Endocrine Issues in Critical Care

Presented by:
Cynthia Webner  DNP, CCNS, RN, CCRN-CMC
Karen Marzlin DNP, CCNS, RN, CCRN-CMC

Endocrine System Basic Function

Central Nervous System sends a signal.....

Bone & muscles
Growth hormone
FSH & LH
GRH
TRH
CRF
Hypothalamus releasing factors
Pituitary Gland releases hormone
Peripheral Gland or Target Organ
Physiological Action occurs in the cell
Pancreas
A cells
Glucagon
B cells
Insulin
C cells
Somatoatatin
- Blood sugar
- Inhibits glucagon & insulin release

Hypothalamus-pituitary-target gland axis
information from the CNS sends a stimulus through the hypothalamus to the pituitary

Oxytocin
Posterior Pituitary
Anti-diuretic Hormone
Kidney arterioles
Distal Tubules
- H2O absorption
- Arteriole constriction
The Endocrine System

- Endocrine system
  - System of glands that produce and secrete hormones
- Hormones
  - Molecules synthesized and secreted by special cells and released into the blood
  - Exert biochemical effects on target cells
  - Control metabolism
  - Transport substances across cell membranes
  - Control fluid and electrolyte balance
  - Control growth and development
  - Control adaptation
  - Control reproduction

The Process

Hypothalamus detects a system need

Pituitary

Releasing Hormone

Growth Releasing Hormone
Thyroid Stimulating Hormone
Cortisol Releasing Factor

Stimulating Hormone

Target Organ

Secrete Hormone
The Glands

Hypothalamus
- Lower central part of the brain
- Regulation of satiety
  - Hunger
  - Rest
  - Sexual stimulation
- Water and electrolyte balance
- Emotions
- Regulation of body temperature
  - Sweat and shiver
- Stimulate or suppress release of hormones in the pituitary gland
Pituitary Gland
- Master Gland
- Size of a pea
- Beneath the hypothalamus
- Two lobes: anterior and posterior
- Anterior Lobe is 75% of gland

Anterior Lobe of Pituitary
- CNS → HYPOTHALAMUS
  - Growth Releasing Hormone
  - Thyroid Releasing Hormone
  - Cortisol Releasing Factor
- ANTERIOR PITUITARY GLAND
  - Growth Hormone → Bone and Muscles
  - FSH and LH → Ovaries/ Testes
  - Thyroid Stimulating Hormone → Thyroid Gland
  - TH, T3 and T4
- ACTH Adrenocorticotropin → Adrenal Gland
  - Cortisol, Aldosterone, Epi, NorEpi
Posterior Lobe of Pituitary

- Not regulated by the Central Nervous System
- Controlled by nerve fibers in the hypothalamus
- Released after activation of cell bodies in the nerve tract
- Responds to changes in plasma osmolality, decreased BP, decreased volume
- Secreted hormones produced in the hypothalamus and stored in the pituitary
- Produces the hormones
  - Antidiuretic hormone (vasopressin)
    - Water conservation
  - Oxytocin
    - Contraction of uterine walls
    - Ejection of breast milk

Thyroid Gland

- Immediately below larynx laterally and anterior to trachea
- Release of thyroid hormones controlled by pituitary
- Normal function
  - ↓ levels of T3, T4 ▶ Pituitary releases TSH ▶ Thyroid produces more T3, T4 ▶ ↓ production of TSH
- Regulates body metabolism
- Stimulates carbohydrate, fat and protein metabolism
- Positive chronotropic and inotropic effect
- Bone growth and brain and nervous system development in children
- Helps maintain blood pressure, heart rate, digestion, muscle tone and reproductive functions
T3, T4

- Thyroid hormones
- Thyroid takes iodine and converts to thyroid hormones
- Combine iodine with amino acid to make T3, T4
- T3 - Triiodothyronine
  - 20%
  - 4 – 10 times stronger than T4
  - More active form
- T4 - Thyroxine
  - 80%

