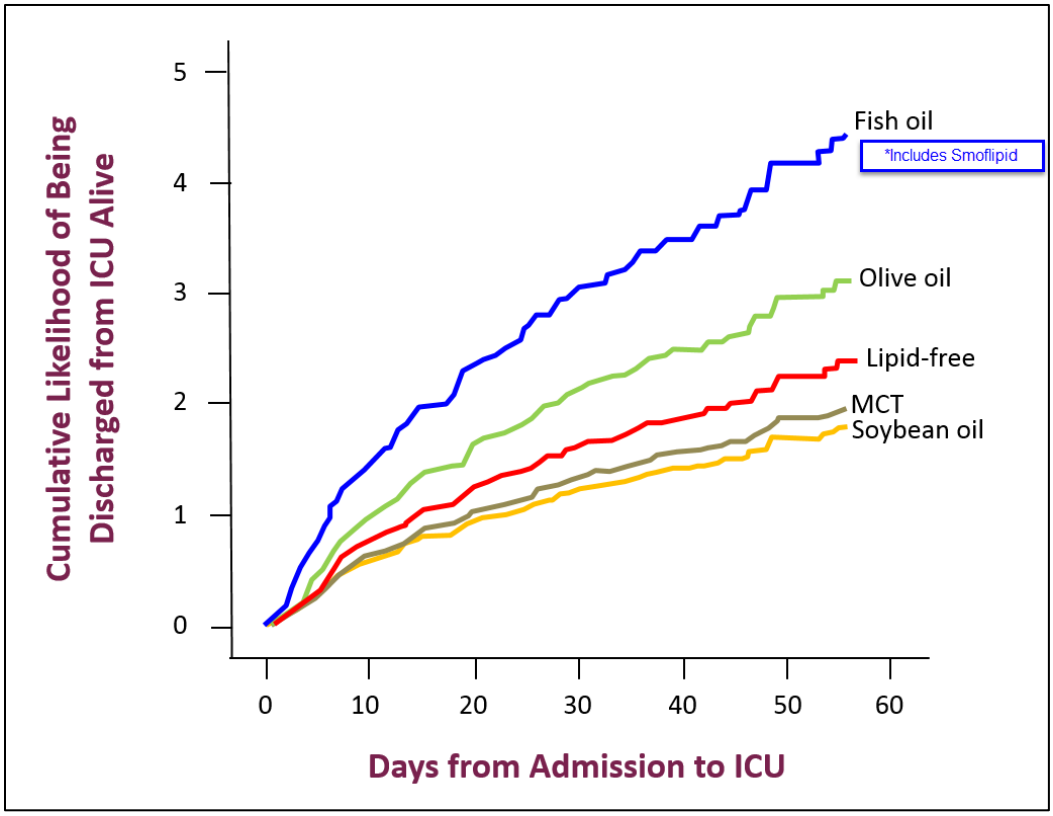


Source: Fresenius Kabi



Source: Fresenius Kabi

III. In ICU:[7]



IV. Meta-analysis:[8]

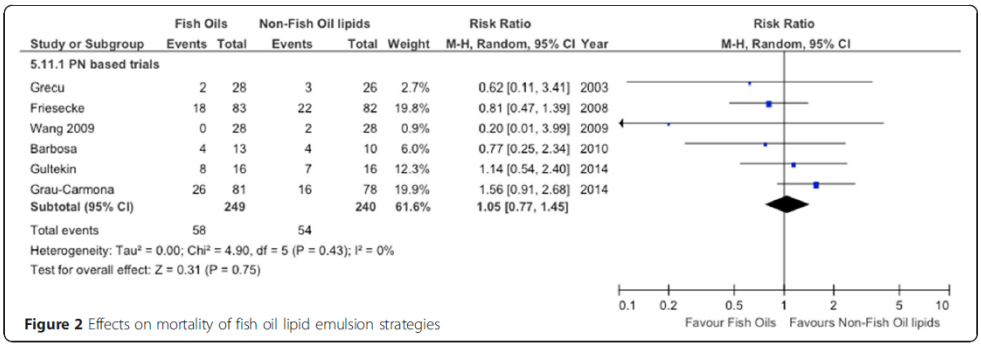


Figure 2 Effects on mortality of fish oil lipid emulsion strategies

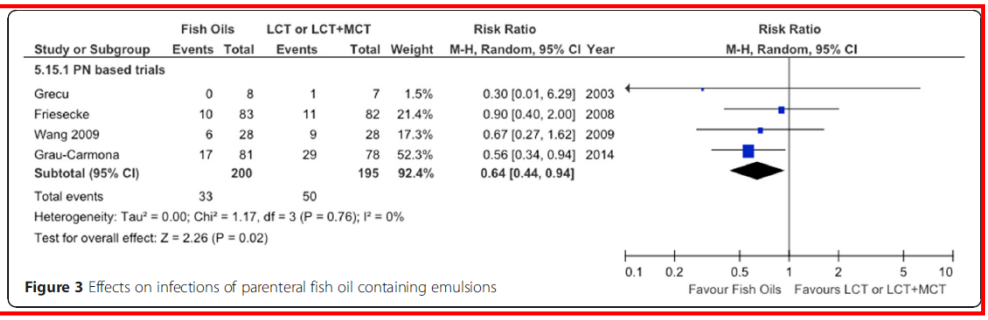


Figure 3 Effects on infections of parenteral fish oil containing emulsions

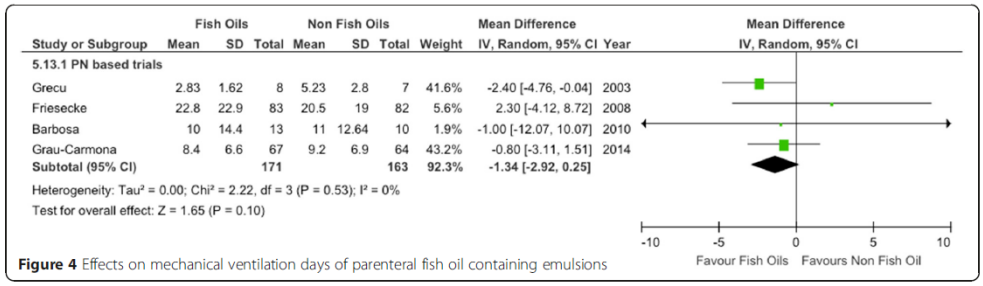


Figure 4 Effects on mechanical ventilation days of parenteral fish oil containing emulsions

