Diabetic Ketoacidosis In Children

JACQUELYN PETERS – PHARMD CANDIDATE 2016 – U OF W PHARMACY

Outline

- Definitions and Pathophysiology of DKA
- Clinical Presentation/Diagnosis
- Treatment Process
- Monitoring in Hospital
- Complication – Cerebral Edema
- Stepdown to SC Insulin

Objectives

- Understand the pathophysiology of DKA
- Recognize the signs and symptoms of DKA
- Recommend appropriate treatment of DKA in children
- Understand the reasoning behind monitoring in DKA and know what monitoring to recommend

CASE – D.K.

- 17 year-old female, wt: 80kg
- Good grades in high school
- Lives with father and twin sister
- Presenting with: vomiting x 8-10/day, Kussmaul respirations, acetone on breath & reported decreased LOC (but GCS on arrival = 15)
- PMH:
  - T1DM Dx at age 11 for which she has an insulin pump

Definitions:

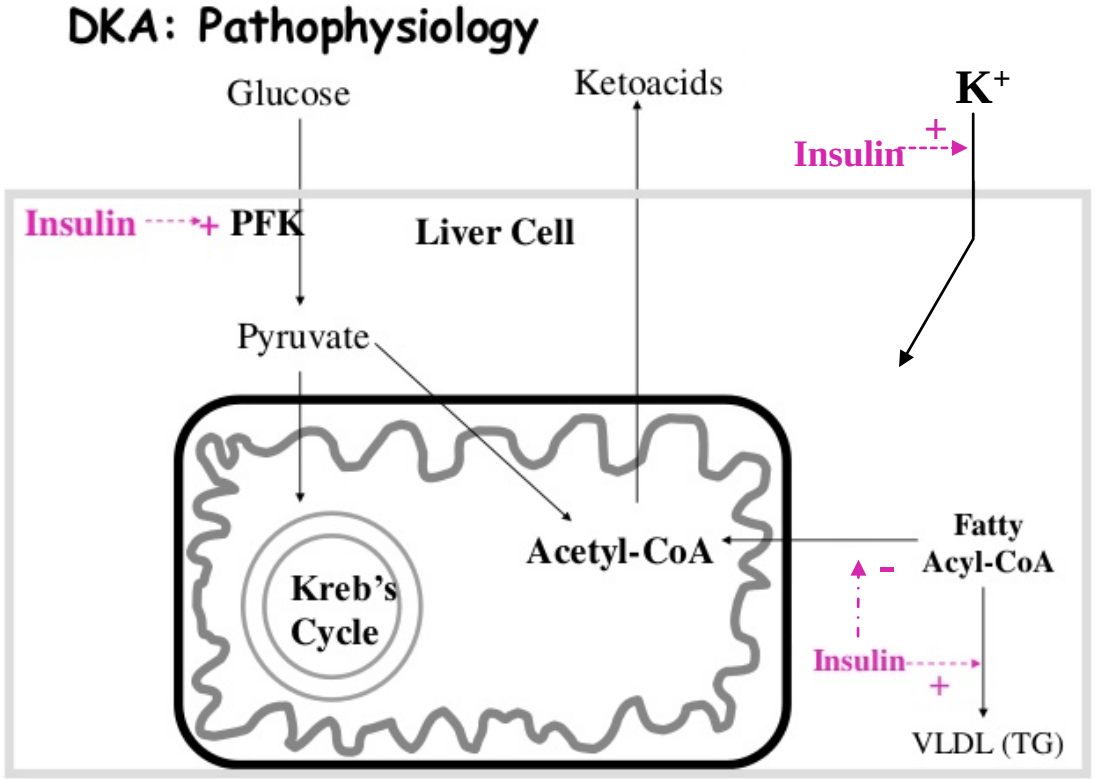
- **Acidemia:** a state of being where the blood is too acidic (pH < 7.35)
- **Acidosis:** a process occurring in the blood that decreases the pH (causing acidemia)
- **Metabolic Acidosis:** a process that decreases the concentration of HCO_3 in the blood, subsequently decreasing the pH
- **Ketoacidosis:** a form of metabolic acidosis that is the result of production of ketones
- **Anion Gap:** an artificial measure of the ion balance in the body, using the ions in the CHEM7, expressed using the following equation:

$$\boldsymbol{Anion\ Gap} = [Na] - ([Cl] + [HCO_3]) = 140 - (104 + 24) = 12\ (\pm 2)$$

