EMERGENCY & TRAUMA SYMPOSIUM
CASPER, WY

DKA: Pathophysiology & Management

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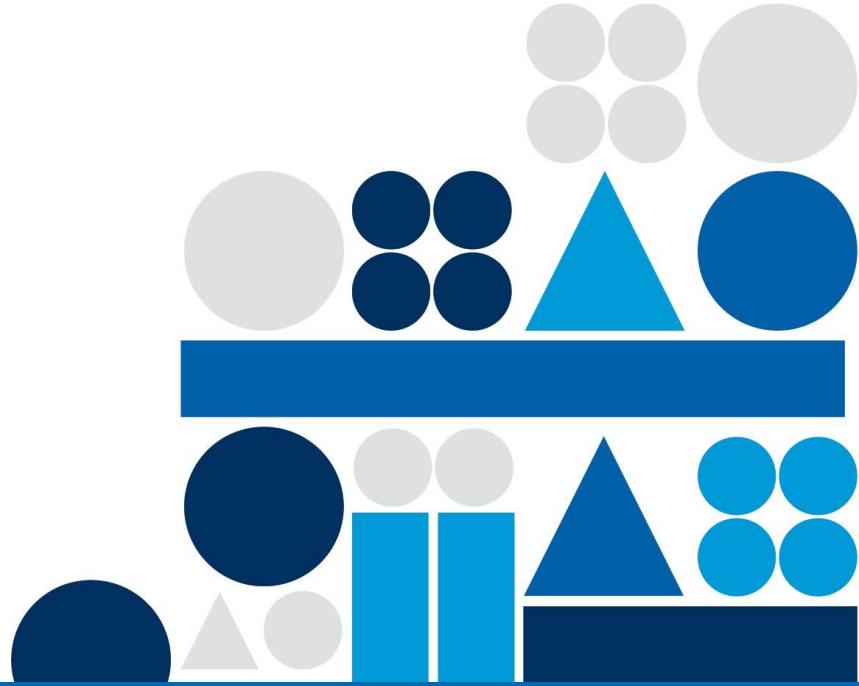
(Critical Care- PICU)



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Learning Objectives:

1. Define DKA
2. Pathophysiology
3. Complications
4. Management & Case Studies
5. Discussion/Questions

Diagnostic Criteria:

- BGL >200 mg/dL
- Acidosis: pH < 7.3
  (Severe < 7.15)
- Presence of Ketones:
  BHB > 3
  +Urine Ketones (mod/large)

Quick Facts:

- 30-40% of new-onset DM 1 cases
- #1 cause of morbidity & mortality
- Age <5 yo, low socioeconomic status, lack healthcare access
- Prevalence 6-8% annually (DM 1)

KETOGENESIS:

In the ***absence of insulin*** or other glucose stores (i.e. glycogen), body switches to burning FAT for energy