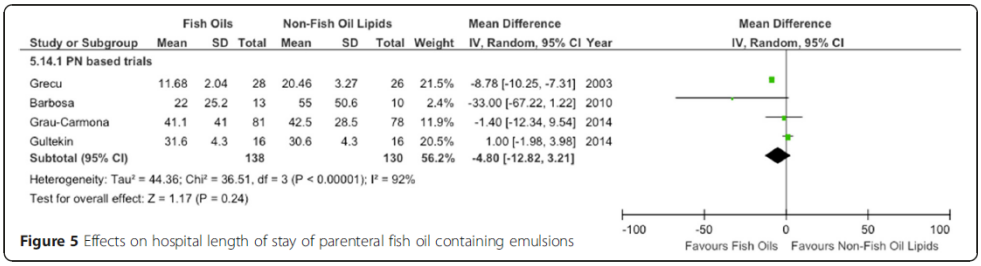


Figure 5 Effects on hospital length of stay of parenteral fish oil containing emulsions

Current Thinking/Guideline recommendations:

I. Guideline recommendations (US and Canada)

a. US:[9]

i. "We suggest withholding or limiting SO-based IVFE during the first week following initiation of PN in the critically ill patient to a maximum of 100 g/wk (often divided into 2 doses/wk) if there is concern for essential fatty acid deficiency. Alternative IVFEs may provide outcome benefit over soy-based IVFEs; however, we cannot make a recommendation at this time due to lack of availability of these products in the United States. When these alternative IVFEs (SMOF [soybean oil, MCT, olive oil, and fish oil emulsion], MCT, OO, and FO) become available in the United States, based on expert opinion, we suggest that their use be considered in the critically ill patient who is an appropriate candidate for PN." – 2016 Guidelines based on data up to 2013.

b. Canadian:[10]
    i. "When parenteral nutrition with intravenous lipids is indicated, IV lipids that reduce the load of omega-6 fatty acids/soybean oil emulsions should be considered. However, there are insufficient data to make a recommendation on the type of lipids to be used that reduce the omega-6 fatty acid/soybean oil load in critically ill patients receiving parenteral nutrition." - 2013 guidelines, unchanged in 2015
c. Omegaven® FDA Approval 2018 – Approved as "a source of calories and fatty acids in pediatric patients with parenteral nutrition-associated cholestasis"[11]

II. Current practice at my institution/pricing concerns
a. My current practice
b. Pricing (AWP):[12]
    i. Intralipid® pricing: $49.39 for 250 mL (20%)
    ii. Smoflipid® pricing: $27.60 for 250 mL (20%)
    iii. Omegaven® pricing: $86.40 for 100 mL (10%)

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Joe Ybarra, PharmD, BCNSP, Clinical Pharmacy Manager, Medical City McKinney (joseph.ybarra@medicalcityhealth.com)

Compounding Strategies, Compatibility Concerns, and Use of Standardized Commercially Available Products for Parenteral Nutrition Therapy

ASPEN 2019 Nutrition Science & Practice Conference

Overview → 2 in 1 vs 3 in 1 PN solution

- Parenteral nutrition (PN) formulations
  - 2 in 1 solution - amino acids + dextrose + micronutrients/electrolytes; lipids are hung separately
  - 3 in 1 solution - amino acids + dextrose + lipids + micronutrients/electrolytes
- Stability of lipids in a 3 in 1 solution
  - Fat droplet stability based on several factors
    - pH considerations
      - Best stability: 6 to 9
      - Cracking occurs: < 5 and > 10
      - Amino acid solutions (for compounding) should be between 5.8 to 7
    - Electrolyte salts (divalent and trivalent)
    - Order of compounding
      - Do not add dextrose directly to IVLE
      - Amino acids should be combined with dextrose prior to the addition of lipids
- Benefits of 3 in 1 solutions
  - Can infuse lipids over 24 hours
  - Only need one IV pump for PN administration
  - Do not need to worry about under or over dosing lipids in amounts other than 100 mL, 250 mL, or 500 mL quantities
  - PN is a hostile growth environment for bacteria and fungi
- Disadvantages of 3 in 1 solutions
  - Opaque solution makes visual inspection difficult
  - At risk for oiling, cracking or creaming (unstable 3 in 1 solution)
  - May cause greater catheter occlusions in the homecare setting
  - Need to maintain a minimal concentration of macronutrients (for all available lipids in USA)
    - Amino acids ≥ 4% of total volume
    - Dextrose ≥ 10% of total volume
    - Lipids ≥ 2% of total volume
  - Need to change out IV administration sets more frequently (every 24 hours)
  - Can only utilize a 1.2-micron filter
- When 3 in 1 solution cannot be utilized
  - PN solutions containing iron salts, albumin, or heparin
  - PN solutions containing excessive quantities of divalent cations (calcium and magnesium)
  - Pediatric PN solutions containing cysteine

Steps to Ensure a Stable 3 in 1 Admixture

- Helpful hints
  - PN initiation
    - Hold lipids for the first day
    - Starter regimens of PN generally do not meet the minimal concentrations for macronutrient provision
    - Add lipids once the PN solution meets - amino acids ≥ 4% and dextrose ≥ 10% of total volume
  - PN discontinuation or kcal weaning off of PN
    - Discontinue lipids as the first step towards transitioning off PN to an oral diet (or EN)
    - Often “cutting the macronutrients in half” will yield an unstable PN admixture

