Hyperammonemia.

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Contents of discussion.

- Interesting Case.
- Causes of high ammonia (cirrhosis is not only cause)
- Metabolism of ammonia.
- Discussion about the case.

Case

- 39 yrs old AAF with h/o Gastric bypass (type 1) surgery in 2008 admitted for reversal of bypass surgery.
- Multiple admissions in the past for excessive weight loss, weakness and peripheral neuropathies secondary to weight loss.

- Weighed around > 400 pounds in 03/08
- Weighed 225 pounds in 04/09
- Patient was diagnosed with multiple vitamin deficiencies including B12, copper, iron and thiamine and being supplemented.

- Other issues

  Anasarca.

  Anemia of chronic disease.

  Weakness- uses cane to walk.

  PMH

  Obesity s/p gastric bypass

- Previous admission. Had elevated LFts and found to have elevated ammonia level. Started on Lactulose and carnitor. S/p Liver biopsy

- Liver biopsy 04/09

  Acute and chronic cholestasis and panlobular macrovesicular steatosis. Mod. Portal inflammation with lymphocytes and histiocytes.

- PSH

  Gastric bypass surgery.

  C-sections.

  Social history- No smoking, no alcohol and no drugs.

- Medications.

Vitamin B1 250 mg once a day.
Vitamin B12
Calcium citrate plus D
Iron
MVI
ASA
Copper 2 mg PO once a day.
Carnitor 330 mg PO BID
Prilosec.
Lortabl

Exam.

- P. 100 BP 131/87 RR 20 sats 98%

  Wasting-temporal. Prominent bones around clavicular and spine area.

  Alert orientedX 3

  CVS s1 s2

  Chest clear

  Abdomen, distended, fluid thrill +

  Edema 2+ b/l

  CNS. Alert oriented X3 4/5 all limbs.

- WBC 11.75
- HB 11.5 MCV 86
- Plt 346
- N 75%
- Total Bili 3.6 Direct 1.4
- AST/ALT 62/62 Albumin 1.9
- Alk. Phosph.
- PT 17.9
- INR. 1.9
- PTT 32.7

Hospital course

- Admitted to get reversal of gastric bypass.
- Started on TPN to build up.

TPN - 1225 Cal

60 GM AA

Dextrose. 635 Kcal

Lipid 350 Kcal

80% patient estimated Kcal.

Ensure supplements BID.

- On 4th day of hospitalization patient got confused and GI consulted for high Ammonia level.
- Patient got more worse and unresponsive with Ammonia of 300 and transferred to ICU.

Labs at that time.

- Na 138
- K 4.4
- CO2 31
- BUN/CRT 12/0.6
- Glucose 89
- Total Bil. 3.8
- AST/ALT 34/30
- Alk Phosp 155
- Ammonia 300
- WBC 10.92
- HB 10.6
- PLT 210
- N 79

ABG 7.5/44/64/34/94%

PT/INR 16.5/1.7

MRI Head.

- No evidence of acute infarct.
- No abnormal intensity or enhancement present within the brain parenchyma.
- No significant abnormal T1 signal seen within basal ganglia.

- EEG. Metabolic encephalopathy.

- Folate. 8.0 (3-16)
- B12 > 2100
- Ceruloplasmin 14 (17-54)
- Copper 78 (80-155)
- Selenium 30 (23-190)
- Zinc 31 52 (60-120)
- Thiamine
- Carnitine

?

- History. Review of history. Admitted before- Got TPN and ammonia went up.
- Biopsy. Abnormal but not cirrhotic.
- ?

- UREA CYCLE DEFECT ?
- Serum Aminoacid panel and urine aminoacids sent.
- TPN stopped.
- Started on buphenyl. Ammonia started coming down. Patient got more responsive on second day.
- Genetic counseler consulted.

- → Tube Feed diet of 60 gms of protein per day.
  50% of protein. Natural protein
  (ensure/boost)
  50% provided through specialized formula
  Cyclinex-2 (essential amino acids)
- → Buphenyl
- → Citrulline.

Protein (L-amino acids), carbohydrates (corn syrup solids), fat (high oleic safflower, coconut, soy oils), L-carnitine, taurine, iron (ferrous sulfate), vitamins, minerals; contains phenylalanine; nonessential amino-acid free.

- Corn Syrup Solids, High Oleic Safflower Oil, Coconut Oil, Sodium Citrate, Soy Oil, L-Leucine, L-Lysine Acetate, L-Valine, Calcium Phosphate, L-Isoleucine, Magnesium Phosphate, Potassium Chloride, L-Tyrosine, L-Threonine, L-Phenylalanine, Silicon Dioxide, DATEM*, Potassium Citrate, Potassium Phosphate, L-Cystine Dihydrochloride, L-Histidine, L-Methionine, L-Tryptophan, L-Carnitine, Calcium Carbonate, Ascorbic Acid, Taurine, Choline Chloride, m-Inositol, Ferrous Sulfate, Zinc Sulfate, Niacinamide, dl-Alpha-Tocopheryl Acetate, Calcium Pantothenate, Ascorbyl Palmitate, Mixed Tocopherols, Cupric Sulfate, Manganese Sulfate, Thiamine Chloride Hydrochloride, Vitamin A Palmitate, Riboflavin, Pyridoxine Hydrochloride, Folic Acid, Potassium Iodide, Chromium Chloride, Beta-Carotene, Biotin, Sodium Selenate, Phylloquinone, Sodium Molybdate, Vitamin D3, and Cyanocobalamin.

- Essential AA phenylalanine, valine, threonine, tryptophan, isoleucine, methionine, leucine, and lysine

SERUM AMINOACID.

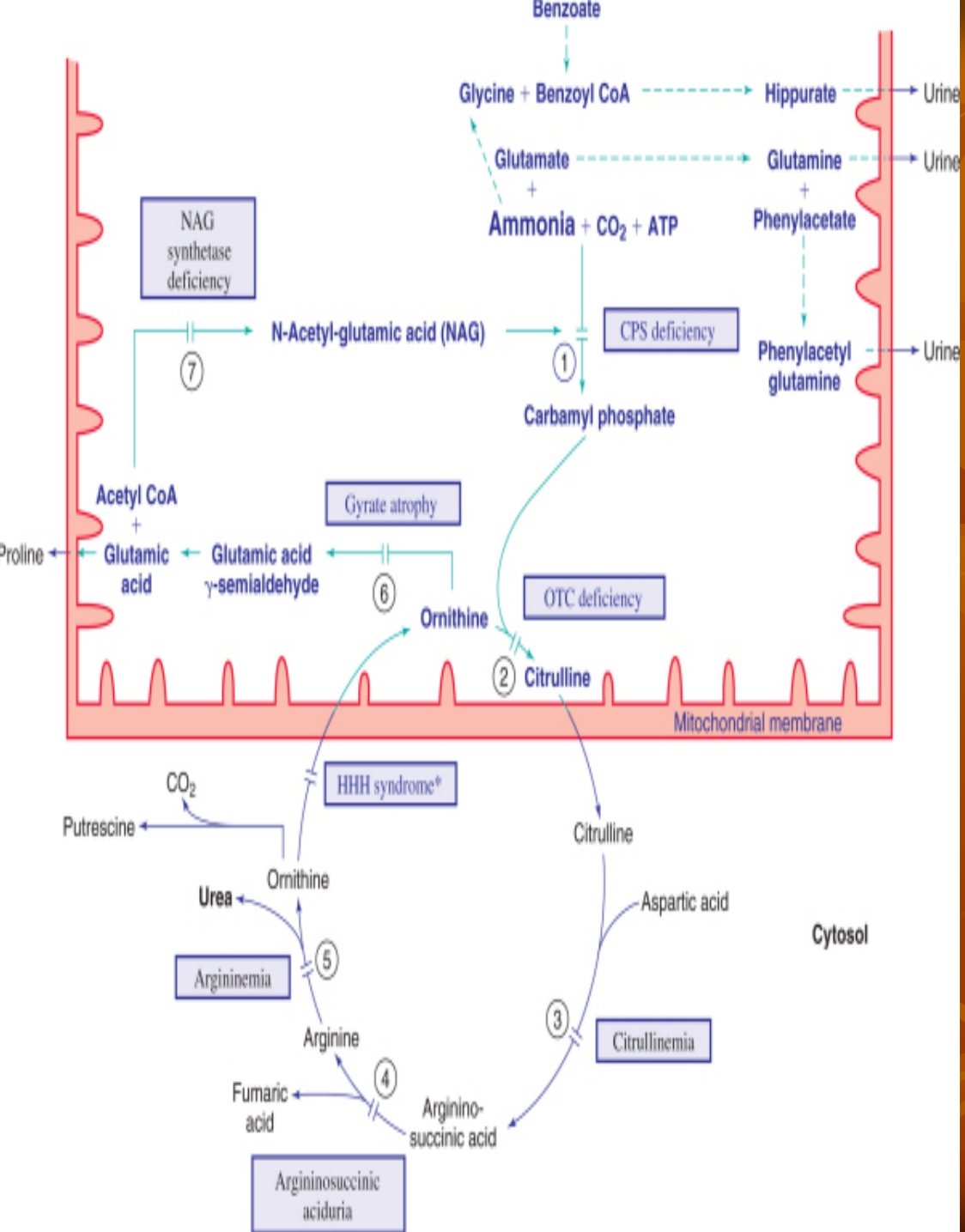
- ALANINE.
- ARGININE.
- ASPARTIC ACID.
- CITRULLINE.
- CYSTINE.
- GLUTAMIC ACID
- GLUTAMINE
- GLYCINE.
- HISTIDINE
- HOMOCYSTINE.
- HYDROXYPROLINE.
- ISOLEUCINE.
- LEUCINE.
- LYSINE.
- METHIONINE.
- ORNITHINE.
- PROLINE.
- SERINE.
- TAURINE.