Parathyroid Glands

- Two pairs (four glands)
- Posterior surface of the thyroid gland
- Release parathyroid hormone
  - Regulates calcium levels in blood and bone metabolism
  - Regulates calcium and phosphate balance
  - Releases calcitonin to decrease levels of calcium
  - Stimulates formation of fat-soluble form of Vitamin D
Adrenal Glands
- Triangular shape
- Sit on top of each kidney
- Two part
  - Adrenal Cortex
  - Adrenal Medulla
- Cortisol Releasing Factor
  - Stimulated in response to stress, ↓ glucose, heat/cold extremes, trauma, surgery, immobility, ↓ cortisol levels
- Activates ACTH – Adrenocorticotropin
  - Response: Release of Adrenocotical Hormones
    - Glucocorticoids - Cortisol
    - Mineralcorticoids – Aldosterone
    - Medullary Hormones - Catecholamines

Adrenal Glands
- Adrenal Cortex
  - Glucocorticoids
    - Cortisol (corticosteroids)
    - Helps cope with stress
    - Carbohydrate, fat and protein metabolism
    - Increases blood pressure
    - Blocks allergic and inflammatory response
      - Blocks WBC response
Adrenal Glands

- **Adrenal Crisis – Addison’s Disease**
  - Lack of Cortisol
    - Pituitary injury, sudden stopping of steroids
    - Fatigue, lethargy, hypotension, fever, tachycardia
    - Treat with IV Cortisone

- **Cushing’s Disease**
  - Overproduction of cortisol
    - Increased appetite, weight gain, fat deposits, slow wound healing, Na and H2O retention, HPTN

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Adrenal Glands

- **Adrenal cortex**
  - Mineralocorticoids
    - Aldosterone
    - Renin – angiotensin system

- **Adrenal Medulla**
  - Medullary Hormones
    - Catecholamines (adrenergic response)
    - Response to stress
    - Fight or flight
    - Increased HR, BP, RR, contractility, and vasoconstriction
      - Epinephrine
      - Norepinephrine
Pineal Gland
- Located in the middle of the brain
- Secretes melatonin
  - Helps regulate the wake-sleep cycle
  - Stimulated by darkness
  - Inhibited by light

Reproductive Glands
Follicle-Stimulating Hormone and Luteinizing Hormone

- Testes
  - Secrete androgens (testosterone)
    - Sexual development
    - Growth of facial and pubic hair
    - Sperm production

- Ovaries
  - Production of eggs
  - Estrogen and progesterone
    - Breast growth
    - Menstruation
    - Pregnancy
Pancreas

- Elongated long organ
- Back of the stomach
- Digestive and hormonal functions
- Exocrine pancreas
  - Secretes digestive enzymes
- Endocrine pancreas
  - Secrete hormones
    - Insulin
    - Glucagon
    - Somatostatin

Disorders of the Endocrine System

- Diabetes Insipidus
- Syndrome of Inappropriate ADH
ADH – 2 Control Mechanisms

1. Serum Osmolality
   - ↑ Serum osmolality
     ↓
     - stimulation of osmoreceptors in hypothalamus
     ↓
     - ↑ secretion of ADH
     ↓
     - ↑ water reabsorption
     ↓
     - serum diluted
     ↓
     - serum osmolality returns to normal
ADH – 2 Control Mechanisms

2. Blood Volume
   - ↓ blood volume
     ↓
   - ↓ pressure on baroreceptors in left atrium
     ↓
   - Stimulates release of ADH
     ↓
   - ↑ water reabsorption
     ↓
   - ↑ blood volume

Diabetes Insipidus
Diabetes Insipidus

- Impaired renal conservation of water, resulting in:
  - Polyuria: 5-20 L/24 hours
  - Dehydration
  - Hypernatremia
- Caused by either:
  - Deficiency of ADH
  - Decreased renal response to ADH

3 Types of Diabetes Insipidus

- Neurogenic
  - Deficit in release or synthesis of ADH
- Nephrogenic
  - Deficit in renal tubular response to ADH
- Psychogenic
  - Psychogenic Polydipsia
  - Can mimic nephrogenic
    - Hypotonic urine
    - Water intoxication versus volume depletion
Neurogenic (Central) Diabetes Insipidus

- Causes
  - Congenital, idiopathic
  - Intracranial tumors (Hypothalamus, pituitary)
  - Malignancy: Lung cancer, leukemia, lymphoma
  - Infections: Meningitis, encephalitis
  - CNS Injury / Trauma
    - Alert in basal skull fractures
  - Post Craniotomy
  - Drugs that inhibit secretion of ADH
    - Alcohol, dilantin, thorazine, lithium