  - Used to diagnose and monitor progression of DKA

Pathophysiology of DKA - Normal

- Insulin's actions on the cell:
  - **Promotes glucose entry into cell**
  - **Decreases fatty acid oxidation**
  - **Promotes K+ movement into cells**
  - Increased glycolysis & glycogen synthesis
  - Decreases lipolysis in adipocytes, stimulates fatty acid synthesis, increases uptake of TG's into tissues
  - Also promotes protein synthesis



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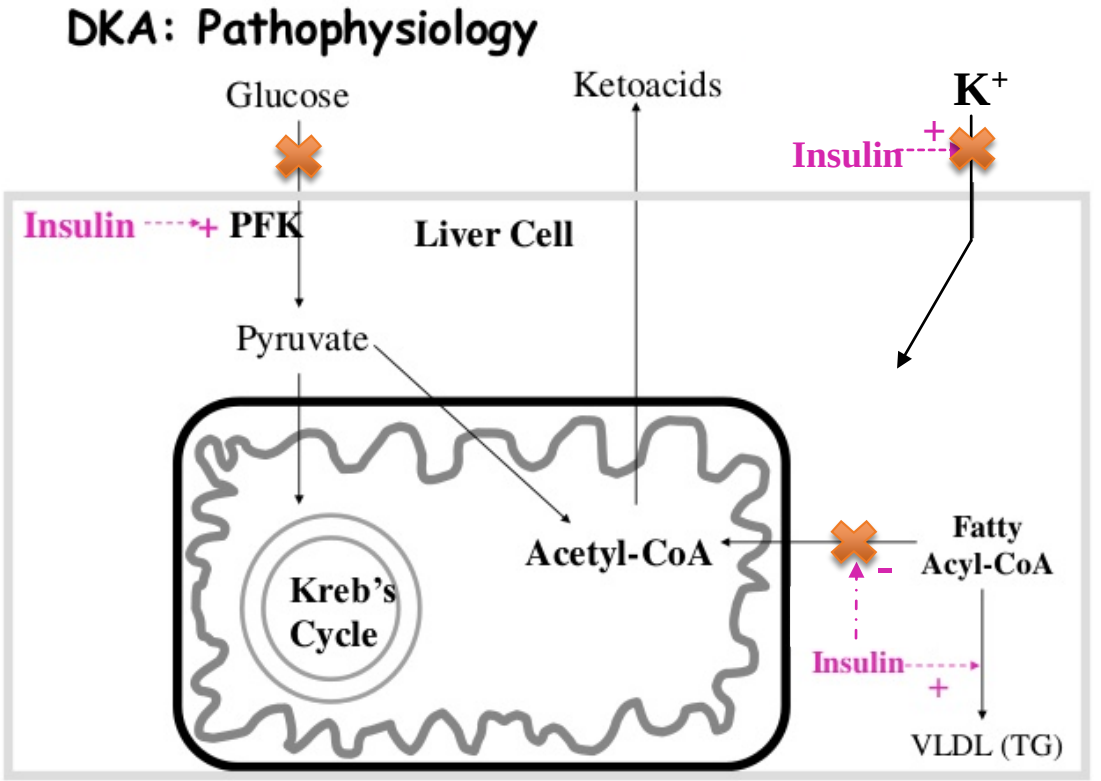
Pathophysiology of DKA

- In DKA, there's no insulin, resulting in the following:
  - **Increased blood glucose levels**
  - **Increased fatty acid oxidation**
    - Resulting in production of Ketone Bodies
    - Ketone Bodies release H^+, which binds to HCO_3 and causes a metabolic acidosis
  - **K^+ movement into blood**
    - K^+ from cells exchanged for H^+ in blood