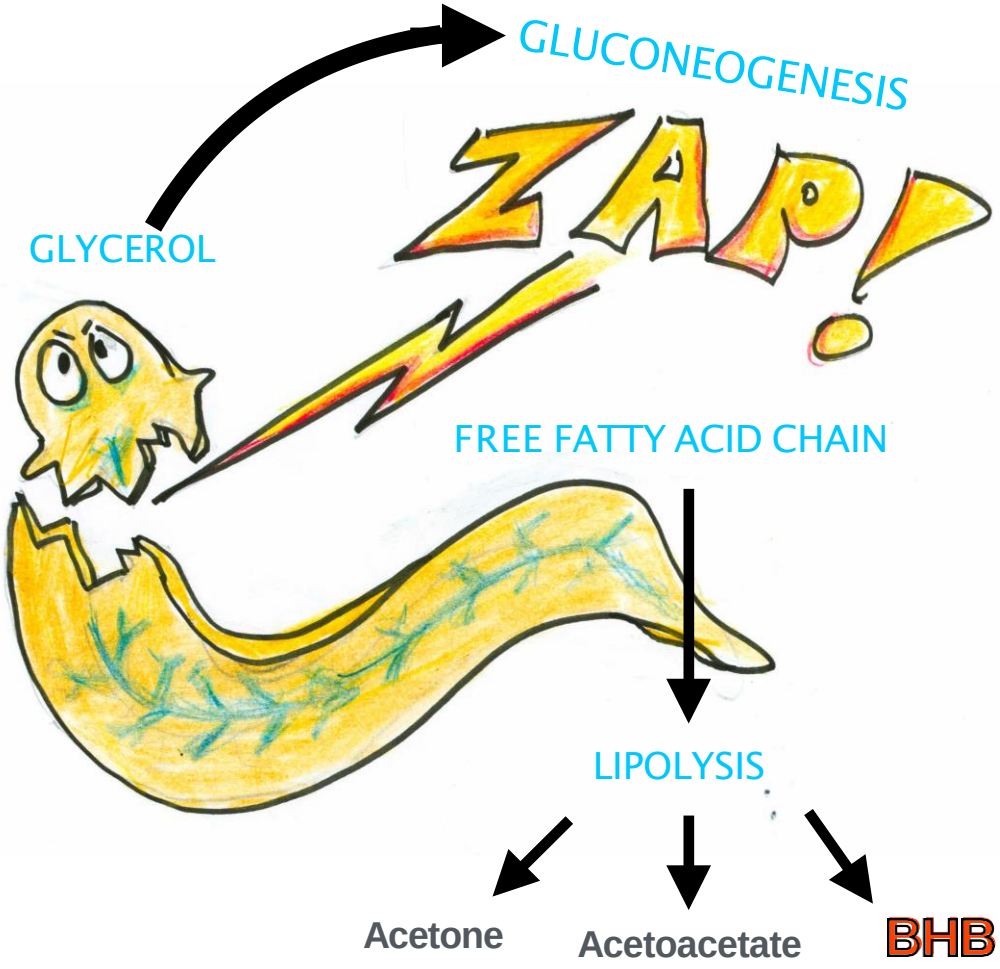
Head of FFA is GLYCEROL…Glucose Source

WHILE….

Ketone Bodies breakdown to Acetyl-CoA & enter the KREBS cycle => ATP

Result is increase in H^+ conc. which binds HCO_3 and subsequent metabolic acidosis

(Carbonic acid: H_2CO_3)



Common Triggers:

- New Onset Dx
- Acute Illnesses:
  - (Vomiting/Diarrhea)
  - Pancreatitis? (↑Lipase)
- Dehydration
- Missed/Improper dosing (↑A1c)
- PUMP FAILURE (△site)
- Non-compliance (adolescents)
- Stress (↑Catecholamines)

HPI/EXAM/LABS:

- 3 P's : Polyuria, Polyphagia, Polydipsia
- Recent Acute weight loss
- Lethargy, Vomiting, Abd. Pain
- Dehydration (5-10% fluid deficit) : ↑HR, ↓skin turgor, sunken eyes, pale, dry mm's
- Rapid/Deep Breathing: Kussmaul
- Fruity Acetone smell ("Juicy Fruit")
- VBG: Uncompensated or partially compensated metabolic acidosis: ↓pH/↓CO_2/↓HCO_3
- Elevated Anion Gap >16
- Presence of Ketones (BHB >3, Urine Ketones: mod.-large)
- BGL> 200 mg/dL (often 300-600mg/dL, consider HHS >500mg/dL)
- Electrolyte derangements: Hyperkalemia, Hyponatremia, Hypophosphatemia
- Evidence of AKI: ↑Cr (x2 baseline, or increase > 0.3 mg/dL in 48h period)

Pediatric Dehydration:

Clinical Sign	Mild Dehydration	Moderate Dehydration	Severe Dehydration
Weight loss (%)	3-5	6-9	≥10
Behavior	Normal	Normal to listless	Normal to lethargic or comatose
Thirst	Slight	Moderate	Intense
Mucous membranes	May be normal	Dry	Dry
Anterior fontanelle	Flat	Sunken	Sunken
Eyes	Normal	Sunken	Deeply sunken
Skin turgor	Normal	Decreased	Decreased
Blood pressure	Normal	Normal	Normal to decreased
Heart rate	Normal rate	Increased	Increased
Urine output	Decreased	Markedly decreased	Anuria