- Consider intermittent lipid dosing
  - Helpful when daily lipid dosing falls below 2% of total volume of solution
  - For example: Patient receiving PN at 3000 mL/d would benefit from 60g of lipids two times per week (2% solution of lipids in PN) vs. 17.1g per day (< 2% solution of lipids in PN)
- IV macronutrient / electrolyte / micronutrient shortages
  - Consider intermittent IV lipid dosing
  - With given shortages, imported products are often used to provide needed electrolytes or micronutrients
  - Some preparations of micronutrients (from Europe) may contain iron salts
  - If stability data is unavailable, consider intermittent lipid dosing or utilizing a 2 in 1 PN solution with lipids given at Y-site
  - Check with your pharmacist or manufacturer about product stability with 3 in 1 PN solutions

Compatibility Concerns

- Can medications be added to a bag of PN?
  - Dependent on:
    - 2 in 1 vs 3 in 1 preparations
    - Medication dose
    - Medication stability
  - Most common → additional micronutrients and GI medications
    - Ranitidine and famotidine → yes
    - Proton pump inhibitors → no
    - Octreotide → controversial, not recommended
  - "Old school" practices that should be avoided
    - Albumin → affects rate/flow, infectious risk
    - Iron dextran → limited to 100 mg/L in 2 in 1 preparations
    - Heparin (adults) → should be reserved for neonates; can consider in adult PPNs
    - Hydrocortisone → PPNs only

Use of Standardized Commercially Available Products

- Fixed doses of amino acids and dextrose in separate chambers
  - Double-chambered products (Clinimix®, Clinimix-E®) → 1000 mL and 2000 mL
    - Lipids delivered at y-site or added to admixture
  - Triple-chambered products (Kabiven®, Perikabiven®) → 1440 mL, 1920 mL, and 2400 mL
  - With or without standard electrolytes
- Available ports for adding insulin, multivitamin, trace elements, IV lipids
  - Available for peripheral or central PN
- Benefits of commercially available products
  - Institutions with low PN census
  - Safe delivery of PN
    - Available calculators to set an initial and goal PN regimen
    - Easy calculations for PPN (osmolarity concerns) provision
    - Compounding safety
    - Lower ICU and hospital length of stay
    - Lower PN associated infections (bloodstream)
  - Effectively manage PN shortages

Joe Ybarra, PharmD, BCNSP, Clinical Pharmacy Manager, Medical City McKinney (joseph.ybarra@medicalcityhealth.com)

- Negatives of commercially available products
  - Fixed macronutrient dosing
    - May not provide enough protein in the critical care setting
  - Fixed electrolyte dosing
    - Additional healthcare costs stem from frequent IV boluses
    - Additional additives to PN bag → compounding errors, compatibility issues
      - Calcium chloride – phosphate solubility curves?
  - Volume issues
    - Patients at refeeding risk → avoid large volumes
    - Critically ill population / organ dysfunction → avoid large volumes

CE Questions

- Which patient population should not get a 3 in 1 PN regimen?
  - ***Neonates***
  - Geriatrics (> 65 years old)
  - Adolescents
  - Long-term PN patients

- Which additive should not be given in a 3 in 1 PN regimen?
  - Sodium phosphate
  - Thiamine
  - ***Iron dextran***
  - Folic acid

- Which patient population would likely require additional protein (amino acid) supplementation to a regimen of premixed PN?
  - Palliative care
  - ***Critical care***
  - Home health (HPN)
  - Neonatal (NICU)

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M. Petrea Cober, PharmD, BCNSP, BCPPS
Clinical Coordinator – NICU/Associate Professor – Pharmacy Practice
Akron Children's Hospital/Northeast Ohio Medical University
ASPEN 2019
mcober@akronchildrens.org

Walking the Tightrope: Balancing Calcium and Phosphorus in the PN Patient

Financial Disclosure: Consultant for BBraun, Baxter, and Lexi-Comp.

Learning Assessment Questions:

1. Which of the following DOES NOT regulate the serum level of calcium?
    a. Magnesium
    b. Parathyroid hormone
    c. Phosphorus
    d. Vitamin D

2. When monitoring serum phosphorus levels, how much time may be needed to replete a depleted patient?
    a. 6-12 hours
    b. 12-24 hours
    c. 1-3 days
    d. 3-5 days

3. Which of the following calcium salts has the best solubility with inorganic phosphates (i.e., sodium and phosphate phosphate) in a parenteral nutrition solution?
    A. Calcium acetate
    B. Calcium chloride
    C. Calcium glubionate
    D. Calcium gluconate