24 URINE

- OROTIC ACID
- LACTIC
- PYRUVIC
- SUCCINIC
- FUMARIC
- KETOGLUTARIC
- METHYLMALONIC
- HYDROXYBUTYRIC
- ACETOACETIC
- KETOACIDS.
- ADIPIC ACID
- SUBERIC ACID
- SEBACIC ACID.
- PHENYLACETIC ACID
- SUCCINLYACETONE

- GLYCINE → 724 (140-490)
- GLUTAMINE → 3210 (410-700)
- CITRULLINE → 15, 11(10-60)
- ARGININE → 59 (40-160)
- ORNITHINE → 48 (20-135)

- ISOLEUCINE - LOW
- LEUCINE - LOW
- LYSINE - HIGH
- SERINE - HIGH.



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- GLUTAMINE → 3210 (410-700)
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URINE.

- OROTIC ACID. 8.0 (.8-2.7)

Genetic testing.

- Blood sample.
- OTC deficiency-Gene deletion/duplication.

  Sequence analysis did not identify mutation.

  OTC Full Gene squencing. One homozygous (2 copies) variant c 137 A-G in the OTC gene

  .

Repeat AA panel in 6 weeks

- Citrulline. 107 H (10-60)
- Arginine 105 (40-105)
- Ornithine 105 (20-135)
- Glutamine 368 L (410-700)
- Glycine 332 (140-490)

- Liver biopsy. 09/2009

  Macrovesicular steatosis portal and pericellular fibrosis and progressive cholestasis.

Comment by pathologist. Fatty change and pericellular fibrosis has been reported as possible feature of OTC deficiency.

Ascites fluid

- Fluid protein. 647 mg/dl
- Fluid Albumin <1.5
- WBC 6

USG

- Echogenic liver with slight nodular contours. This may represent fatty infilteration but cirrhosis cannot be ruled out.
- Large volume ascites.
- Gall bladder with sludge.

Doppler USG.

- Non occlusive thrombus-portal vein.
- Ascites.

Ammonia Metabolism.

Elevated Ammonia.

- Production.
- Metabolism.
- Excretion .

Which organ is involved in ammonia metabolism.? T/F

- Gut
- Kidney.
- Muscle.
- Liver.
- Brain.
- None of the above.
- All of the above.

Which organ is involved in ammonia metabolism.? T/F

- Gut
- Kidney.
- Muscle.
- Liver.
- Brain.
- None of the above.
- All of the above. True.

- **Gut.** Byproduct of protein digestion and bacterial metabolism.

- **Kidneys.** Essential for renal handling of acid. Ammonium is synthesized from glutamine (proximal tubule) either released into systemic circulation or excreted.

(Hyperammonemia in the ICU. Chest. 2007:132:1368-1378)

- Skeletal muscle. Seizures or intense exercise increased ammonia production.

Figure 1A: Ammonia Production and Urea Synthesis

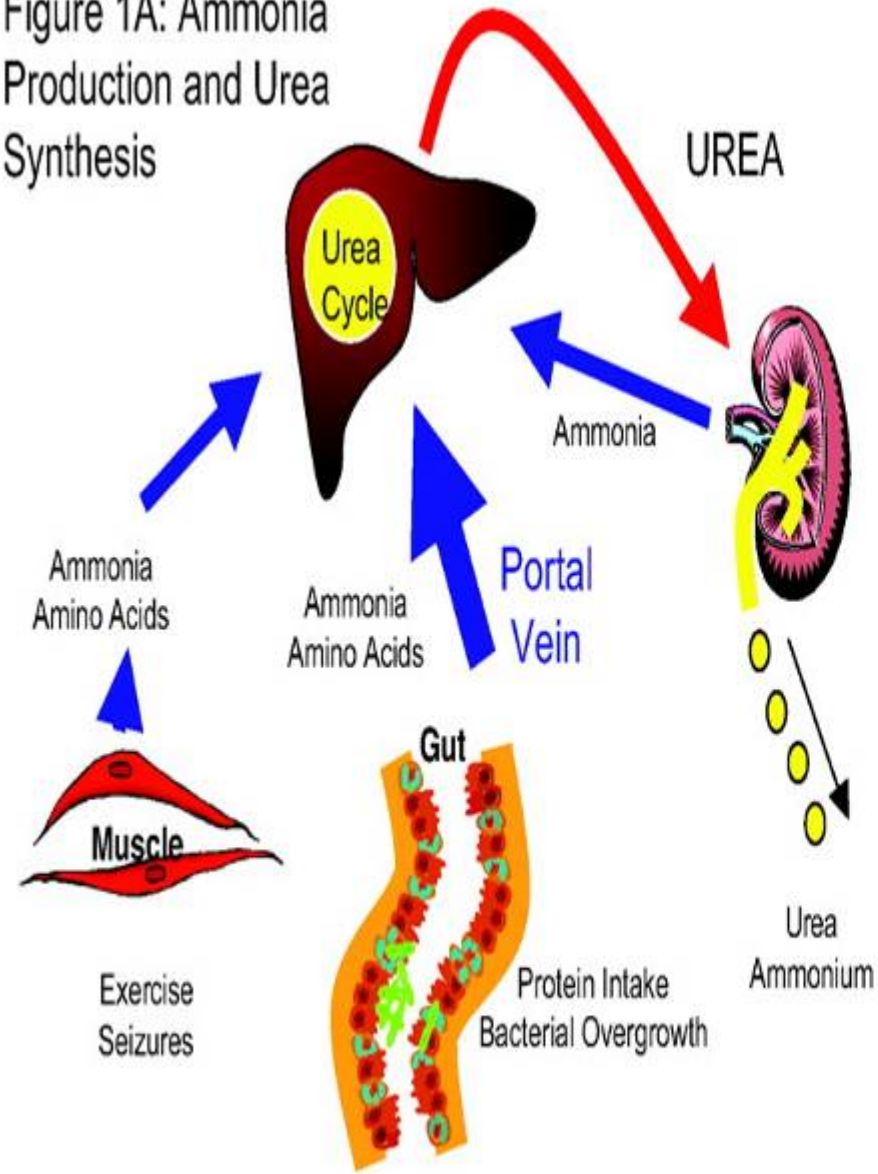
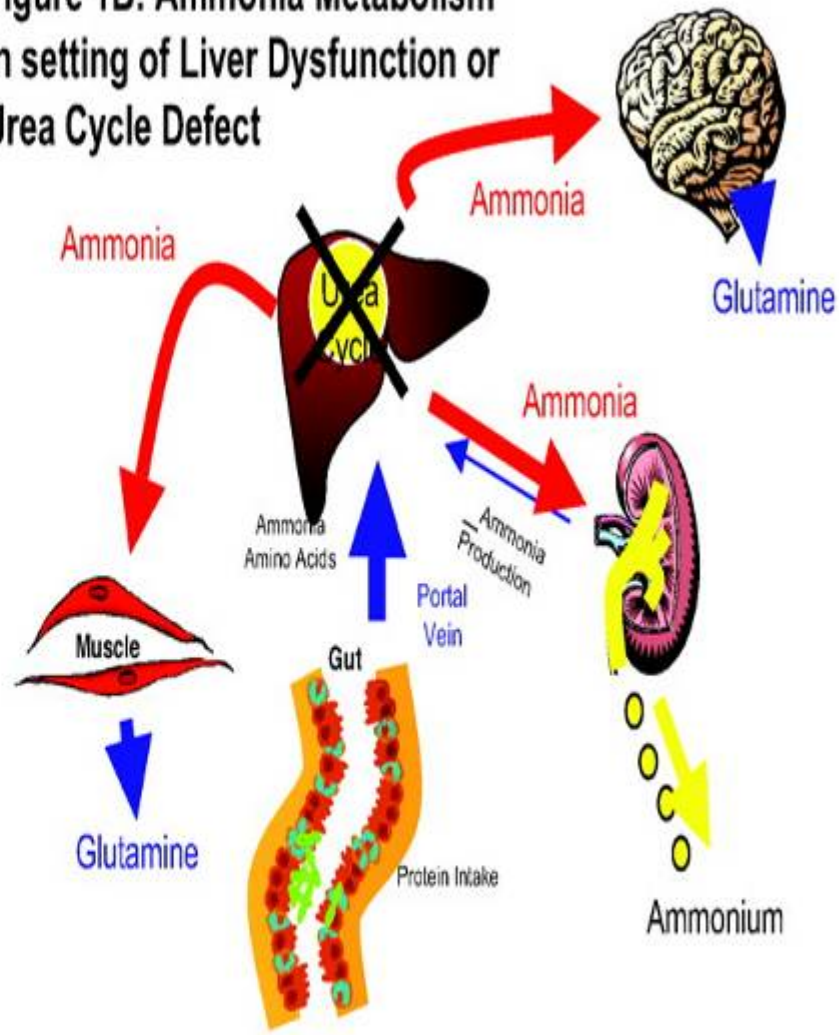