	Mild Dehydration	Moderate Dehydration	Severe Dehydration
Older child	3% (30 mL/kg)	6% (60 mL/kg)	9% (90 mL/kg)
Infant	5% (50 mL/kg)	10% (100 mL/kg)	15% (150 mL/kg)

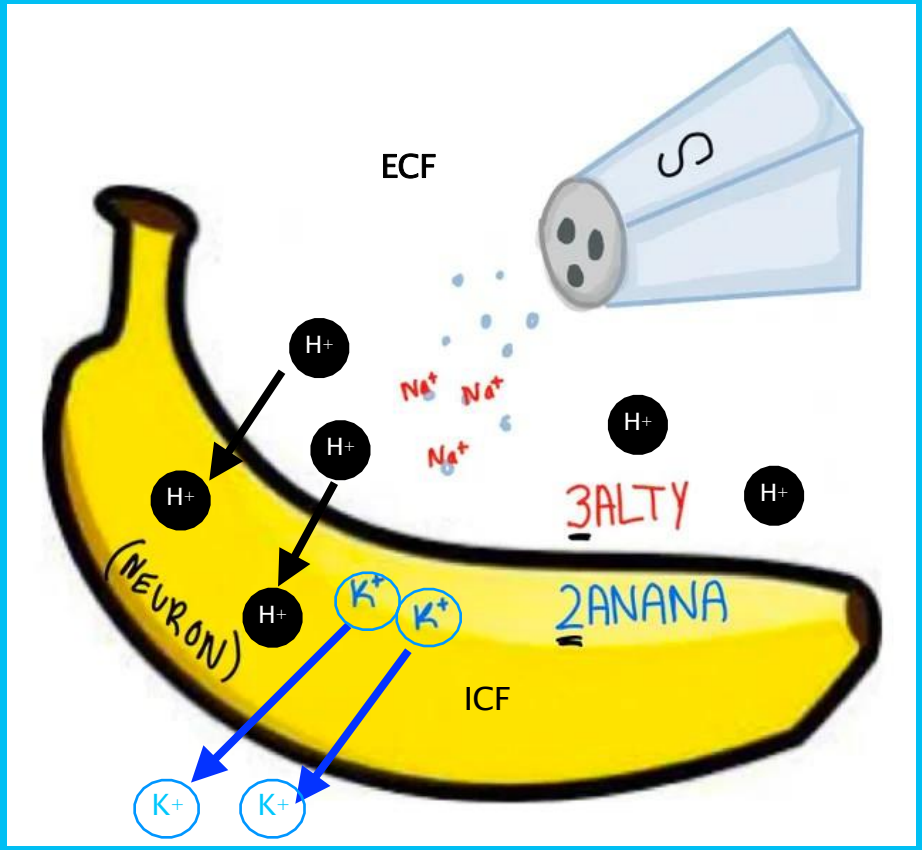
ELECTROLYTE DERANGEMENTS:

"HYPERKALEMIA"