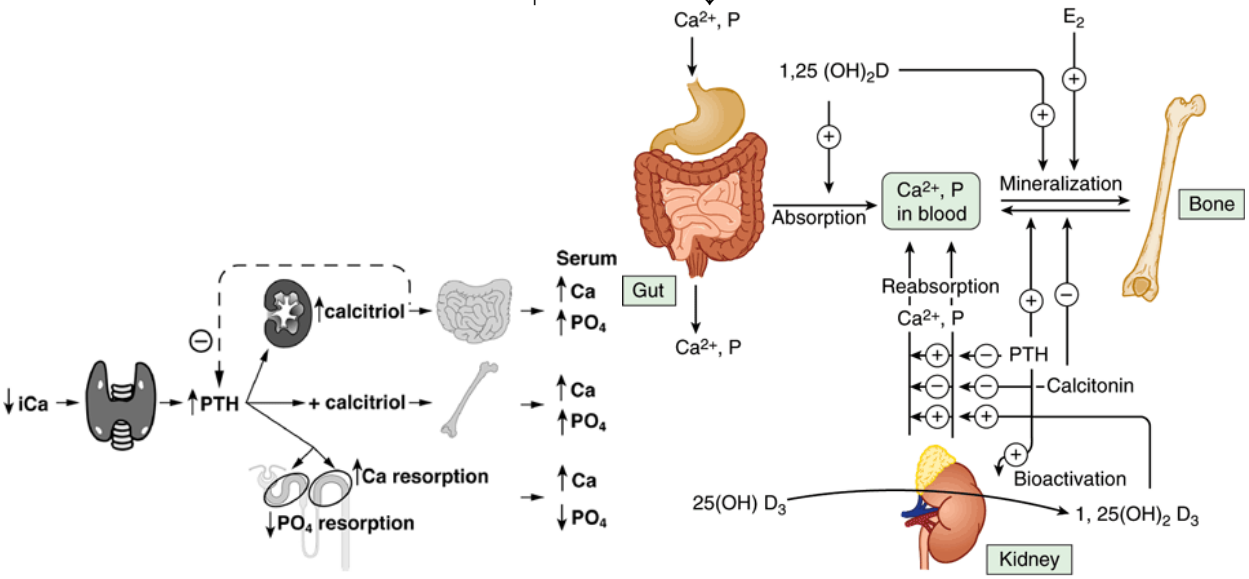
4. Which of the following factors increases the solubility of calcium and phosphate in the same parenteral nutrition solution?
    A. Decreased final pH of the solution
    B. Addition of cysteine hydrochloride
    C. Use of organic sodium glycerophosphate
    D. All of the above

5. Which of the following is the optimal ratio of calcium to phosphate in short term use of neonatal parenteral nutrition solutions to optimize bone mineralization?
    A. 1 mg:1 mg
    B. 1.7 mg:1 mg
    C. 3 mg:1 mg

Why does one need calcium and phosphate?

- Calcium:
    - Primarily found in bone (> 99.5%)
    - Major functions
        - Bone metabolism
        - Blood coagulation and platelet function
        - Conduction of smooth muscle (cardiac muscle)

- Normal range
  - Adults/Pediatrics
    - Total Calcium = 4.4-5.2 mEq/L (8.5-10.5 mg/dL)
    - Ionized Calcium = 1.1-1.35 mmol/L (4.4-5.4 mg/dL)
  - Neonates
    - Total Calcium = 7-12 mg/dL
- Amount needed in PN
  - Adults = 5-15 mEq/day
  - Pediatrics/Term Neonates = 0.5-4 mEq/kg/day (depending on age)
  - Preterm Neonates = 2-4 mEq/kg/day
- Serum levels highly regulated
  - Inverse relationship between serum Ca and P
  - Complex interaction regulated between
    - Parathyroid hormone (PTH): ↑ PTH → ↑Ca
    - Vitamin D
    - Calcitonin: ↑Calcitonin → ↓Ca



- Phosphorus:
  - Found in bone (80-85%) and soft tissue (ICF)
  - Major functions
    - Bone and cell membrane composition
    - Nerve conduction
    - Maintenance of normal pH
    - Muscle function (diaphragm → respiratory drive)
    - Energy → ATP
  - Should always be measured in milligrams (mg) or millimoles (mmol or mM) - not milliequivalents (mEq)
    - Millimoles = [(amount in mg) / (atomic or molecular wt)]

- Normal range
  - Adults = 2.5-4.5 mg/dL (1-1.4 mmol/L)
  - Pediatrics = 4.5-5.5 mg/dL
  - Neonates = 4.5-9 mg/dL
- Amount needed in PN
  - Adults = 20 – 40 mmol/day
  - Pediatrics/Term Neonates = 0.5 – 2 mmol/kg/day (depending on age)
  - Preterm Neonates = 1-2 mmol/kg/day
- 20 mmol of phosphate intravenously increases serum ~ 1 mg/dL
- Provide as either sodium or potassium salt
  - 1 mmol K_3PO_4 = 1.5 mEq K^+
  - 1 mmol $NaPO_4$ = 1.33 mEq Na^+
- About 2/3 of dietary intake is absorbed in the small intestine
- Increased by 1,25-OH (active) vitamin D
- Decreased by high intestinal levels of aluminum or calcium
- Filtered at glomerulus and reabsorbed at proximal tubule
- Hidden PO_4 in FreAmine III, HepatAmine, Hepatasol amino acids

The Highs and Lows of Calcium and Phosphorus:

- Calcium
  - Hypercalcemia
    - Causes
      - Release into serum from bone – overactive parathyroid, cancer with bone metastases, immobility
      - Excessive vitamin D
      - Dehydration
  - Hypocalcemia
    - Causes
      - Bound to albumin, calculate corrected Ca or obtain ionized Ca for more accurate level
      - Vitamin D deficiency
      - Hypomagnesemia
      - Hyperphosphatemia (remember inverse relationship between Ca and P)
      - Medications → foscarnet, pentamidine
    - Signs/symptoms
      - Osteoporosis
      - In severe deficiency
        - Cardiovascular = hypotension, decreased myocardial contractility, prolonged QT interval
        - Neuromuscular = distal extremity paresthesias, muscle cramps, tetany, seizures

- Phosphorus
    - Hyperphosphatemia
        - Causes
            - Renal dysfunction
            - Tumor lysis syndrome
    - Hypophosphatemia
        - Causes
            - Starvation, alcoholism, burns, DKA
            - Hyperparathyroidism
            - Chronic diarrhea
            - Medications – long term diuretic use, foscarnet, glucocorticoids, insulin, long term aluminum-containing antacid use, dialysis (particularly CVVHD)
        - Signs/symptoms
            - Neurologic = ataxia, confusion, or paresthesias
            - Neuromuscular = weakness, myalgia, or rhabdomyolysis
            - Cardiopulmonary = cardiac and ventilatory failure
            - Hematologic = reduced 2,3-diphosphoglycerate concentration or hemolysis
            - If severe, consider consequences of refeeding syndrome
                - Can lead to congestive heart failure, respiratory distress, peripheral edema, convulsions, and coma

How much should I add to PN?