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Presentation/Signs&Symptoms of DKA

- Older children/Adolescents:
  - GU: **Polyuria**, **polydipsia**, nocturia, daytime enuresis, vaginal candidiasis
  - CV: **Tachycardia**, hypovolemia, orthostatic hypotension, poor peripheral perfusion
  - GI: Polyphagia, anorexia, **N/V**, abdominal pain, weight loss
  - Resp: Acetone on breath, **Kussmaul Respirations** (the deep, rapid, sighing respirations that arise as an involuntary response to metabolic acidosis (https://www.youtube.com/watch?v=TG0vpKae3Js))
  - Neuro: **fatigue**, lethargy, reduction in alertness, diminished sensation of pain, cerebral edema, coma
- Infants: (harder to diagnose – not toilet trained or able to express thirst)
  - **Decreased energy/activity**, **irritability**, weight loss, physical signs of dehydration
  - **Severe** *Candida* **diaper rash**

Diagnosis of DKA

- Defined as:
  - Hyperglycemia: blood glucose **> 11 mmol/L**
  - Metabolic acidosis: venous **pH <7.3** or plasma **HCO_3 <15 mmol/L**

  AND
  - Ketosis: **presence of ketones** in the blood or urine
    - May also use beta-hydroxybutyrate concentration (> 3 mmol/L)

Classification of DKA

- Categorized based on severity of DKA:

Severity	Blood pH	Blood [HCO_3] (mmol/L)
Mild	7.2 – 7.3	10 – 15
Moderate	7.1 – 7.2	5 – 10
Severe	< 7.1	< 5

CASE – D.K. – Labs on Admission

Arterial Blood Gas:

ABG pH	6.91 (L)
ABG pCO_2	11 (L)
ABG HCO_3	2.2* (L)
ABG pO_2	126 (H)

CHEM 7:

Na^+	140
K^+	6.4 (H)
Cl^-	102
CO_2	< 5* (L)
SCr	117 (H)
Random Bl Gluc	38.6 (H)

* Essentially the same

CBC & Temp:

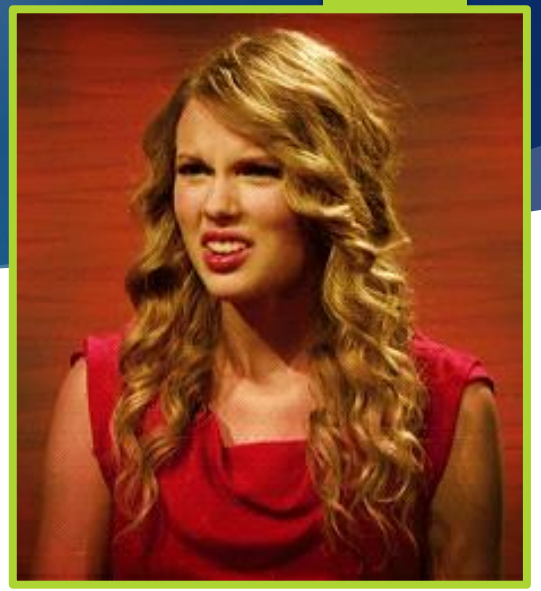
Temperature	37.0 C
WBC	56.6 (H)
RBC	5.22
Hgb	155
Plt	317
Neut #	45.56 (H)

- Tox screen positive for ketones in blood
- Urinalysis revealed protein, glucose and ketones. Negative for nitrates and leukocyte esterase

CASE – D.K. – Diagnosis

- Diagnosis: All three components of the diagnosis present
  - BG = 38.6 mmol/L
  - pH = 6.91 → **Severe DKA**
  - Both blood and urine positive for ketones
- Other signs & symptoms:
  - Kussmaul respirations
  - Vomiting
  - Acetone on breath
  - Altered LOC

CASE – D.K. – Anion Gap



- Calculate the Anion Gap for D.K.
  - AG = Na^+ - (Cl^- + HCO_3^-)
  - AG = 140 - (102 + 2.2)
  - AG = 35.8
- Less HCO_3^- = metabolic acidosis
  - Normal AG = 12, therefore there's an extra 23.8 negative charges causing the acidosis
  - These charges are from the ketone bodies (ketoacidosis)