- Transient Hyperkalemia 2/2 Acidosis & Lack of Insulin

  Intra-cellular Shift of H^+
  Extracellular Shift of K^+

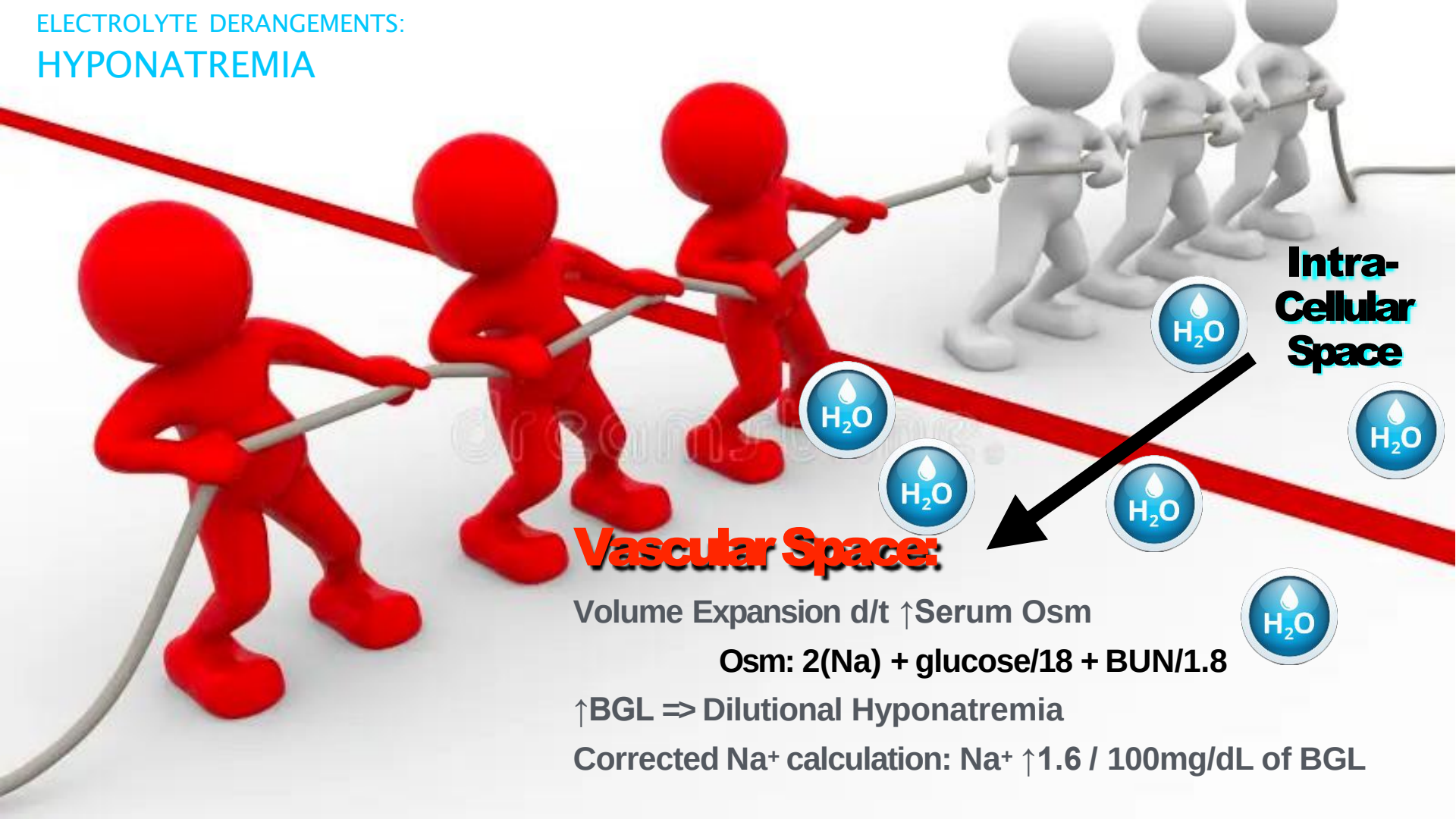
- Result: overall Total LOSS of K^+
  - Osmotic diuresis
- Insulin: intra-cellular shift PO_4, K^+
- Ventricular Arrhythmias ($\uparrow/\downarrow K^+$)



Diffusion maintains Electro-Chemical Gradient

ELECTROLYTE DERANGEMENTS:

HYPONATREMIA



Volume Expansion d/t ↑Serum Osm

Osm: 2(Na) + glucose/18 + BUN/1.8

↑BGL => Dilutional Hyponatremia

Corrected Na^+ calculation: Na^+ ↑1.6 / 100mg/dL of BGL

ELECTROLYTE DERANGEMENTS:

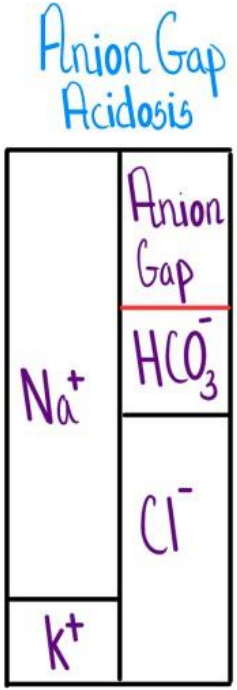
OSMOTIC DIURESIS

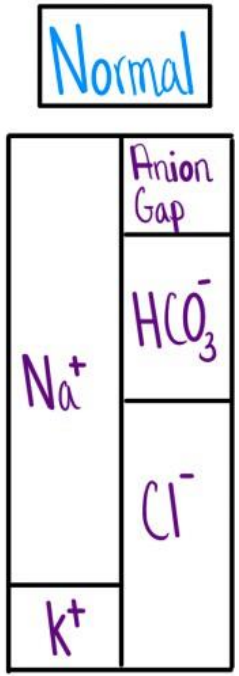
- **Hypokalemia**
- **Hypophosphatemia**
- **Hyponatremia**

  GI losses and/or Dilution

“MIND the GAP”:

- Calculates difference between unmeasured Cations (+) and Anions (-)
- Normal range: 8-12 (Neonates <16)
- MUDPILES (DDX)
- GI (diarrhea)/Renal losses (ATN) of HCO_3
- Acute increase in AG / ↓pH d/t dilution of HCO_3 (fluid expansion)
- DKA: ↑H^+ 2/2 ketone production
- MIND the GAP: AG closes as DKA resolves





$[NA^+] - [CL^- + HCO_3]$

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- ***SOLID HPI***
- **TOXIC INGESTIONS**
- **ROLE OF DIALYSIS?**
- **FOMEPIZOLE/ETHANOL GTT'S (COMPETITIVE INHIBITION OF ALCOHOL DEHYDROGENASE)**
- **HCO_3 ADMIN., ACIDOSIS <7**

Causes of High-Anion Gap metabolic Acidosis

Anion gap = Na - [Cl^- + HCO_3^-]

A CAT MUDPILE

Aspirin

Carbon monoxide, **C**yanide, **C**affeine

Acetaminophen

Theophylline

Methanol, **M**etformin

Uremia

Diabetic ketoacidosis (Alcoholic ketoacidosis)

Propylene glycol

Isoniazid, **I**buprofen, **I**ron

Lactic acidosis

Ethylene glycol

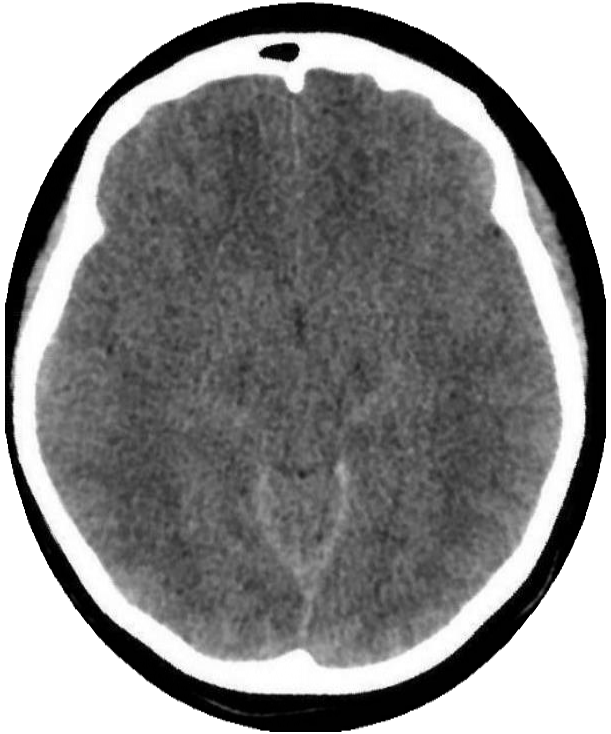
Give HCO_3 ???