- Calcium
    - Remember, serum levels reflect very little of body stores. You may want to determine daily needs and provide that amount by PN, and try to minimize adjustments based on labs as much as possible.
    - Hypocalcemia
        - Acute hypocalcemia should be treated outside of PN solution
        - Treatment of asymptomatic hypocalcemia due to low albumin not indicated
        - In critically ill or at risk may correct asymptomatic with Ca gluconate 1-2 g infused over 1 hour per gram (improved dose retention)
            - Pediatrics = 100-200 mg/kg/dose (not elemental calcium)
        - Chronic hypocalcemia treatment depends on disorder
        - Usually doses in PN solutions are adequate and meet recommended > 1 g/day calcium supplementation
        - Dose may be limited in PN based on amount of P (Ca/P precipitation) → more to come on this topic
    - Hypercalcemia
        - Evaluate calcium dose in PN
        - Acutely remove from PN solution
        - Dose that is returned to PN depends on etiology of hypercalcemia
        - Evaluate total hydration provided in PN solution
        - Evaluate phosphorus level
            - Pediatrics: Must maintain appropriate Ca:P ratio for bone growth

- Phosphorus
    - Hypophosphatemia
        - Assess for acute losses / shift versus chronic losses – what is cause for ↓P?
        - PN Dosing strategies
            - Can I avoid or lessen impact of loss or shift?
            - Refeeding – increase to upper limits of dosing on day 1 PN to replete
            - Remember IV fat emulsion provides ~1.5 mmol/100mL of emulsion
        - Monitor labs - may take 3 -5 days to replete depleted patient
            - Major intracellular anion of the human body
    - Hyperphosphatemia
        - Rule out pseudo hyperphosphatemia (lab specimen contaminated with PN or other P-containing fluids)
        - Be sure to examine all sources (IV fluids, enteral and PN, drugs)
        - Remove other sources before altering PN dosing as PN usually providing maintenance
        - Evaluate renal function and reduce or eliminate P from PN if appropriate

The Big Problem – Calcium-Phosphate Solubility in PN:

- Calcium-phosphate solubility = major compatibility concern with PN formulations
    - Can result in microprecipitates
        - April 1994 FDA Safety Alert
            - 2 deaths and at least 2 cases of respiratory distress associated with administration of PN containing calcium phosphate crystals
            - All receiving low-osmolality PN admixture and lacked inline filtration
                - Additionally, unfavorable mixing sequence and short time from compounding to administration
            - Found to have diffuse microvascular pulmonary emboli containing calcium phosphate upon patient autopsies

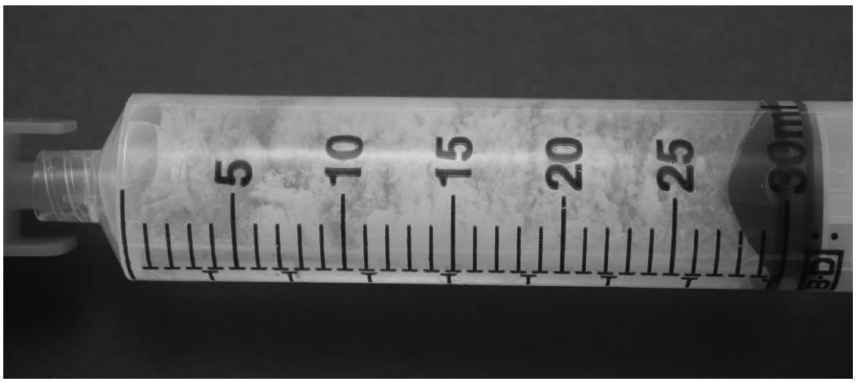


Figure 7-4 Calcium Phosphate Precipitation

- Importance of knowing limitations of PN formulations
- Importance of appropriate filtration of PN formulation
    - Minimum of 5-µm filter to remove participate
    - 0.22-µm filter recommended for a 2-in-1 formulation
    - 1.2-µm filter recommended for a 3-in-1 formulation

Factors Influencing Calcium-Phosphate Solubility:

- Amino acid concentration
  - Higher concentration favors solubility
- Amino acid product composition (i.e., pH or phosphorus content)
  - Lower pH favors solubility (want pH < 5.3)
  - Must include inherent phosphorus from amino acids in total (i.e., FreAmine)
- Calcium and phosphate concentration
  - Depends on calcium-phosphate solubility curves (see below)
    - Product specific
    - Developed using fixed concentrations of amino acids, dextrose, calcium, and phosphate
    - Intersection of final calculated calcium and phosphate concentrations must be below the solubility curve
      - Farther concentrations below the curve = greater probability of non-precipitation
      - Closer to or father above the curve = greater probability of precipitation
    - Do not use single sum or product of calcium and phosphate concentrations as sole criterion for determining compatibility
    - "Compatibility curves . . . are generally elbow shaped, with a slope slightly left of vertical as calcium declines from 50 to 2 mEq/L and phosphate increase from 5 to 8 mMol/L and a slope slightly below horizontal as calcium declines from 14 to 5 mEq/L and phosphate increases from 8 to 23 mMol/L."[8]
  - Direct relationship (i.e., increased concentrations are more likely to precipitate)
  - Should express phosphate concentration in mMol/L because of difference between monobasic and dibasic forms
- Calcium slat form
  - Solubility → Sodium Glycerophosphate > Calcium gluconate > Calcium chloride
    - Calcium gluconate less likely to dissociate than calcium chloride
    - Calcium-phosphate solubility curves are calcium salt specific
      - Newer curves for sodium glycerophosphate exist
    - Calcium chloride
      - Less aluminum content
      - In several multi-chambered or group electrolyte products
- Dextrose concentration
  - Higher concentration favors solubility
- pH of formulation
  - Lower pH favors solubility
    - Low pH favors presence of monobasic calcium phosphate which is relatively soluble salt form of calcium
    - Increasing pH increasing availability of dibasic phosphate to bind to free calcium ions and increases chance of precipitation
    - Example = L-cysteine HCl addition in neonatal/pediatric PN formulations
      - Unfavorable environment for IVFE though
- Temperature of formulation
  - Cooler favors solubility
- Order of mixing additives
  - Sequence matters
    - Phosphate = 1st electrolyte while calcium = last electrolyte
  - Must mix well so high localized concentrations do not occur