Figure 1B: Ammonia Metabolism in setting of Liver Dysfunction or Urea Cycle Defect



Ammonia degradation.

- **Liver** is primarily responsible for ammonia degradation.
- Ammonia is metabolized by urea cycle.
- In case liver does not metabolize or more ammonia which liver can handle elimination is dependent on the kidneys, muscle and brain.

- Kidneys. Increase urinary excretion of ammonia.
- Muscle and brain. Metabolize ammonia to glutamine.

Brain and glutamine.

- **Acute rise in ammonia**.

  Astrocytes rapidly metabolize ammonia to glutamine→ increased intracellular osmolarity→ cerebral edema + inflammatory cytokine release→ Apoptosis

  Excessive activation of NMDA (glutamate) receptors→ neuronal degeneration and death.

Mechanizm of CNS injury.

- Intracerebral accumulation of glutamine is the major cause of encephalopathy.
- High level of ammonia result in conversion of glutamate to glutamine by glutamine synthetase which occurs in astrocytes.
- Increased intracellular osmolality results in astrocytic swelling, brain edema and cerebral hypoperfusion.

Role of MRI in Acute Hyperammonemic Encephalopathy.

- Four groups.

a. Diffuse cerebral Edema followed by diffuse cerebral atrophy.

b. Extensive infarct like abnormality presenting as acute hemiplegia.

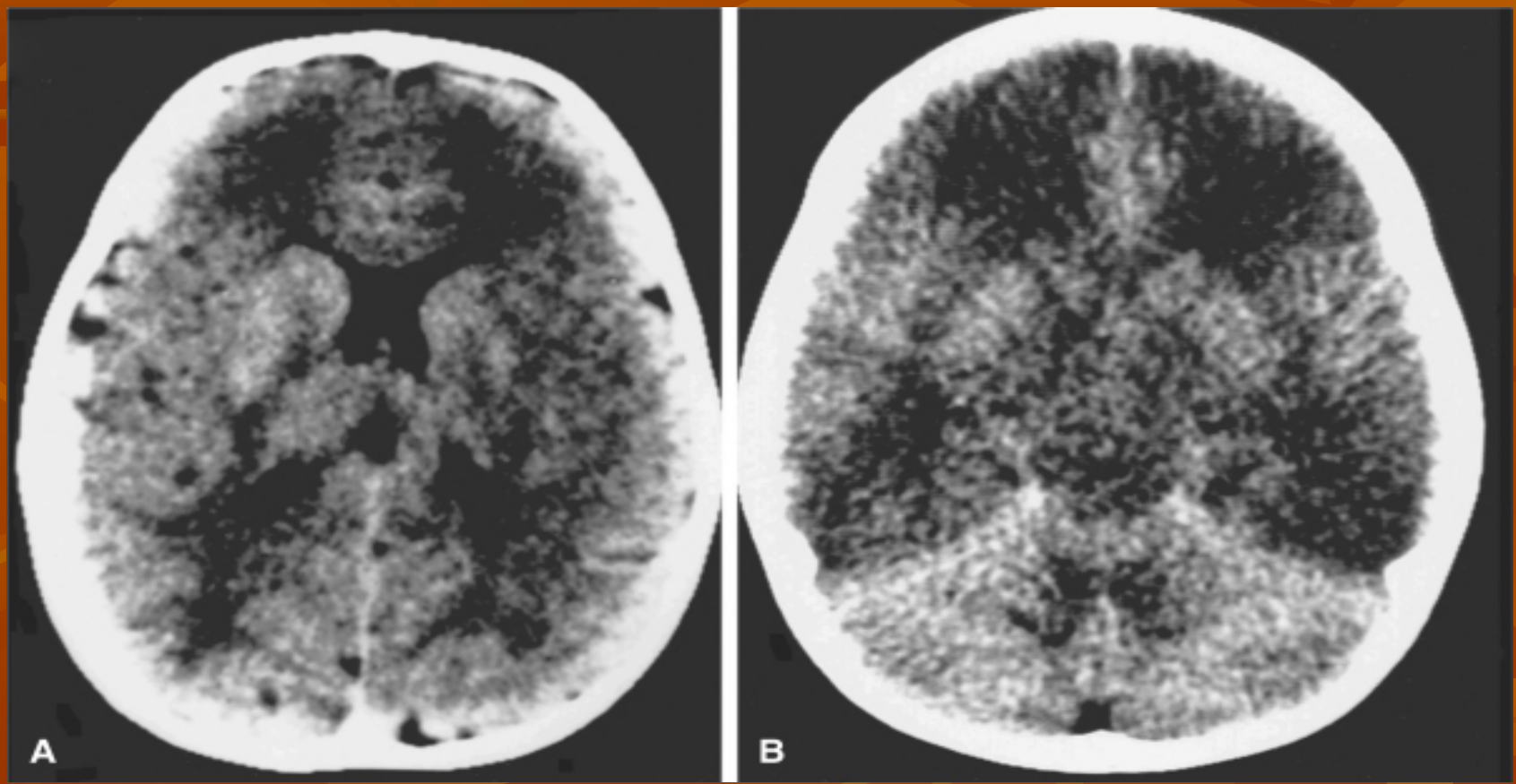
c. Ischemic lesions in cerebral vascular territory.

d. Reversible symmetric cortical involvement of cingulate gyri, temporal lobes and insular cortex.