Nephrogenic Diabetes Insipidus

- Causes
  - Congenital
  - Renal Disease
    - Polycystic kidneys, polynephritis
  - Drugs that block the effect of ADH on renal tubules
    - Lithium, tetracycline derivatives, general anesthetics, alpha adrenergic blockers
  - Multisystem Diseases
    - Amyloidosis, multiple myeloma
Diabetes Insipidus
Pathophysiology

- Inadequate Antidiuretic Hormone
- Diuresis of large volumes of hypotonic urine
- Dehydration and hypernatremia
- Potential shock and/or neurologic effects

Diabetes Insipidus
Presentation

- Onset may occur several days after insult if neurogenic
- Polydipsia – thirsty for cold liquids
- Fatigue, Weakness
- Polyuria
  – Suspect DI if UO > 200 ml/hr x 2 hrs
- Signs of dehydration and volume depletion
- Neurological
  – Restless, confusion, irritability, lethargy, coma
Diabetes Insipidus Diagnosis

- **Serum:**
  - Sodium > 145 mEq/L
  - ↑ BUN
  - ↑ Osmolality
    - > 295 mOsm/kg (Normal 280-295)
  - ↑ Hematocrit
  - ↓ ADH (Neurogenic)
    - <1 pg/ml

- **Urine**
  - Specific Gravity
    - < 1.005 (hallmark sign)
    - Normal 1.005 – 1.030
  - Osmolality
    - < Serum osmolality
    - < 500 mOsm/kg
    - < 200 mOsm/kg (hallmark sign)
    - Normal 300-800 mOsm/kg
    - Extremes of normal 50-1200 mOsm/kg
Diabetes Insipidus: Diagnosis

Water Deprivation Test
- Prestudy: Weight, serum osmolality, urine osmolality, urine specific gravity
- Withhold fluid intake
- Measure prestudy parameters q1hour
  - Negative test (Negative for DI)
    - Urine SG exceeds 1.020
    - Urine Osmol. > 800mOsm/L
    - Urine becomes more concentrated able to retain fluid
  - Positive test (Positive for DI)
    - 5% of body weight lost OR
    - Urine Specific gravity does not increase x 3 consecutive hours
    - Unable to retain fluid

Vasopressin Test
- If Water Deprivation Test Positive
- Give exogenous ADH – Vasopressin SQ
- Collect urine specimen q30min x 2 hours
- Evaluate quantity and osmolality
- For neurogenic:
  - Positive if urine output ↓ & urine osmolality ↑
- For nephrogenic:
  - No response
## Diabetes Insipidus: Treatment

### Correct Fluid Deficit
- Hypotonic Solution (.45NS or D5W)
  - Moves fluid into the cells
  - Caution with fluid shifting
- Rate: Hourly Urine output + 50cc

### Correct Electrolytes
- K+ usually needs replaced
- NA: correct slowly to avoid rapid fluid shifts in the brain resulting in cerebral edema
  - Decrease 0.5 to 1.0 mEq/L per hour

### Treat Cause

- **Neurogenic DI**
  - Exogenous ADH - Vasopressin
    - Aqueous Pitressin - IV/SQ
    - Lysine vasopressin – nasal
    - Desmopressin acetate – DDAVP (less vasoactive effects)
  - Hypophysectomy – Removal of pituitary tumor

- **Nephrogenic DI**
  - ADH Potentiator – Diabenese (chlorpropamide)
  - Thiazide diuretics and sodium restriction
    - Increase water reabsorption in proximal tubule – less available in distal for excretion
    - Normal mechanism – inhibit sodium reabsorption in distal tubule

- **Psychogenic DI**
  - Pharmacologic agents
Nursing Considerations for DI

- Monitor VS q15 minutes until stable
- I and O hourly
- Cardiac monitoring
- Assess urine output and specific gravity hourly
- Daily weights
- Low sodium diet
- Monitor neuro status

Diabetes Insipidus Complications

- Coma
  - Increased sodium
- Shock
  - Decreased circulating volume
- Thromboembolism
  - Dehydration
Syndrome of Inappropriate ADH (SIADH)

Impaired renal excretion of water resulting in:
- Oliguria
  - 100 to 400 ml / 24 hours
- ↑ urine specific gravity
- Water intoxication
- Hyponatremia

Caused either by:
- Excess excretion of ADH
- Increased responsiveness to ADH
SIADH