But Patient Needs More:

- Very true, especially in the neonatal/pediatric population
    - Optimal ratio in neonatal PN formulation = 1.7mg Calcium:1mg Phosphate
    - Recommended calcium of 10-15 mEq/day for adults
- Remember bones will be sacrificed to maintain serum calcium

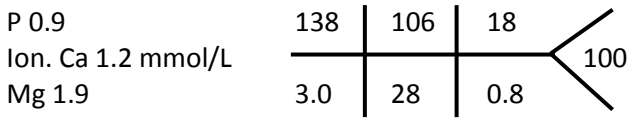
Patient Case Examples:

Calcium and Phosphate Requirements:

67 yo female admitted 7 days prior due to outlet obstruction. GI tract is not functional so PN is ordered. A PN bag with 5% Amino Acids and 15% Dextrose hung @ 1800 with: (electrolytes in PN are per day amounts)

60 mEq NaCl 80 mEq KCl
40 mEq Na Ace 10 mEq CaGluc
20 mmol NaPO4 15 mEq MgSO4
Wt 70kg

The labs the next morning:



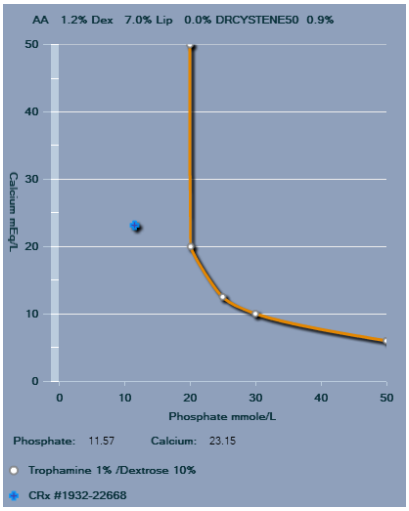
1. Does this patient have hyper or hypophosphatemia?
2. How would you like to treat this patient? What product? What dose? Why?
3. Any change to the PN solution?

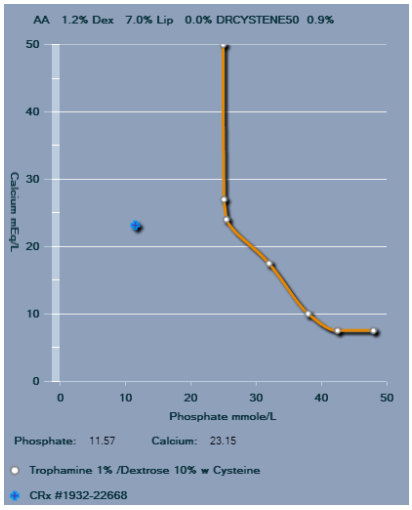
Calcium and Phosphate Solubility:

- Concentration is everything . . .
    - Patient weight = 1.25kg; want to provide Ca = 2 mEq/kg/day and Phos = 1 mMol/kg/day
        - Scenarios
            - #1
                - PN volume = 108 mL/day
                - Amino acids = 1 g/kg/day
                - Dextrose = 7%
            - #2
                - PN volume = 108 mL/day
                - Amino acids = 3.5 g/kg/day
                - Dextrose = 12.5%
            - #3
                - PN Volume = 60 mL/day
                - Amino acids = 2.8 g/kg/day
                - Dextrose = 15%

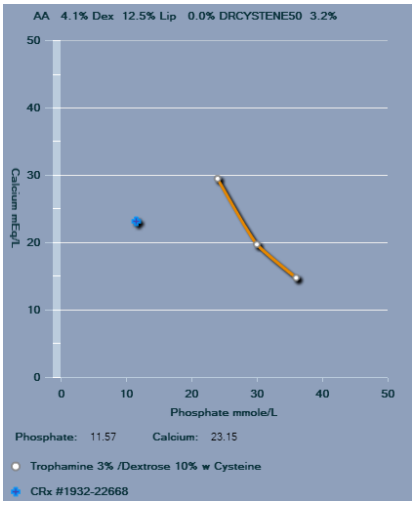
- Calculations
  - #1
    - Amino acids = 1.2%
    - Dextrose = 7%
    - Ca = 23.1 mEq/L
    - Phos = 11.6 mMol/L
  - #2
    - Amino acids = 4.1%
    - Dextrose = 12.5%
    - Ca = 23.1 mEq/L
    - Phos = 11.6 mMol/L
  - #3
    - Amino acids = 5.8%
    - Dextrose = 15%
    - Ca = 41.7 mEq/L
    - Phos = 20.8 mMol/L
- Calcium-Phosphate Curves