(Takanashi J. Brain MR imaging in neonatal hyperammonemic encephalopathy resulting from proximal urea cycle disorder. Am J Neuroradiology)

. A, Image done on admission to the community hospital. B, Image done 24 hours later demonstrates bilateral hemispheric edema with effacement of cerebrospinal fluid spaces

Hyperammonemia in OTC deficient patient.



Venous or Arterial Ammonia.?

Which is better to check ?

Venous or Arterial Ammonia.?

- **Liver is working.**

  Venous and arterial ammonia do not correlate. As liver metabolize venous ammonia.

- **Fulminant hepatic failure**.

  Venous ammonia correlate with Arterial ammonia. Arterial ammonia correlate with brain glutamine level which correlate with development of ICH (intracranial Hypertension).

Consult of increased ammonia.

- Increased ammonia production.
- Decrease Ammonia elimination.

Increased ammonia production.

- High protein load and increased catabolism.
- Seizures.
- Trauma or burns.
- Steroid administration.
- Starvation.
- GI hemorrhage.
- TPN
- Urease producing bacteria (proteus, klebsiella) infection.
- Severe exercise.
- Chemotherapy.
- Cancers. (multiple Myeloma)

Decreased Ammonia Elimination.

- Liver Failure.
- TIPS.
- Drugs.
- Inborn errors of metabolism.

  Urea cycle disorders.

  Organic acidurias.

Drugs associated with Hyperammonemia

A. Drugs causing liver failure.

B. Drugs associated with UCDs.

Glycine.

Salicylates.

Valproate.

Carbamezipine.

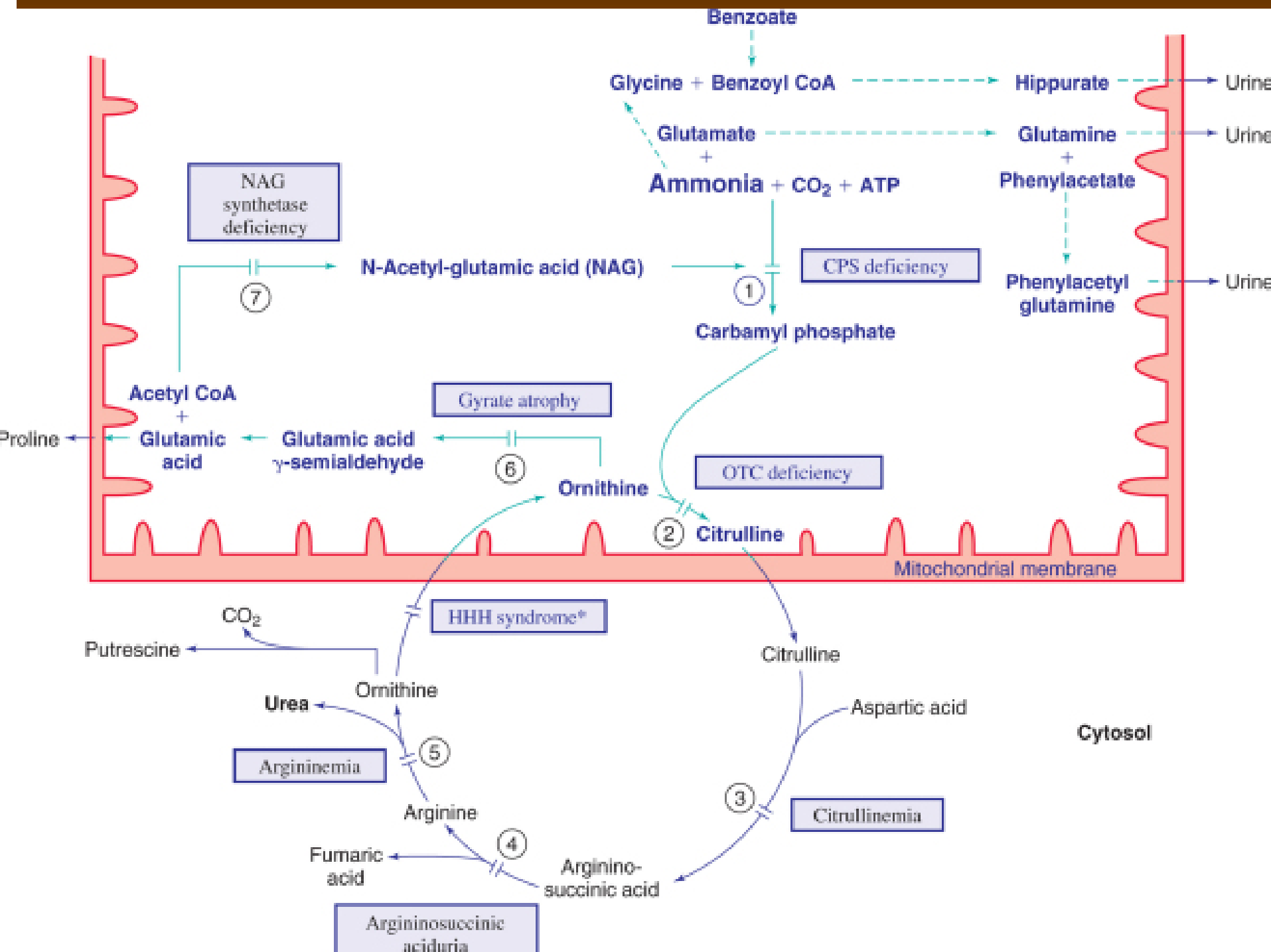
Sulfadiazine.

Pyrimethamine.

Work up for high Ammonia

- History is very important.
- Rule out liver disease. Blood/Imaging
- Two conditions can co-exist.
- Medications.
- Consider inborn errors of metabolism.

UREA CYCLE.


Benzoate
Glycine + Benzoyl CoA
Hippurate
Urine
Glutamate
+
Ammonia + CO_2 + ATP
Glutamine
+
Phenylacetate
Urine
NAG synthetase deficiency
N-Acetyl-glutamic acid (NAG)
CPS deficiency
Phenylacetyl glutamine
Urine
Carbamyl phosphate
Acetyl CoA
+
Glutamic acid
Proline
Glutamic acid γ-semialdehyde
Gyrate atrophy
Ornithine
OTC deficiency
Citrulline
Mitochondrial membrane
CO_2
Putrescine
HHH syndrome*
Citrulline
Ornithine
Urea
Aspartic acid
Cytosol
Argininemia
Arginine
Citrullinemia
Fumaric acid
Arginino-succinic acid
Argininosuccinic aciduria

UREA cycle disorders.

- Carbamyl phosphate synthetase deficiency.
- Ornithine transcarbamylase deficiency.
- Arginosuccinate synthetase deficiency.
- Arginosuccinate lyase deficiency.
- N-acetyl glutamate synthetase deficiency.
- Arginase deficiency.

- Epidemiology.

  1 in 8200 live births

Pathophysiology.

Urea cycle converts nitrogen from peripheral (muscle) and enteral source (protein ingestion) into urea that is water soluble and excreted.

- Two moles of nitrogen one from ammonia and one from aspartate are converted to urea in each cycle.
- Ammonia nitrogen derives from circulating aminoacids, mostly glutamine and alanine.
- Aspartate is a substrate for arginosuccinic acid synthesis.

- NAGs, OTC, CPS are located in mitochondria, primary mitochondrial disease may affect urea cycle activity.

Genetics.

- All UCDs are autosomal recessive except
- OTC deficiency- X linked.

All female offsprings of a male OTC-deficient parent will carry an OTC mutation and 50% of all offspring from a female OTC deficient will carry the mutation.

- 10% of female carriers of OTC become symptomatic.
- Clinical severity in affected females depends on the pattern of X-inactivation in the liver (lyonization) and ranges from asymptomatic to severely symptomatic.
- Hemizygous males usually are more severely affected than are the heterozygous females.

Clinical presentation.

- Mostly seen in newborns. Partial enzyme deficiency may become symptomatic later in life.
- Typical symptoms. Once feeding is started (human or infant formula)

Somnolence and poor feeding.

Vomiting.

Lethargy.