Treatment Process - Overview

1. Fluid administration to correct dehydration
2. AFTER 1-2hr, may start Insulin administration to correct hyperglycemia
   - Monitor BG levels and may add extra Dextrose IV PRN
3. Always monitor Lytes:
   - Add K+ IV PRN (usually needed), and consider Na+ levels
4. Monitor Anion Gap to assess resolution of metabolic acidosis

Goals

- Correct the dehydration
- Gradually correct hyperosmolality and restore BG to normal
- Correct acidosis and reverse ketosis
- Monitor for complications of DKA and its treatment, (eg. cerebral edema)

AND

- Identify and treat any root causes

1. Fluids

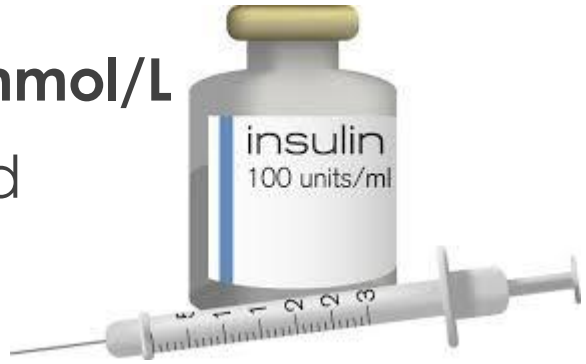
1. Estimate fluid loss: approximately 70 mL/kg (range 30-100 mL/kg)
2. Unless hypotensive, start fluid replacement slowly, with isotonic fluids*, at **1.5x** the usual maintenance rate (or 2500mL/m^2/day)
   - If hypotensive, give one bolus of 10mL/kg of isotonic fluids over 1hr
     - If necessary, may repeat once
   - *Usually 0.9% NaCl for the first 4-6 hrs (with K+ added – see future slide)
3. After first 48 hrs, may increase to **2.0-2.1x** usual maintenance rate (or 3500mL/m^2/day) to rehydrate fully
4. Do **NOT** give excess fluids within the first 24-36h, as this can lead to cerebral edema

2. Insulin

- Start Insulin at a rate of **<u>0.1 unit/kg/hr</u>**

  (0.05 units/kg/hr in younger kids with increased insulin sensitivity)

- Hyperglycemia will correct before the acidosis
  - Will likely need to **give IV D5W or D10W** using the two-bag system to offset the insulin
  - Titrate serum glucose to **maintain BG between 10-15 mmol/L**
  - Usually need D5W when BG reaches 17-14 mmol/L and need D10W if BG drops to < 8mmol/L



2. Insulin

- Do **NOT** start insulin until 1-2 hrs after initiation of fluid replacement, as this can increase risk of cerebral edema
- Do **NOT** give bolus insulin
- Insulin can bind to the tubing/syringe. **Flush the** insulin through the **tubing/syringe** prior to starting the drip to prevent this
- Ketoacidosis should resolve within the first 2-4 hrs
  - If it does not, reassess patient & flush a new line
  - May just need increased rate of infusion

3. Electrolytes - Potassium

- Estimate K^+ loss: approximately 6-7 mmol/kg
  - Will always have total body deficit of K^+ but, because the hyperglycemia pulls water out of the cells & K^+ follows, it may appear as high, normal or low serum K^+
- Check baseline K^+ levels and give KCl PRN as per the following:
  - Hyperkalemia – **hold K^+ replacement** until K^+ levels fall and urine production is confirmed
  - Normokalemia – **give K^+ when starting insulin** (usual starting dose = 40 mmol/L added to the isotonic fluids once insulin is started, not before)
  - Hypokalemia – **K^+ treatment should start immediately**, and **insulin treatment should be delayed** until K^+ is normalized
    - Max K^+ IV rate: 0.5 mmol/kg/hr – monitor hourly and adjust PRN