If it works for other causes of Metabolic Acidosis Why not for DKA…

CEREBRAL EDEMA:

- < 1% DKA pt's (clinically evident) first 12h (up to 48h)
- Mortality 20-30%, ~10-35% irreversible injury
- Etiology: Hypoxic injury, Hyperosmolality & Fluid shifts, Inflammatory, Vasogenic edema… complex
- Risk Factors:

  Age < 5yo
  HCO_3 admin. (assoc. ↓O2 delivery -Rapid Lshift Oxyhgb, ↑CO2)
  Severe DKA/Dehydration/↓CO_2
  Bolusing Insulin (rapid ↓BGL >100mg/dL per hr)
  Hyponatremia (after corrected)
  Excessive Fluid Resuscitation



CEREBRAL EDEMA: DIAGNOSTIC CRITERIA

ONE DIAGNOSTIC CRITERION, TWO MAJOR OR ONE MAJOR AND TWO MINOR PRESENT: 92% SENSITIVE & 4% FALSE POSITIVE

DIAGNOSTIC CRITERION:

- Abnormal motor or verbal response to pain,
- Decorticate or decerebrate posture
- Cranial Nerve Palsy (esp. III, IV, and VI)
- Abnormal Neurogenic respiratory pattern (grunting, tachypnea, Cheyne-Stokes respirations, apneusis)

MAJOR CRITERIA:

- Altered mentation, confusion, fluctuating level of consciousness
- Sustained HR deceleration (decrease >20 beats per min.) not attributable to fluid resuscitation or sleep state
- Age-inappropriate incontinence

MINOR CRITERIA:

- Vomiting
- Headache
- Lethargy or not easily arousable
- Diastolic Blood Pressure >90mmHg
- Age <5yrs.

(Muir, et. al., 2004)

DKA Management:

- Volume Resuscitation 10-20mL/kg NS
- Insulin gtt (0.05-0.1 u/kg/hr)
- Ongoing fluid resuscitation x1.5 MIVF
- Repletion of K+ / Phos
- ↓BGL <100mg/dL per hour
- Strict NPO!!!
- C/f Cerebral Edema:
  - MIVF x1 (slow resuscitation)
  - Hyperosmotic therapy???
- MIND the GAP
- eventual Transition to subQ Insulin

“DI-FF-ER-EN-CE-S” in HHS (Hyperosmolar DKA):

- **Criteria: BGL >600mg/dL, Osm >320 mOsmol/kg**
- **Mild acidosis** (lesser degree of Ketosis ~**pH 7.2-7.3, BHB<3**):
  - **“DI”= delay/decrease insulin (.025-0.05), drop <50mg/dL per hour**
- **“FF”= Fluid replacement/management**
  - **Severe Dehydration:** 2x greater losses than DKA **(goal ~40mL/kg in first 6h)**
- **“ER”= ↑Electrolyte replacements:** more frequent replacement (K^+, PO_4, Mg)
- **“EN”= *Encephalopathy*** more prevalent (Osm >330, Na >160, hypovolemia)
- **“CE”=** decreased prevalence of **Cerebral Edema** (**rare**)
- **“S”= *Systemic: Multi-organ Involvement***: Rhabdo/AKI, Coagulopathy, Arrhythmia
- Rare in pediatric DKA, increased prevalence in teenage patients

(Zahran & Jaded, 2023)

CASE STUDY 1:

4yo F presents to ED with AMS/Lethargy, is responsive to painful stimuli, withdrawing to pain, but otherwise not opening eyes spontaneously. You note that patient has wet her pants, parents report that she is potty trained and does not normally have “accidents”.