Coma.

- → Hyperventillation (cerebral edema) then hypoventillation→abnormal posturing and resp. arrest.
- →Atypical presentation. Partial enzyme deficiencies. Chronic vomiting, developmental delay, seizure disorder, headache, lethargy.
- → Protein intake/catabolic state→make them worse.

→ Prefer vegetarian diet.

When do you suspect urea cycle disorder.

- Elevated ammonia with normal LFTs.
- Labs to be ordered.

  Serum ammonia.

  ABGs

  Urine organic acids. Normal

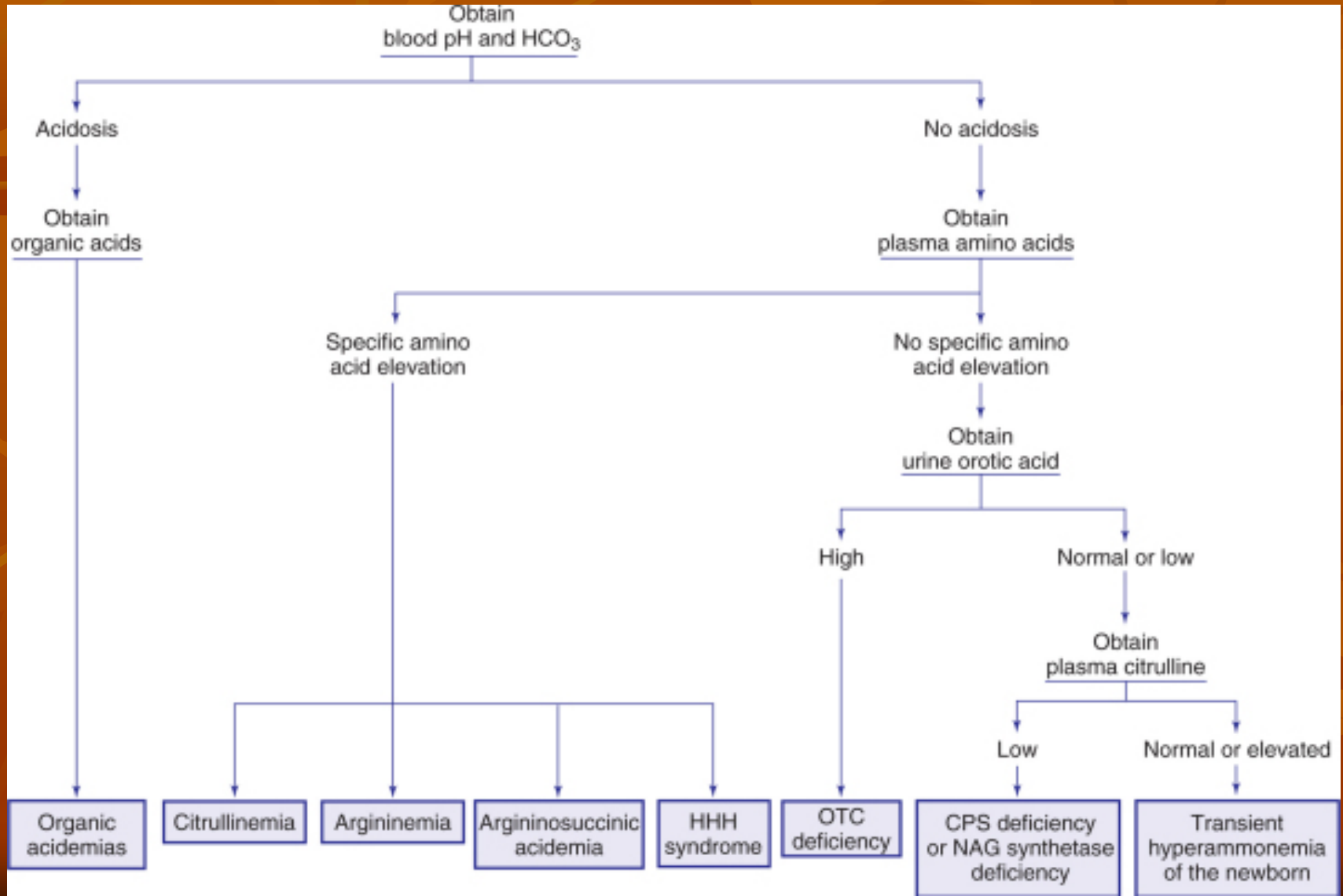
  Serum AA

  Urinary orotic acid.

Genetic causes of Hyperammonemia.

- Organic acidemias result from inhibition of one of the urea cycle enzymes. (metabolic acidosis/and or ketotic hypoglycemia)
- Fatty oxidation defects. Non- ketotic hypoglycemia.
- Disorders of pyruvate metabolism. Lactic acidemia usually seen.

Clinical approach to a newborn infant with symptomatic hyperammonemia. (Kliegman)



Rare causes

- HHH syndrome. (Hyperornithinemia, hyperammonemia, homocitrullinemia.) Impaired transport of ornithine across inner mitochondrial membrane. Presents with Lethargy, hypotonia and seizures.

- THAN (transient hyperammonemia of the newborn) – Low birth weight , respiratory distress.

Lab evaluation.

- Elevated ammonia.
  (arterial or venous.)

  Chilled tubes with ammonia-free sodium heparin (green top) or EDTA (purple top), placed on ice.

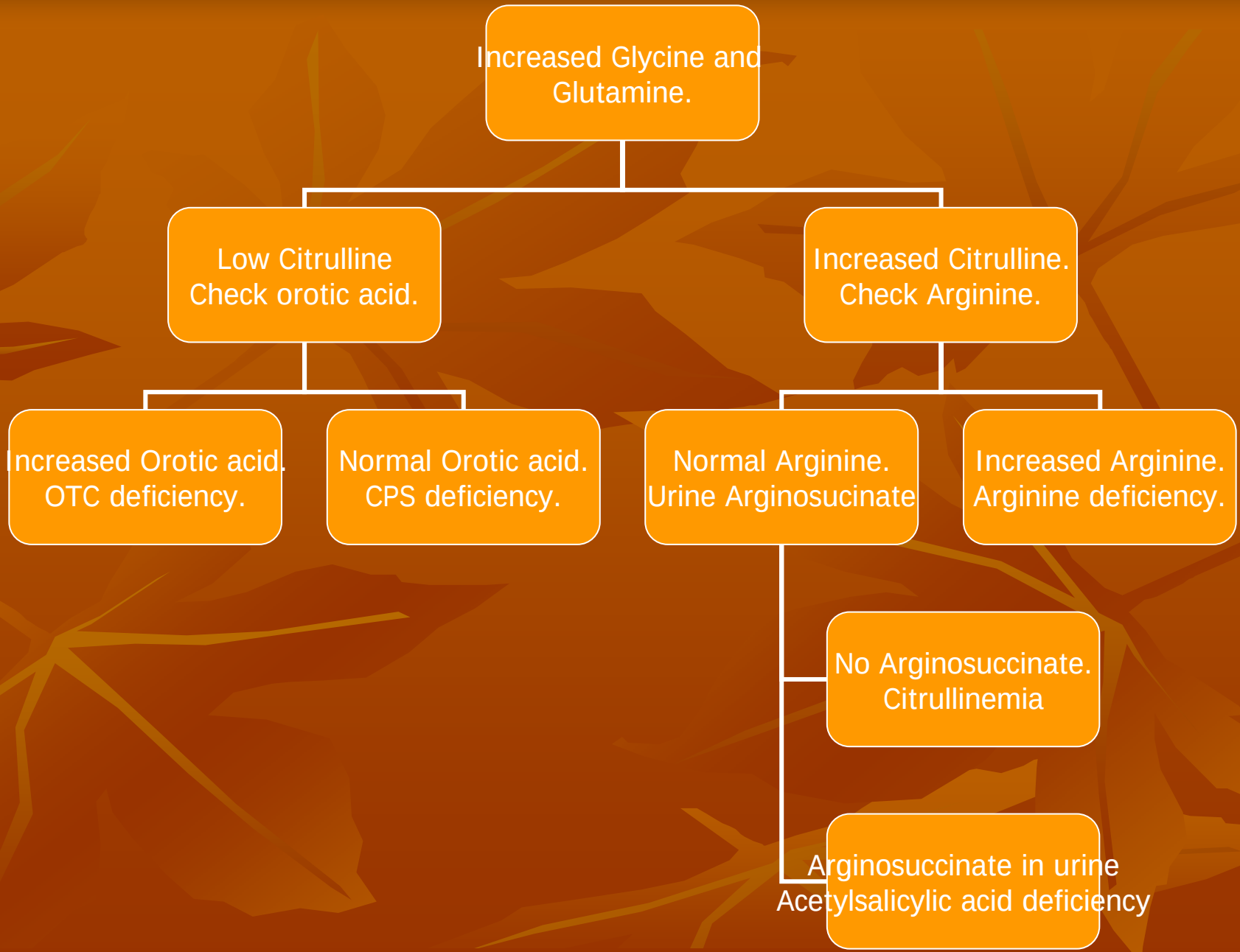
Ammonia Levels.