3 Types
- Neurogenic SIADH
  - ↑ production and / or release of ADH
- Ectopic SIADH
  - Production of a substance indistinguishable from ADH by tissue
- Nephrogenic SIADH
  - Pharmacological agents that ↑ ADH secretion or ADH effect

Neurogenic (Central) SIADH
- Pituitary Tumor
- CNS Trauma
  - Skull fracture
  - Subdural hematoma
  - Subarachnoid hemorrhage
  - Cerebral contusion
  - Post neurosurgery
- Infections
  - Meningitis
  - Encephalitis
  - Brain Abscess
  - AIDS
- Gullian Barre'
- Stoke
- Aneurysm
- Pulmonary Causes
  - TB
  - Pneumonia
  - Lung Abscess
  - COPD
  - Positive Pressure Ventilation
Ectopic SIADH

- Oat Cell CA
- Pancreatic CA
- Prostatic CA
- Leukemia

Nephrogenic SIADH

- General Anesthesia
- Narcotics (MS, Demerol)
- Barbiturates
- Thiazide Diuretics
- Tricyclic Antidepressants
- Tylenol
- Cytotoxic Agents
- Nicotine
- Anticonvulsants
SIADH Pathophysiology

- ↑ secretion of ADH or ADH like substance or increased renal responsiveness
- Failure of negative feedback system: ADH secretion continues despite low serum osmolality
- Renal reabsorption of water increases
- Water intoxication
- Hyponatremia and hypoosmolality

SIADH Presentation

Early
- Headache
- Weakness
- Anorexia
- Muscle Cramps
- Weight Gain
  - NO EDEMA
- Lethargy

Late
- Lower sodium levels
- Personality changes
- Hostility
- Sluggish Deep tendon reflexes
- Nausea and vomiting
- Diarrhea
- Oliguria
SIADH Presentation

- Impending Crisis
  - Confusion
  - Lethargy
  - Chene-Stokes respirations
  - Na level < 110 mEq/L
    - Cerebral Edema
      - Brain with higher osmolality draws fluid in
    - Seizures
    - Coma
    - Death

SIADH Diagnosis

- Serum
  - ↓ sodium* (<120mEq/L)
  - ↓ potassium
  - ↓ calcium
  - ↓ osmolality
    - <280 mOsm/kg (280-295)
  - ↓ BUN
    - <10mg/dl
  - ADH > 5pg/ml

- Urine
  - ↑ osmolality
    - > 1200 mOsm/kg
  - ↑ Specific Gravity
    - >1.030
    - Normal 1.005-1.030
  - ↑ Urine NA

Rule out adrenal, renal and thyroid disorders.
SIADH Diagnosis

- **Water load Test**
  - Give fluids 20 ml/kg
  - Measure urine output over 5-6 hours
  - Negative (No SIADH)
    - Excretion of 80% of fluid administered
  - Positive (Yes SIADH)
    - Excretion of <40% of fluid administered

SIADH Treatment

- **Treat Cause**
  - Surgery to remove malignant lesion
  - Stop drugs causing SIADH
    - May restart later
- **Correct Fluid Volume Excess**
  - Restrict Fluids (1,000 ml/d)
  - Diuresis
    - Lasix or mannitol
SIADH Treatment

- Correct electrolyte imbalance
  - Encourage dietary sodium
  - Fluid restriction
  - Hypertonic saline 3%
    - If sodium < 115 mEq/L
      - 250-500 ml at rate of 1-2ml/kg/h
    - If sodium > 125 mEq/L
      - Stop hypertonic saline

- CAUTIONS
  - Rapid infusion of 3% saline can cause cerebral osmotic demyelination syndrome
    - Pulls fluid from the cells
  - Caution with cardiac and renal patients
    - Shift in fluid from intracellular to extracellular

SIADH Treatment

- Medications
  - Declomycine (ADH antagonist)
    - Tetracycline derivative
    - Potentially nephrotoxic
  - Lithium (ADH antagonist)
  - Lasix – decrease circulating volume
Nursing Considerations for SIADH

- VS q15 until stable
- I and O hourly
- Fluid restriction – 1000ml/24 hours
- Daily Weights
- Neuro Assessment – seizure precautions
- Urine Specific Gravity Q1-2hours while NA is low
- Frequent mouth care to help with thirst
- Relieve pain and stress as both promote ADH release

Diabetic Disorders

- Diabetic Ketoacidosis (DKA)
- Hyperosmolar Hyperglycemic Nonketotic Syndrome (HHNK)
Diabetes Mellitus

- Diabetic disease characterized by hyperglycemia that results from deficits in insulin secretion, insulin action or both.
  