She has been otherwise healthy prior to this illness per POC, but family note recent weight loss on her last well-child check despite normal appetite at home. POC report she has been more tired recently, had a dozen or so episodes of vomiting, % head pain prior to just sleeping the past 24h. Family thought she had a stomach bug and have been trying to give her Pedialyte but will not take much by mouth, and are concerned about her degree of dehydration.

VS: BP 110/32, HR 84, RR 60, T 36.5, O2: 91% on RA

Gen: Thin, but otherwise well developed female, lethargic, and awakens to painful stim but otherwise minimal interaction, dry mucus membranes, sunken eyes, decreased turgor, pt has “sweet” smell

CV: Cool extremities, 1+ pulses, 4-5 sec cap refill

Resp: Tachypnea, deep labored breathing, clear breath sounds

Abdomen: Soft, non-tender, no HSM, hypoactive BS

Neuro: GCS 8 (opens eyes & withdraws to pain, moaning incomprehensibly), pupils 4-5mm and sluggishly reactive, grossly non-focal, normal tone

LABS/DATA:

VBG: 6.9/20/<5/-25
Na 122 mmol/L
K 3.5 mmol/L
Cl 92 mmol/L
HCO3 <5 mmol/L
BUN 52 mg/dL
Cr 0.7 mg/dL
Gluc 550 mg/dL
LFT's: mildly elevated
WBC: 11>18/62< 350
Hgb A1C: 16
BHB: 13

PERTINENT+/-

Recent weight loss

Lethargy, AMS

Abd. pain/vomiting (non-specific)

Severe Dehydration: ↑HR, delayed CR, dry MM, sunken eyes

Age (4yo)

S/S of possible CE (↑ICP)

Risk Factors: Hyponatremia, Age (<5yo), Severe DKA (pH/dehydration)

CEREBRAL EDEMA?

DX CRITERIA: 2 MAJOR OR ONE MAJOR 2 MINOR

4yo **F presents to ED with** ***AMS, Lethargy,*** **is responsive to painful stimuli, withdrawing to pain, but otherwise not opening eyes spontaneously. You note that** ***patient has wet her pants,*** **parents report that she is potty trained and does not normally have "accidents".**

She has been otherwise healthy prior to this illness per POC, but family note recent weight loss on her last well-child check despite normal appetite at home. POC report she has been more tired recently, had a dozen or so episodes of ***vomiting, % head pain*** **prior to just sleeping the past 24h. Family thought she had a stomach bug and have been trying to give her Pedialyte but will not take much by mouth, and are concerned about her degree of dehydration.**

VS: ***BP 110/32***, ***HR 84***, **RR 60, T 36.5, O2: 91% on RA**

Gen: Thin, but otherwise well developed female, lethargic, and awakens to painful stim but otherwise minimal interaction, dry mucus membranes, sunken eyes, decreased turgor, pt has "sweet" smell

CV: Cool extremities, 1+ pulses, 4-5 sec cap refill

Resp: Tachypnea, deep labored breathing, clear breath sounds

Abdomen: Soft, non-tender, no HSM, hypoactive BS

Neuro: GCS 8 (opens eyes & withdraws to pain, ***moaning incomprehensibly***), **pupils 4-5mm and sluggishly reactive, grossly non-focal, normal tone**

VS

Mannitol 0.5-1mg/kg (filter needle/warmer)

Hypertonic (3%): 5mL/kg (admin. ~20min.)

Both suitable & admin. via PIV: *Vesicant!!!*

Central Line in DKA?

"GCS 8, Intubate" ???

CASE STUDY 2:

15yo M, previously healthy, who presents to ED with a 2-3 week hx of malaise, and poor PO intake, parents initially thought he had the flu but tested negative at PCP last week. Brought him into ED due to more pronounced lethargy today and upon arrival appears quite altered, withdraws to painful stimuli, opens eyes on painful stim and seems confused with speech that is at times non-sensical. Parents deny any significant N/V or abdominal pain, no fevers reported, but that he appears very dehydrated, and pale appearance.

Patient has no known recent sick contacts. Family deny any known ingestion of substance, but know that he "smokes pot" with his friends and has gotten in trouble at school recently. Family hx of DM on both sides, GFOC died of heart attack at age 55.