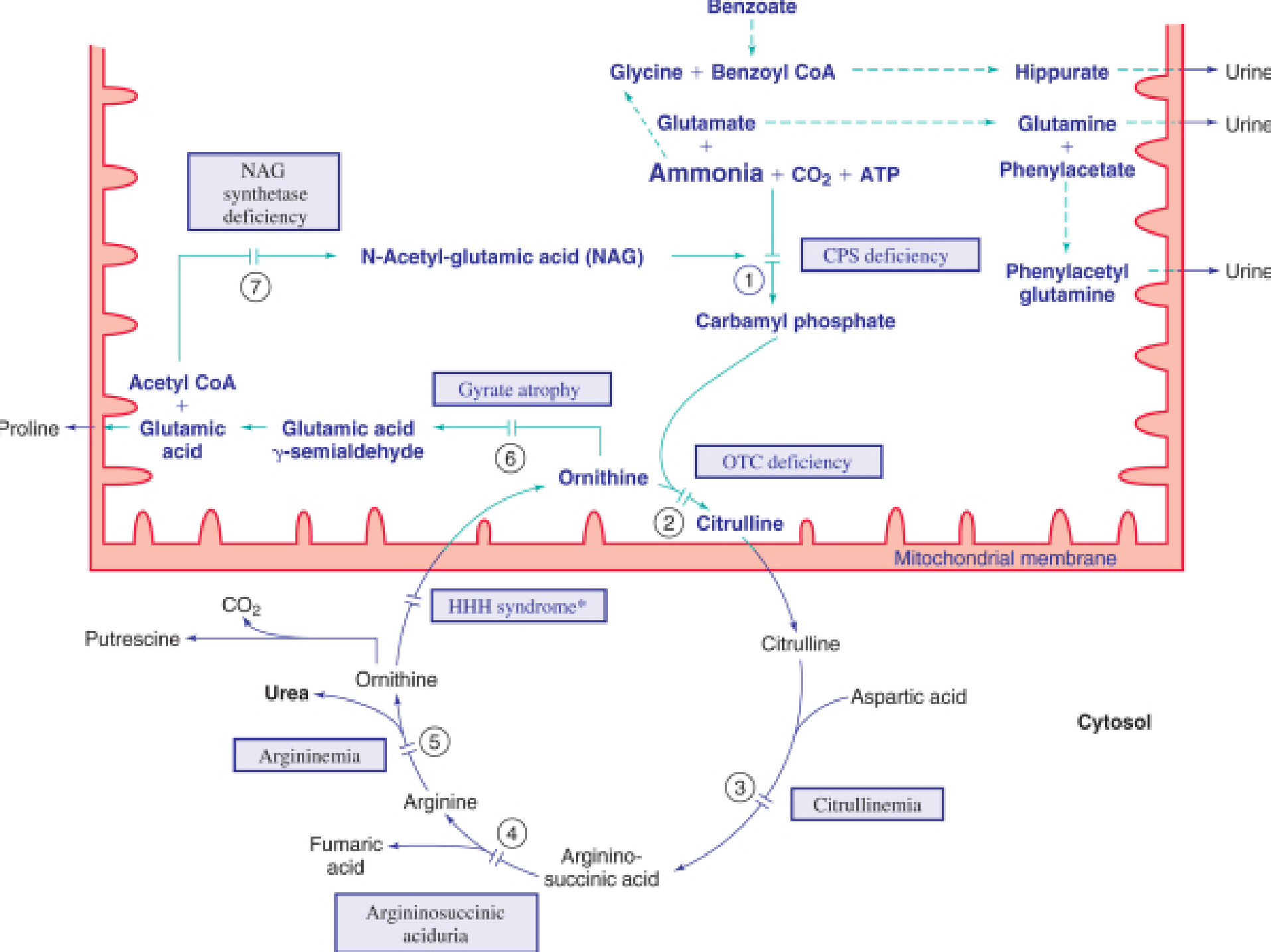
Ammonia level higher in newborns.

Healthy term infant-	45 mean (upto 90 micromol/L)
At 32 week preterm	71 micromol/L
Children >1 month	Less than 50 micromol/l
Adults	less than 30 micromol/l

- Quantitative plasma aminoacids.
- Citrulline level. Absent or low in CPSI, OTC or NAGS.
- Arginine is low
- Glutamine is increased.
- Urine orotic acid increased in OTC

  normal 1-11 micromol/mol creatinine) ,Low in CPS


Increased Glycine and Glutamine.
Low Citrulline Check orotic acid.
Increased Citrulline. Check Arginine.
Increased Orotic acid. OTC deficiency.
Normal Orotic acid. CPS deficiency.
Normal Arginine. Urine Arginosucinate
Increased Arginine. Arginine deficiency.
No Arginosuccinate. Citrullinemia
Arginosuccinate in urine Acetylsalicylic acid deficiency


Benzoate
Glycine + Benzoyl CoA
Hippurate
Urine
Glutamate
Glutamine
Urine
+
Ammonia + CO_2 + ATP
Phenylacetate
NAG synthetase deficiency
N-Acetyl-glutamic acid (NAG)
CPS deficiency
Phenylacetyl glutamine
Urine
7
1
Carbamyl phosphate
Acetyl CoA
+
Glutamic acid
Proline
Glutamic acid γ-semialdehyde
Gyrate atrophy
6
Ornithine
OTC deficiency
2
Citrulline
Mitochondrial membrane
CO_2
Putrescine
HHH syndrome*
Citrulline
Ornithine
Urea
Aspartic acid
Cytosol
5
Argininemia
3
Citrullinemia
Arginine
4
Fumaric acid
Arginino-succinic acid
Argininosuccinic aciduria

Enzyme deficiency	Plasma ammonia	Citrulline	Arginosuccinate (urine or serum)	Orotic acid Urine	Arginine/ornithine serum
Carbamyl phosphate synthetase	High	Low	Low	Low	Low
OTC	High	Low	Low	High	Low
Arginosuccinate synthetase	High	High	Low	Normal or high	Low
Arginosuccinase	High	High	High	Normal or high	Low
Arginase	High	High	High	Normal or high	High

Enzyme analysis

- Liver biopsy: CPSi, OTC and NAGs deficiency.
- Fibroblasts from skin biopsy. ASS and ASL deficiency.
- Red blood cells: Arginase deficiency.

(Levels may be normal)

Specialized testing (research)

Allopurinol test.

Measurement of urinary orotic acid after administration of allopurinol. Mild cases may have minimal elevation.

Increased excretion may occur in mitochondrial disease limiting specificity.

DNA mutation analysis.

More than 150 mutations mostly single base substitutions.

- OTC is most common DNA testing should be considered if plasma AA is not diagnostic.
- False negative results (microdeletions).
- Failure to detect a pathogenic mutation does not exclude the diagnosis.

Prenatal testing.