3. Electrolytes - Other

- **Sodium:** levels can vary widely in DKA patients
  - Estimate Na^+ loss (approximately 5-13 mmol/kg) & check baseline Na^+ levels
  - Fluids and insulin will cause water to move intracellularly, thereby increasing serum Na^+ concentration - monitor levels to ensure only gradual rise in Na^+
  - Failure to rise may indicate early signs of cerebral edema – consider increasing Na^+ concentration in fluids and decrease rate of administration
- **Phosphate:** replacement **NOT** necessary OR recommended
  - May induce hypocalcaemia and hypomagnesemia – and any deficit will be replaced once patient resumes eating
- **Bicarbonate:** do **NOT** use sodium bicarbonate to directly replace bicarb
  - Many side effects – including cerebral edema

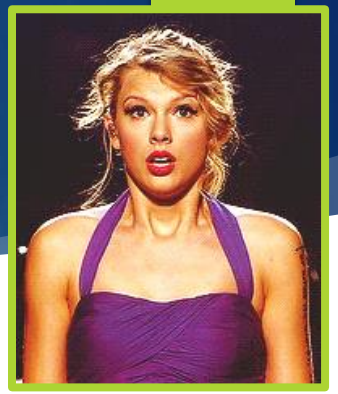
CASE – D.K. – Treatment

- HPI: dad mentioned that D.K. has changed her diet recently
  - Has been only eating meat and occasionally milk – so she didn't have to count carbs – over last few months
- MD Dx: Diabetic Ketoacidosis
- Treatment/Labs/Monitoring ordered:
  - Started Insulin drip at 0.1 units/kg/hr (8 units/hr based on wt= 80kg)
  - Fluids started
  - ABG, lytes, glucose Q2h; POC BG Q1h; BUN, SCr and CBC in AM
  - Cover for infection with Ceftriaxone 2 g IV Q24hr

4. Metabolic Acidosis (Monitoring)

- Ketoacidosis should resolve within the first 2-4h of administration of insulin
- **Anion Gap** (AG) should be monitored to indicate level of recovery
  - Insulin: prevents further production of KB's and promotes metabolism of current KB's
  - Rehydration: improves renal perfusion and promotes excretion of current KB's
  - Regeneration of HCO_3^- is usually delayed by high Cl- levels in the IV fluids, therefore may develop a hyperchloremic metabolic acidosis (allows time for kidney to make more HCO_3^-)

CASE – D.K. – Monitoring AG



Date/Time	AG ion concentrations*	Calculated AG
July 6		
2148h	132 – (102+2.4)	= 27.6
2353h	141 – (112+2.2)	= 26.8
July 7		
0208h	137 – (111+2.6)	= 23.4
0415h	137 – (115+3.4)	= 18.6
0635h	138 – (116+5.0)	= 17.0
0820h	140 – (118+6.8)	= 15.2
1031h	139 – (117+9.6)	= 12.4
1230h	139 – (116+10.8§)	= 12.2§