#1





#2



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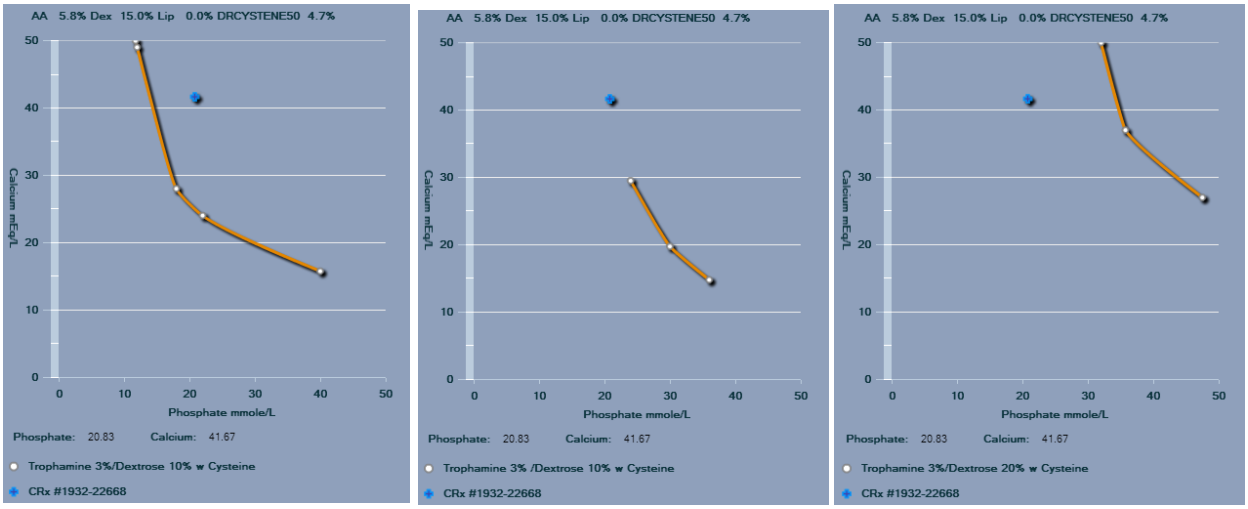

Answers to Learning Assessment Questions:

1. Answer = A; Serum calcium homeostasis is regulated by all of the following: serum phosphorus, calcitonin, parathyroid hormone, and vitamin D. Serum magnesium levels do not affect serum calcium levels.
2. Answer = D; Serum phosphate is not an adequate measurement of total body phosphorus since phosphorus is the primary intracellular anion of the body. For this reason, it may take 3-5 days to replete a depleted patient.
3. Answer = D; Rationale: Calcium acetate and calcium glubionate are both only available as enteral products and would thus not be appropriate for use in a parenteral nutrition solution. Calcium chloride has less solubility with the inorganic phosphate salts than calcium gluconate due to its increased ability to dissociate into its individual ions resulting in a greater risk of precipitation.
4. Answer = D; Rationale: The addition of cysteine hydrochloride to the parenteral nutrition solution results in a decreased final pH of the solution and this improves the solubility of calcium and phosphate in the same parenteral nutrition solution. Recent studies have shown improved solubility of even calcium chloride with the use of organic sodium glycerophosphate.
5. Answer = B; Rationale: In short-term PN, a Ca:P of 1.7:1 mg:mg (1.3:1 mmol:mmol) is associated with the best calcium and phosphate retention based on quantitative ultrasonography. Since the longest study assessing this has only lasted a total of 6 weeks, true recommendations regarding long-term PN therapy cannot be made.

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ASPEN 19 March 24 2:00-3:30pm Basic Skills in Parenteral Nutrition Management (S36)

Is Parenteral Nutrition (PN) Appropriate? Using Evidenced-Based Recommendations to Support Clinical Practice.

Renee Walker MS, RDN, LD, CNSC, FAND

Learning Objectives:

1. Recognize appropriate candidates for PN therapy
2. Identify factors from early PN studies that contributed to the unfavorable outcomes
3. Discuss conditions that are likely to require PN, including contraindications to EN.
4. Determine the best time to initiate PN and the recommended route of access.

Outline

I. Unfavorable outcomes of Early PN Studies
II. Conditions likely to require PN
III. PN initiation
   a. Degree of malnutrition/timing
   b. Lab values warranting caution
   c. Vascular Access Devices
IV. Contraindications to EN
V. Questions

Q1. Early PN studies often report poor outcomes with PN usage. This may be due to

A. Poor glucose control
B. Failure to account for disease severity
C. Overfeeding
D. All of these

Q2. A moderately or severely malnourished patient in which enteral/oral intake is not possible, should consider starting PN _____. Using the same answers, if the pt was well nourished, PN should start _____.

A. After 7 days
B. On day 5
C. ASAP
D. Within 24 hours of surgery

Q3. Be careful when initiating PN if

A. K+ 2.9 mEq/L
B. Phos 2.2 mg/dL
C. BUN 90 mg/dL
D. All of these

Q4. Rather than focusing on specific diagnosis for PN initiation, look at conditions(i.e. impaired absorption, mechanical bowel obstruction) in which enteral or oral intake is precluded or inadequate. (T/F)

Answer: 1. D 2. C, A 3. A 4. T

References: When is Parenteral Nutrition Appropriate? *JPEN 2017; 41(3):324-377.*

Guidelines for Provision and Assessment of Nutrition Support Therapy in the Critically Ill Pt: SCCAM/ASPEN. 2016; 40(2):159-211.

Unfavorable outcomes from PN

- RCTs with significant design differences
- Impact of clinical practices at the time(i.e glu accepted range prev higher, VAD stds different)
- Failure to account for disease severity
- Often excluded those without nutrition > 2 weeks and the severely malnourished
- Prescribing patterns (i.e. early studies delivered 30-35 kcal/kg)
- *VA Cooperative study attributed septic complications to PN lipids, now thought aggressive feeding protocol & poor glu control a more likely the cause**newer trials indicate PN may not contribute to adverse outcomes*

PN Appropriateness Consensus Recommendations

- Best practices, 14 recommendations
- Adults, pediatrics, neonates
- Incorporates evidence up to September 2016

PN indication

- *Do not use PN based solely on medical dx or disease state, look at conditions in which enteral or oral intake is precluded or inadequate*
- *PN has not shown to heal or treats any specific ds or conditions other than malnutrition*
- *Consider- gut access, ds severity (catabolic state or critical illness), baseline nutrition status/ malnutrition/nutrition risks, timing of PN start and anticipated therapy length, medical interventions to promote EN(i.e. prior attempts to gain access), metabolic stability, end of life considerations*