1. DNA analysis. (if mutation is known)
   OTC and CPSI deficiency.

2. Biochemical testing. ASS and ASL enzyme activity can be measured in amniocytes and chorionic villus cells.

Management of Urea cycle disorders

- Start treatment as soon as UCD is suspected.
- Rehydration with good urine output.
- Remove nitrogen

  Medicines and hemodialysis

  Decrease or stop protein intake.

  Minimize catabolism.

  Stimulate anabolism and uptake of nitrogen precursors by muscle.
- Control infection.

- **Avoid.**

  Steroids. Increase catabolism.

  Valproic acid. Decrease urea cycle, and increase ammonia level.

- Hemodialysis.

  For severe hyperammonemia.

  Continous Arteriovenous or Venovenous

  hemodialysis (CAVHD or CVVHD) with flow rates > 40-60 ml/min

Pharmacologic therapy

- **Removal of Glutamine and Glycine to reduce total nitrogen pool.**
- **Phenylacetate** combine with glutamine to form Phenylacetylglutamine.
- **Benzoate** combines with glycine to form hippurate.
- Both phenylacetylglutamine and hippurate are water soluble and excreted in urine.

Ammonul (sodium phenylacetate-sodium benzoate)

- Approved in 2005 for parenteral delivery.

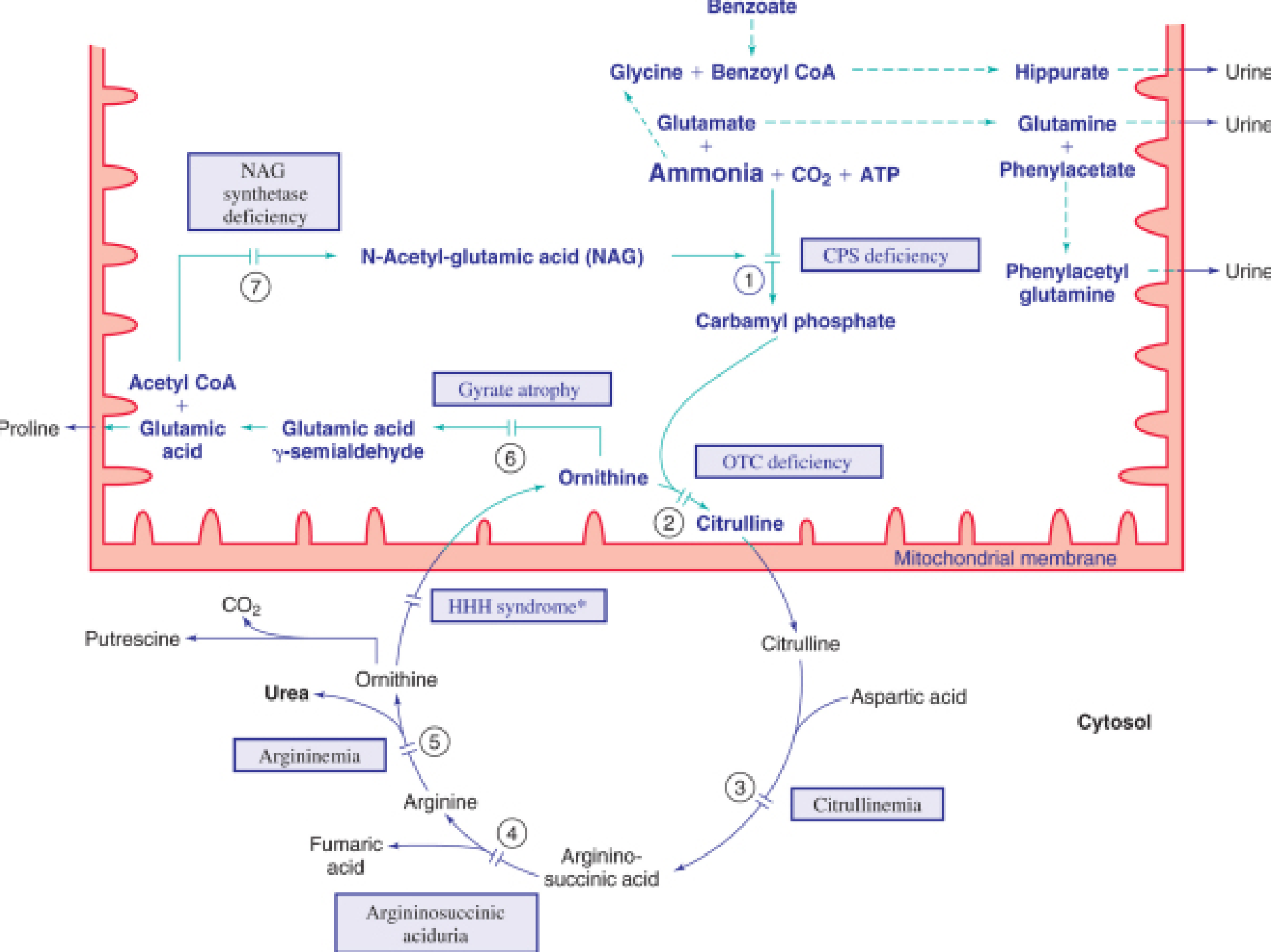
<20 Kg loading dose of 500 mg/kg in a volume of 25-35 ml/kg of 10% dextrose infused over 90 minutes.

>20 Kg, dosing is based on surface area. Loading dose is 11 g/m2

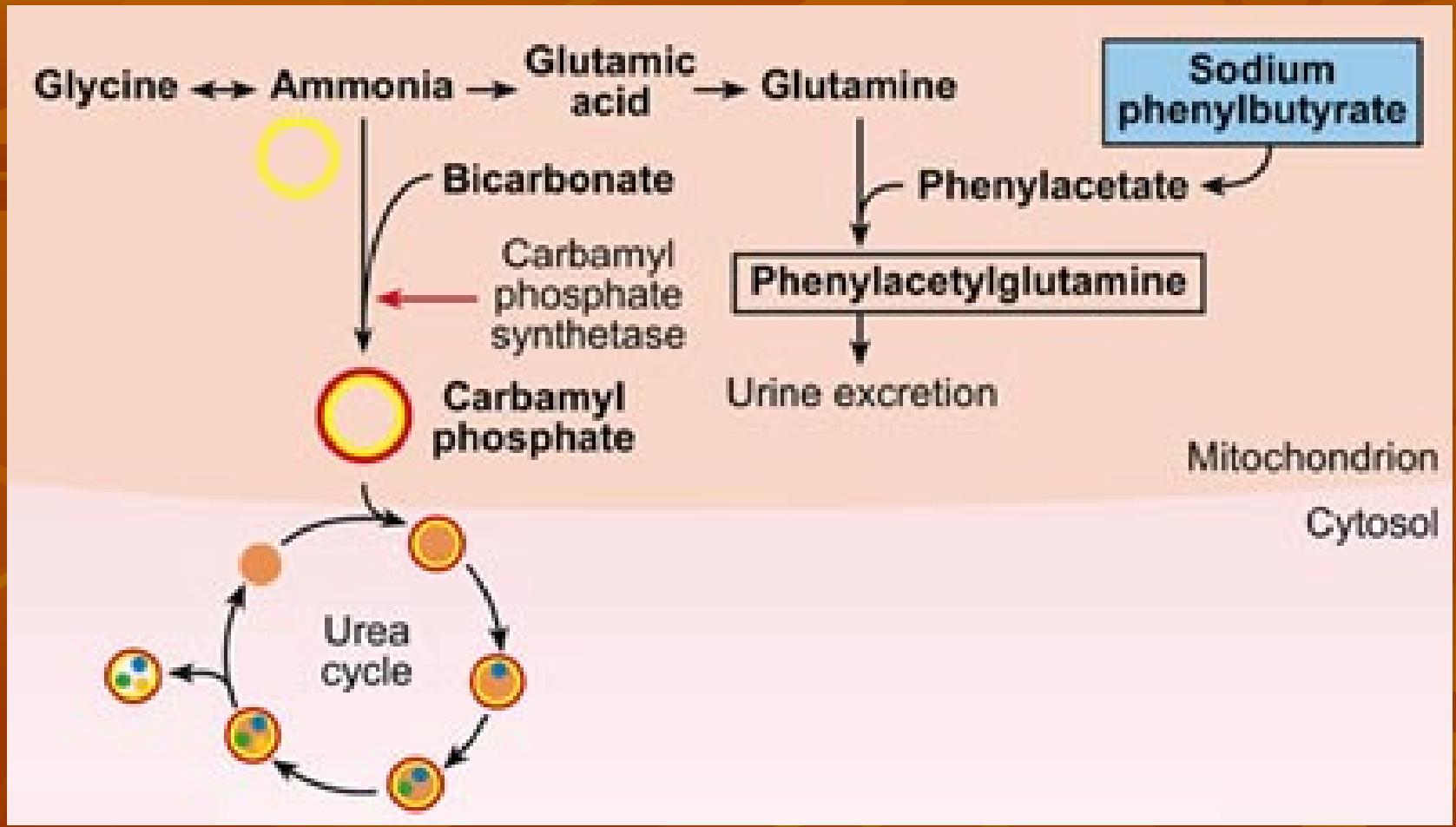
- Maintenance infusion is continued until oral medications can be tolerated.