*Reminder: AG equation

$AG = Na^+ - (Cl^- + HCO_3^-)$

$= 140 – (104 + 24)$

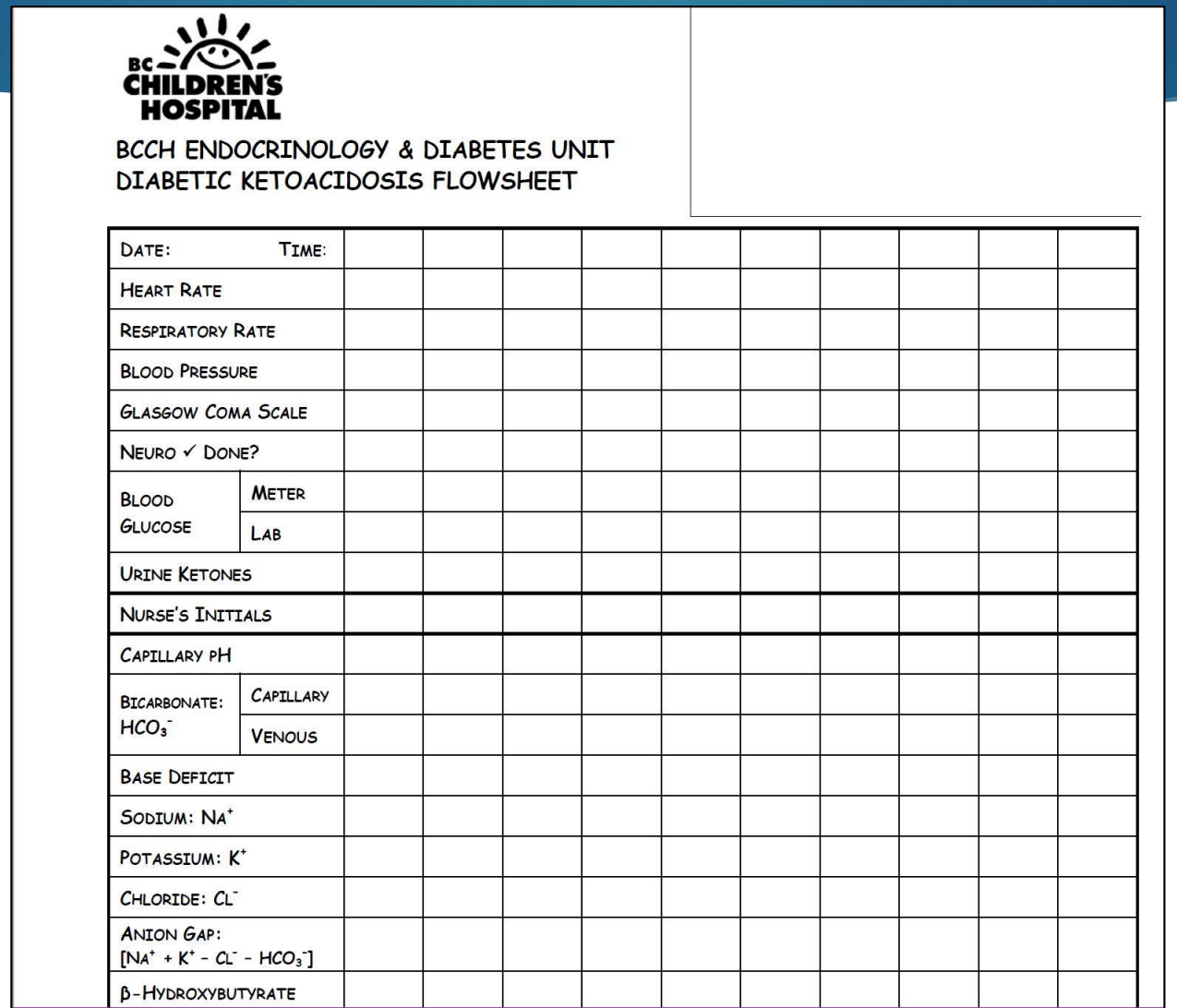
$= 12 (\pm 2)$ (normal)

§Notice the anion gap has resolved, but HCO_3 levels are still not normalized, hence the use of AG to monitor resolution of acidosis as opposed to bicarb levels

Monitoring in DKA

- Obtain baseline values of all the following values
- **Vitals** Hourly: HR, BP, RR, O_2 sat, and ECG (for hyper/hypokalemia)
- Bedside **BG levels** hourly for initial 4-6hrs, or until dextrose added to IV, then Q2h (and 1h after any changes to insulin dose)
- **Blood gas, lytes, urea, urine ketones, serum osmolality** Q1h for first 3-4hrs, then Q2h – once appropriate, may decrease frequency to Q4-6h
- **Neurovitals** and presence of **headache** (HA) hourly – to monitor for cerebral edema
- Accurate **Ins/Outs** Q1hr in ICU, and Q2-4hrs on peds
- Can recommend use of BCCH monitoring form (next slide)