5 Conditions that likely require PN

Conditions	*Example*
Impaired Absorption Loss of Nutrients	SBS (bowel 60 cm in continuity or 120 cm w/o colon), Bariatric Surgery Complications, Volvulus, High Output Fistula (>500 mL/d), Small Bowel Mucosal Ds (i.e. radiation enteritis)
Mechanical Bowel Obstruction	Intestinal Blockage- stenosis, strictures, inflammatory ds, Severe Superior Mesenteric Artery Syndrome
Bowel Rest Required	Ischemic Bowel, Severe Pancreatitis (↑pain or lipase w EN), Chylous Fistula(↑output w Low fat or elemental diet), preoperative status(severe malnutrition w/ non fxn GI 7-10 d preop)
Motility Disorder	Prolonged ileus, pseudo obstruction, Severe adhesive dx
Inability to achieve/maintain EN access	Varies with circumstance (i.e. HD instability, GIB)

Timing of PN initiation

Time Frame to Initiate PN	*Degree of Malnutrition**	*Comments*
After 7 days	Well Nourished (Low Nutrition Risk)	Received < 50% of estimated needs via oral or EN
3-5 days	Nutritionally at Risk	Unlikely to achieve desired oral or EN intake
ASAP	Moderate or Severe (High Nutrition Risk)	EN/Oral not possible or sufficient, consider preoperative start w/ severe malnutrition
Delay		In those with severe metabolic instability May need to adjust additives /macronutrients, advance slowly
Supplemental PN	(Low or High Nutrition Risk)	Consider after 7-10 days if unable to meet > 60% of energy/pro needs solely by enteral route

**( ) from SCCM/ASPEN 2016 guidelines. Nutritionally at Risk: wt loss 10% x 6 mo, 5% x 1 mo, or 10# x 6 mo, BMI < 18.5, inadequate intake, altered diets, increased metabolic needs.*

Be cautious when initiating PN if labs are….

• *Glu >180 mg/dL* • *BUN>100 mg/dL* • *Na < 130 mEq/L*	• *K+ < 3.0 mEq/L* • *Mg < 1.6 mEq/L* • *Pho <2.0 mg/dL*	• *Ionized Ca < 4.5 mg/dL* • *Triglyceride >200 mg/dL*

Selecting and placing appropriate VAD

Choose smallest device with fewest lumens necessary
Dedicate 1 lumen for PN administration
Tip of CVAD in lower 1/3 of superior vena cava near the junction of the R atrium
Confirm and document position of CVAD prior to PN start
Scheduled rotation of PIVs most prudent
Peripheral Midlines may remain in place for 29 days-deeper insertion may mask s/s of phlebitis

Types	*Dwell Time*	*Other*
PIVs	*72-96 hr, rotation based on clinical indication not rx*	*Osmolarity limitations, Not for home PN Increased phlebitis risk*
Peripheral Midline Catheters	*Up to 29 d*	*Osmolarity limits, not for home PN, safety w PN unknown*
Percutaneous non-tunneled central catheters (subclavian, internal jugular, femoral)	*5d to few weeks*	*Femoral not rx 2' high infx risk, appropriate for acute care setting but not for home , easily dislodges*
PICCS	*Max dwell time unknown*	*For acute care, short term and medium term PN pts, increased risk for DVT*
Tunneled Catheters (Hickman or Broviac)	*3 mo to years*	*Appropriate for long-term PN*
Implanted Ports	*6mo to years*	*Lowest risk for CLABSI 2' reduced manipulation*

PPN recommended if

- *Short term (10-14 days)*
- *Bridge therapy*
- *EN/oral intake suboptimal and placing CVAD not justifiable*
- *Osmolarity limit to 900 mOsm/L*
- *Able to tolerate large fluid volume*
- *Nutrient provisions are appropriate given nutrition status and illness severity*

PN in pts undergoing elective/non urgent surgery

- Preoperative PN for the severely malnourished unable to tolerate oral intake or EN
- Reserve post op PN for severely malnourished unable to tolerate EN for more than 7 days unless initiated preoperatively.
- Unless high nutrition risk, PN should be delayed 5-7 days(ASPEN/SCCM)

PN and Palliative pts

- Do NOT use to solely treat poor oral intake/ cachexia associated w/ adv malignancy.
- Limit use to those w/ expected survival of 2-3 mo
- Evaluate clinical factors and performance status when starting PN in those at end of life
- Involve pts/caregivers in clearly communicated, realistic goals of PN
- Define criteria for stopping PN

Contraindications to EN Based on Enteral Access

All Access types	*Nasal placement*	*Percutaneous/surgical abdominal placement*
GI mechanical obstruction *Uncontrolled peritonitis* *Uncorrected coagulopathy* *Bowel ischemia* *High risk of recurring GIB*	*Skull fracture* *Recent transsphenoidal surgery* *Facial, nasal, or sinus trauma* *Esophageal stricture, tumor or severe esophagitis* *Varices with recent bandings(delay placement 72 h)*	*Massive ascites* *Hemodynamic instability* *Morbid obesity w large panniculus* *Gastric outlet or duodenal obstruction* *Expected duration less than 4 weeks*

Factors to Consider to Determine Feasibility of EN

Hemodynamic stability	• *Unstable if hypotension systolic BP less than 90 m Hg* • *MAP < 65 mm hg* • *orthostatic hypotension*
Physical exam	• *assess fistula output* • *abdominal distention* • *bowel sounds suggestive of ileus(high-pitched tinkling early and reduced bowel sounds later)* • *ileus((hypoactive to absent bowel sounds)* • *pain level(out of proportion to physical exam may be related to mesenteric ischemia)* ***Reduced bowel sound in conjunction w/ physical exam may indicate increased risk of EN intolerance*
Diagnostic tests	*Abdominal x rays, CT, angiography* • *Ileus-dilated loops of bowel with air-fluid in upright film* • *Obstruction –dilated loops of bowel* • *Mesenteric ischemia(pneumatosis intesternalis(* • *Perforation(free air in peritoneum)*