  (500 mg/kg per 24 hrs < 20 Kg.

  11 g/m2 per 24 hrs for > 20 Kg)


Benzoate
Glycine + Benzoyl CoA
Hippurate
Urine
Glutamate
Glutamine
Urine
+
Ammonia + CO_2 + ATP
Phenylacetate
NAG synthetase deficiency
N-Acetyl-glutamic acid (NAG)
CPS deficiency
Phenylacetyl glutamine
Urine
7
1
Carbamyl phosphate
Acetyl CoA
+
Glutamic acid
Proline
Glutamic acid γ-semialdehyde
Gyrate atrophy
6
Ornithine
OTC deficiency
2
Citrulline
Mitochondrial membrane
CO_2
Putrescine
HHH syndrome*
Citrulline
Ornithine
Urea
Aspartic acid
Cytosol
5
Argininemia
3
Citrullinemia
Arginine
4
Fumaric acid
Arginino-succinic acid
Argininosuccinic aciduria

Buphenyl (Sodium phenylbutyrate)



- The usual daily dose of BUPHENYL Tablets and Powder is:

  450 – 600 mg/kg/day for patients <20 kg,

  or

  >9.9 – 13.0 g/m2/day in larger patients.

Adverse Events **of Buphenyl**

- Amenorrhea/menstrual dysfunction.
- Decreased appetite occurred in 4% of all patients.
- Body odor (probably caused by the metabolite phenylacetate) and bad taste or taste aversion were each reported in 3% of patients.

- Metabolic: acidosis (14%), alkalosis and hyperchloremia (each 7%), hypophosphatemia (6%), hyperuricemia and hyperphosphatemia (each 2%), and hypernatremia and hypokalemia (each 1%)
- Nutritional: hypoalbuminemia (11%) and decreased total protein (3%)
- Hepatic: increased alkaline phosphatase (6%), increased liver transaminases (4%), and hyperbilirubinemia (1%)
- Hematologic: anemia (9%), leukopenia and leukocytosis (each 4%), thrombocytopenia (3%), and thrombocytosis (1%)

Arginine

- Decreased formation of Arginine making it essential aminoacid.
- Arginine deficiency leads to catabolic state resulting in more protein breakdown and mobilization of nitrogen.
- Decrease formation of ornithine, citrulline and Arginosuccinic aced. Providing arginine generate these water-soluble compounds that can be excreted and results in removal of NH3

- Dose

IV Arginine hydrochloride.

Loading dose

<20 Kg loading dose 600 mg/kg dissolved in 25-35 ml/kg of 10% dextrose infused over 90 minutes.

>20 kg loading dose is 12 g/m2

- Maintenance dose.

  200 mg/kg per 24 hrs. <20 kg

  4 g/m2 per 24 hrs >20 Kg

  For ASS and ASL deficiency higher maintenance dose of 600 mg/kg used to increase generation of citrulline and Arginosuccinic acid.

Citrulline

- OTC and CPS deficiency.

  Oral dose of citrulline

  150-250 mg/kg per 24 hrs <20 kg

  3-4 g/m2 per 24 hrs > 20 kg.

What to monitor during therapy

- → Electrolytes and routine labs. Potassium and sodium.
- → Ammonia every hour during dialysis and once stable below 200 micrmol/L for 24 hrs measurement can be reduced to every 4 hrs.
- → Serum Aminoacids are measured (daily) to assess efficacy of glutamine removal and to determine replacement of Arginine or citrulline

Protein Restriction.

- Infants.. 2-2.5 gm/kg per day
- Adults. 0.6-0.8 gm/kg

Children require less than recommended daily intake of protein for normal growth. Patient with partial deficiency of urea cycle may tolerate greater protein intake.

- In acute hyperammonemia oral feeding is discontinued
- Calories are provided by IV administration of lipids and glucose and protein intake is stopped.
- Protein should not be stopped more than 24-48 hrs after treatment to avoid protein catabolism

- Enteral feeding is initiated as soon as possible
- Protein free formula such as Mead johnson or Ross formula Prophree in conjunction with amino acid mixtures and cow milk based formulas.

(less Nitrogen in aminoacid mixtures)

Pro-phree (abbott). Protein free, L carnitine, linolenic acid, vitamins

- Measure serum levels of essential aminoacids (branched chain AA, phenylalanine, lysine). Samples are obtained 3-4 after feeding and repeated every 2-3 days.

Chronic management. Weight and growth

total protein, albumin and prealbumin.

Nutritional deficiencies following Bariatric Surgery: What have we learned?

- Protein Deficiency.
- Iron deficiency.
- Vitamin B12 and Folate deficiency.
- Calcium and Vitamin D deficiency.
- Thiamine (vit. B1) deficiency.
- Fat soluble Vit. Def. Vit A, E, K
- Magnesium.
- Zinc
- Selenium.

(Obesity Surgery, 15. 2005)

Routine laboratory testing after malabsorptive bariatric surgery

3 months postoperatively. Complete blood count; glucose; glycosylated hemoglobin[a]; lipids; chemistry group

At 6-month intervals during first 3 years & then once yearly

Chemistry ; complete blood count; lipids; ferritin; zinc; copper; magnesium; vitamin A; total 25-hydroxy vitamin D; folate; whole blood thiamine; vitamin B12; 24-hour urinary calcium

(Postoperative Metabolic and Nutritional Complications of Bariatric Surgery Gastroenterology Clinics - Volume 39, Issue 1 (March 2010)

General supplementation recommendations.

(RYGB-Roux Y gastric Bypass, VSG vertical sleeve gastroplasty, AGB- Adjustable Band, BPD- biliopancreatic diversion, BPD-DS –biliopancreatic diversion with duodenal switch)

Multivitamin containing folic acid	AGB/VSG RY GB BPD-DS	Once daily 1-2 daily 2 daily.
Calcium citrate with Vitamin D3	AGB RYGB and BPD-DS	1200-1500 mg/day 1800 mg/day
Vitamin D3	RYGB BPD-DS	1000 IU/day 2000 IU/day
Vitamin B12	RY GB BPD-DS	Orally or 1000 ug/month IM Monitor and start if needed
Elemental Iron	RYGB and BDP-DS	65 mg elemental iron in mensturating females.
Vitamin B1	All procedures	Once daily in first 6 months
Vit A and Vit K	BPD-DS	10,000 IU vitamin A and 300 ug vitamin K

Laboratory testing for nutritional disorders after bariatric surgery

- Anemia Ferritin; vitamin B12; folate & then consider vitamin A; vitamin E; zinc; copper
- Neurologic disorders. Vitamin B12; whole blood thiamine & then consider vitamin E; copper; plasma niacin
- Visual disorders. Vitamin A; vitamin E; whole blood thiamine
- Skin disorders. Vitamin A; zinc; plasma niacin
- Edema Selenium; whole blood thiamine; plasma niacin

(Postoperative Metabolic and Nutritional Complications of Bariatric Surgery Gastroenterology Clinics - Volume 39, Issue 1 (March 2010)

Thank you.