BC Children's Hospital Monitoring Form



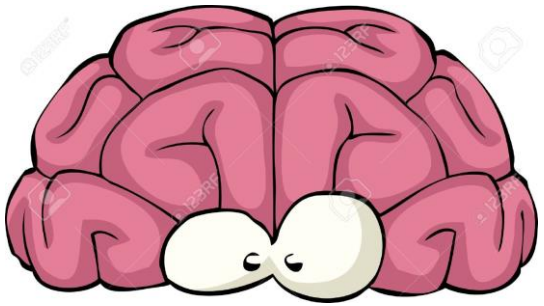
BC CHILDREN'S HOSPITAL

BCCH ENDOCRINOLOGY & DIABETES UNIT
DIABETIC KETOACIDOSIS FLOWSHEET

DATE: TIME:											
HEART RATE											
RESPIRATORY RATE											
BLOOD PRESSURE											
GLASGOW COMA SCALE											
NEURO ✓ DONE?											
BLOOD GLUCOSE	METER										
	LAB										
URINE KETONES											
NURSE'S INITIALS											
CAPILLARY pH											
BICARBONATE: HCO_3^-	CAPILLARY										
	VENOUS										
BASE DEFICIT											
SODIUM: Na^+											
POTASSIUM: K^+											
CHLORIDE: Cl^-											
ANION GAP: $[Na^+ + K^+ - Cl^- - HCO_3^-]$											
β-HYDROXYBUTYRATE											

Cerebral Edema

- Presentation:
  - HA, irritability, decreasing pulse, increasing BP, decreased LOC
- Treatment:
  - Raise head of the bed to 30°, decrease fluids to regular maintenance levels
  - Give one of the following:
    - Hypertonic saline (3%), at 5-10 ml/kg IV over 30 min
    - 0.25-1.0 g/kg mannitol IV over 20 min
- Arrange for head CT when stable



SubQ Stepdown of Insulin

- Insulin infusion should continue until patient meets the following conditions:
  1. Serum anion gap/beta-hydroxybutyrate normal on 2 successive occasions
  2. Venous pH > 7.3 OR serum HCO3 > 15mmol/L
  3. Blood glucose < 11.1 mmol/L
  4. Tolerating oral intake
  - If meet these criteria, can restart subcutaneous insulin
- First SubQ injection should be given based on the onset of action of the insulin: (most convenient when timed just prior to a meal)
  - Rapid-acting Insulin: wait 15 minutes after SC dose before d/c infusion
  - Short-acting Insulin: wait 30-60 min after SC dose before d/c infusion

CASE – D.K. - Discharge

- In ICU for 48h, then moved to Pediatrics
- Given 3% NS for cerebral protection
- No S/Sx of cerebral edema
- Converted back to basal insulin pump SC
- ABG: pH:7.46; pCO_2:26; pO_2:109; /HCO_3:18.5 (L)
- CHEM7: (Na^+)140/(K^+)4.0 | (Cl^-)111/(HCO_3^-)18.5 | (BUN)n/a/(SCr)45 < (Glu)4.8
  - Anion Gap: 140 – (111+18.5) = 10.5 (within normal range)

Consider Etiology

- Not covered in this presentation, but very important!
  - DKA is most often seen in young children and teenaged females (Why?)
    - Young children – often first presentation of T1DM
    - Teen girls – inadvertent/intentional omission of insulin dose, OR eating disorders, OR unstable family circumstances (all increase risk of DKA)
- Therefore always consider psychological impact of T1DM on lifestyle of patient and educate about the importance of insulin whenever possible

Helpful Sites

- MedCRAM Acid/base explained clearly: https://www.youtube.com/watch?v=4wMEMhvrQxE&list=PLBD832B100067ECFF
- MedCRAM DKA explained clearly: https://www.youtube.com/watch?v=yIc2XFNLhm8
- BC Children's Hospital DKA protocols: http://www.bcchildrens.ca/health-professionals/clinical-resources/endocrinology-diabetes/dka-protocol
- All guidelines were fairly comprehensive, but an AAFP article by D Westerberg had very helpful flowcharts for treatment in both adults and children: http://www.aafp.org/afp/2013/0301/p337.pdf

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Thank You!

Any Questions?