  - Type I
    - Beta cell destruction leading to absolute insulin deficiency
    - Usually Juvenile Diabetics
    - IDDM
  
  - Type II
    - Insulin resistance and a relative insulin deficiency
    - Normal amounts of insulin inadequate
    - Adult Onset
    - NIDDM

Hyperglycemic Crisis

- Diabetic Ketoacidosis (DKA)
  - Hyperglycemic crisis associated with metabolic acidosis and elevated serum ketones

- Hyperglycemic Hyperosmolar Non-Ketotic Condition (HHNK)
  - Hyperglycemic crisis associated with absence of ketone formation
Diabetic Ketoacidosis (DKA)

Causes
- Undiagnosed Type I diabetics
- Illness or infection
- Omission of insulin
- Trauma
- Surgery
- Noncompliance: Too many calories
- Cushing’s Syndrome
- Hyperthyroidism
- Pancreatitis
- Pregnancy
- Drugs: Prednisone, HCTZ, dilantin, sympathomimetics
DKA Pathophysiology

- Insufficient insulin or cells ability to use insulin
- Hyperglycemia
- Osmotic diuresis
- Glycosuria, dehydration, electrolyte imbalance
- Impaired glucose uptake by adipose tissues
- Impaired triglyceride synthesis and liberation of free fatty acids
- Ketoacidosis

DKA Presentation

- Altered Mental Status (confusion to coma)
- Blurred Vision
- Excessive urination
- Enuresis – unable to control urine
- Abdominal Pain
- Nausea / Vomiting
- Polydipsia – excessive thirst
- Kussmaul’s ventilation – deep rapid breathing, gasping, air hunger
- Acetone fruity breath
- Weight Loss
- Signs of dehydration
DKA Diagnosis

- **Serum**
  - ↑ Glucose 300-800 mg.dl (average 600mg/dl)
  - ABG’s
    - pH <7:30; HCO’s <18; PaCo2<35 (compensating)
  - ↑ Ketones
  - ↑ BUN/Creatinine Ratio > 10:1
  - ↑ Osmolality - Usually 295 – 330 mOsm/kg
  - ↑ Lipids
  - ↑ HCT
  - Anion Gap

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Anion Gap

- (Na+) minus (Cl- + HCO3-)
- Normal gap 12 +/- 4

- Gap > 30
  - DKA
  - Lactic Acidosis

  - Means H+ have been added to the positive side
DKA Diagnosis

- **Urine**
  - + for Ketones
  - + for glucose

- **EKG**
  - Changes associated with hypokalemia
  - Flat T waves - dehydration

DKA Treatment

- **Increase circulating volume**
  - **1st hour**
    - 10-30 ml/kg/h (1-2 L NS)
  - **After 1st hour**
    - 500-1000ml/h depending on volume status
    - .9NS if serum Na low OR if serum osmolality <320 mOsm/kg
    - >45NS if Serum Na normal or elevated OR if serum osmolality > 320mOsm/kg
    - Add dextrose after blood glucose levels <250 mg/dl
DKA Treatment

- Decrease Blood Glucose
  - IV Insulin
    - Bolus 10-20U (.15u/kg)
    - Drip 5-10U (0.1u/kg/h)
  - Serum glucose decrease no greater than 75-100 mg/dl/hr (200 mg/dl/hr)
    - Cerebral edema, hypokalemia, hypoglycemia
  - Drip discontinued 30 minutes –2 hours after SQ dose given
  - SQ started usually after BS < 250mg/dl, pH > 7.3 and HCO3 > 18 and no further ketone production OR acidosis resolves and anion gap 10-12

- Correct Electrolyte Imbalance
  - K+ level represents extracellular potassium
  - Only indirectly reflects intracellular potassium
  - Intracellular potassium may be much lower
  - Serum potassium < 4.5mEq/L -> add potassium to IV Fluids
  - Give in combination of KCL and KPO4
  - Insulin will return potassium to the cell