VS: BP 70/45, HR 170, RR 12, T 36.5, O2: 93% on RA

Gen: Well-nourished, well-developed male, lethargic, decreased LOC, dry mucus membranes, sunken eyes, ashen/ pale color

CV: Cool extremities, 1+ pulses, 5-6 sec cap refill

Resp: slow, deep breathing, easy WOB, clear breath sounds

Abdomen: Soft non-tender, non-distended, no HSM, hypoactive BS

Neuro: GCS 9-10, pupils 5mm and reactive, MAEE but decreased movement with AMS, does not follow commands

LABS/DATA:

VBG: 7.2/38/12/-8
Na 160 mmol/L
K 2.8 mmol/L
Cl 134 mmol/L
HCO3 13 mmol/L
BUN 60 mg/dL
Cr 1.9 mg/dL
Glucose undetectable (>500)
Serum Osm: 374
LFT's: mildy elevated
CBC: 19> 18/56 < 380
Hgb A1C: 12
BHB: 2.8
Lactate 8
Utox +THC., APAP/Salicylate neg.

PERTINENT +/-

Lethargy, AMS

Severe Dehydration, AKI

Hyperglycemia

Metabolic acidosis (mod. ketosis), ↑Lactate

Electrolyte derangements: Hypernatermia, Hypokalemia

Hypovolemic Shock

Family Hx of DM

Non-obese, teenage male (higher prevalence)

HHS or mixed HHS/DKA; *Initial Resuscitation*:

- **ABC's**: Airway, Breathing = lower risk intubation given mild acidemia
  C: FLUID!!! correct hypotension, at least 40mL/kg in first 6h

- **Delay/Decreased Insulin** (q1 BGL's, **Goal ↓BGL's <100/dL/hr,↑*Risk of CE***)
  Delay (fluid first!), start slow = 0.025-0.05u/kg/hr

- **Monitor Serum Osm's,** c/f Cerebral Edema be mindful with HTS/Mannitol
  Osm: 2(Na) + glucose/18 + BUN/1.8 (goal <330)

- **Frequent K/phos replacements** (monitor closely, esp. once on insulin gtt)

CASE STUDY 3:

11yo M with 3 day Hx of Abd. pain and Vomiting and generalized malaise. Has had decreased energy since onset of illness, feels warm and lethargic but A&O x3. MOC reports patient was in his normal state of health until this seemingly acute onset of symptoms.

Pt with Asthma and obesity. Fam Hx: DM2 on both sides of family. No significant exposures. Pt takes Albuterol inhaler prior to exercise and Flovent daily.

VS: BP 90/45, HR 140, RR 40's, T 39.2, O2: 92% on RA

Gen: Obese, but otherwise well developed male, lethargic but interactive, dry mucus membranes

CV: Warm extremities, 1-2+ pulses, brisk CR

Resp: Tachypnea, labored breathing, clear breath sounds

Abdomen: Soft but tender most notably over RLQ, cannot palpate Liver/Spleen, hypoactive BS

Neuro: Tired but appropriate, pupils PERRL brisk 3mm, MAEE, CN 2-12 grossly intact, Pain 7/10

LABS/DATA:

VBG: 7.1/30/8/-24
Na 140 mmol/L
K 6.5 mmol/L
Cl 110 mmol/L
HCO3 9 mmol/L
BUN 78 mg/dL
Cr 1.2 mg/dL
Gluc 366 mg/dL
LFT's: elevated
WBC: 32> 16/40 < 250
Hgb A1C: 9
BHB: 1.2
Lactate 6

PERTINENT +/-

(-) No report of 3 P's
Lethargy, AMS
(-) Abd. pain (RLQ)
Vomiting (non-specific)
Severe Dehydration: ↑HR/↓BP, delayed CR, dry MM
Family Hx of DM2
Fever (ID w/u?)
No Hx of Ingestion
S/S Septic Shock?

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