FLUSH IV TUBING!!!!!
DKA Treatment

- Correct Electrolyte Balance
  - Phosphorus Levels
    - Acidosis and osmotic diuresis cause a decrease in phosphorus -> decrease 2,3 DPG -> shift to the left
    - Phosphorus and Calcium function inversely
    - Replace phosphorus slowly and monitor Calcium
    - Too rapid replacement of Phosphorus -> rapid decrease in calcium - > tetany

DKA Treatment

- Prevent Complications
  - Hyperkalemia (initially)
  - Hypokalemia
  - Hypoglycemia
  - Cerebral Edema
  - Pulmonary Edema
  - Renal Failure

- Renal Disease
  - Dialysis
Nursing Considerations

- VS q 15 minutes until stable
- Hourly I and O
- Urine SG q 2 hours
- Labs initially Q1-2 hours
  - Glucose q1
  - Renal profiles q 2 hours
  - Labs for anion gap q2 hours
- Neuro checks

Hyperglycemic Hyperosmolar NonKetotic Syndrome (HHNS)
HHNS

Definition
- Hyperglycemic crisis associated with the absence of ketone formation; most common severe metabolic disturbance in type 2 diabetes mellitus

Causes
- Dehydration
- Pancreatitis
- Burns
- Infection
- Stroke
- Uremia
- Sepsis

Drugs
- Glucocorticoids
- Thiazide diuretics
- Loop diuretics
- Phenytoin
- Immunosuppressive drugs
- Beta Blockers
- Tagamet
- Calcium Channel Blockers
- Mannitol
- Sympathomimetics
HHNS Pathophysiology

Insulin deficiency

→

Hyperglycemia without ketosis

→

Osmotic diuresis

→

Serum hyperosmolality, cellular dehydration, decreased glomerular filtration rate

→

Thrombosis, renal failure and neurologic changes

HHNS Presentation

- Weakness, fatigue
- Dehydration: dry mouth, polydipsia, dry skin
- Hypotension
- Tachycardia
- Changes in LOC
- Respirations rapid and shallow
- No ketosis
- No breath odor
HHNS Diagnosis

**Serum**
- ↑ Glucose
  - 600-2,000mg/dl (average 1,100 mg/dl)
- Ketones: Normal or mildly elevated
- pH: Normal
- Osmolality > 330m Osm/L
- Sodium: Normal or elevated
- Potassium: Low
- Bicarbonate: Normal
- Phosphorus: Low
- ↑BUN / Creatinine: 10:1 ratio
- ↑HCT

HHNS Diagnosis

**Urine**
- Glucose +
- Ketones -

**EKG**
- Changes associated with K levels if K is abnormal
- Sinus Tachycardia
HHNS Treatment

Increase circulating volume
- 1st hour
  - 10-30 ml/kg/h NS
- After 1st hour
  - 500-1000 ml/hr depending on volume status
  - 0.9% saline
    - If serum Na low OR
    - If serum osmolality < 320 mOsm/L
  - 0.45% saline
    - If serum Na elevated OR
    - If serum osmolality > 320 mOsm/L
  - 5% Dextrose (D5.9NS, D51/2 NS)
    - Added when serum glucose reaches <250 mg/dl

HHNS Treatment

Decrease Blood Glucose
- IV Insulin
  - Bolus 10 - 20U (0.15-0.30 U/kg)
  - Drip 5-10 U/hr (0.1 U/kg/hr)
  - Serum Glucose should not decrease > than 75-100 mg/dl/hr
- SC Insulin
  - Started after glucose < 250 mg/dl
  - Insulin infusion stopped when SC initiated (overlap not necessary)
HHNS Treatment

- Correct Electrolyte Imbalance
  - Potassium
    - Monitor hourly – usually severely low
    - No intracellular to extracellular shift
    - Replace with KCL or KPhos
  - Phosphorus
    - Often low
    - 1/3 to ½ of K+ is replaces with KPO4
    - To prevent hypocalcemia do not exceed 1.5 mEq/kg increase in 24 hours
  - Magnesium
    - Often low
    - 1-2 g 10% solution if renal function OK

- Prevent Complications
  - Aspiration from paralytic ileus
  - Hyovolemic shock
  - Dysrhythmias
  - Embolism
  - MI
  - Pulmonary Edema
  - Cerebral Edema
  - Intracranial Hypertension
  - Hypoglycemia
  - Acute renal failure