Pediatric Diabetic Ketoacidosis

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Causes

- Failure to take insulin
- Acute stress, trauma, or illness (often febrile) which elevates the counterregulatory hormones GH, glucagon, epinephrine and cortisol.
- Poor sick day management when the child is not eating/vomiting, is febrile etc.
- New onset of disease
Differential Diagnosis

- Sepsis
- methanol ingestion
- alcoholic ketoacidosis
- ASA poisoning
- uremia
- Anion gap metabolic acidosis “MUD PILES”
Definition

- Hyperglycemia >15mmol/L
- Hyperketonemia > 3mmol/L or large ketonuria
- Acidosis pH<7.3 and/or HCO$_3$ <15mmol/L
Insulin vs. Glucagon

Homeostatic System (Insulin and Glucagon)
Clinical Presentation

- Hyperglycemia - insulin deficiency results in starvation state, protein and fat breakdown provide the building blocks for gluconeogenesis, and liver glycogenolysis also attempts to raise blood sugar.
- Thirst/Dehydration - hyperglycemic osmotic diuresis.
- Vomiting/acidosis - ketone body production triggers nausea and vomiting.
Clinical Presentation

- Kussmaul breathing - deep rapid respiration in an attempt to resolve ketosis and lactic acidosis
- Hyperosmolality - Na (mmol/L) X2 + glucose (mg/dL)/18 + BUN/2.8 (mg/L) when >320mosm/L is associated with coma and risk of cerebral edema/herniation
- Pseudohyponatremia - due to osmolar dilution by glucose. Corrected Na - for every 100mg/dL of glucose above normal (100mg/dL) add 1.6 to the measured serum sodium.
- Relative normokalemia - K is shifted outward from tissues due to acidosis but actually is deficient from ongoing polyuria and will lower as K shifts inward with acidosis correction.
Other Lab findings

- Elevated WBC with L shift probably represents stress.
- BUN may be elevated due to dehydration.
- Cr may be elevated falsely due to ketonemia interfering with lab assay.
- Serum amylase without lipase elevation may reflect salivary irritation.
Treatment Guidelines from the duPont Hospital for Children

- Initial evaluation should include…
- Vital signs and level of consciousness or Glasgow coma scale.
- Blood sample for glucose, pH, lytes, BUN, Cr, Ca, Mg, Phosphorus, amylase, lipase some of which can be performed by I-stat at the bedside.
- First urine void for ketones, glucose, and UA.
New onset Labs

- Serum insulin prior to any insulin therapy!
- Hgb A1c
- TPO and antithyroglobulin antibodies (20% of type 1 DM have autoimmune thyroid disease), total T3 &4, TSH
- Autoimmune polyglandular syndrome Ab’s including ICA512, anti-GAD-65, insulin, TTG, adrenal antibodies.
Initial Monitoring

- Q1 VS, bedside serum glucose, and level of consciousness.
- Q2 laboratory serum glucose, electrolytes including Ca and Phosphorous whenever K is being supplemented in the form of Kphos.
- The above can be transitioned to Q4 as the patient improves.
Initial Therapy

- Any patient in DKA (pH<7.34, HCO3<15) is assumed 5%-10)% dehydrated.
- Initial fluid should be 10cc/kg NSS over 15minutes to be repeated as needed. Expect the blood glucose to fall >100mg/dL/hr in the first hour.
- If in shock and hemodynamically unstable bolus as needed for support of CVS.
Initial Insulin

- IV loading dose of insulin is NOT proven to be useful and is NOT needed.
- Instead use 0.05-0.1 Units/kg/hour IV continuous infusion of REGULAR insulin.
- 1:1 dilution of 50U/50cc of NSS is used and can be piggy backed into the fluids not added to the fluid bottle or filtered in any way.
Initial 24 hour Therapy

- Example of a 30kg child who is 10% dehydrated, received 2 20cc/kg boluses in the ED and is on an insulin drip of 0.1U/kg/hr.
- Calculate the preillness weight as….
  - (present weight X 100)/(100 - %dehydrated)
  - (30 X 100)/(100-10) = 33kg  
    33kg-30kg = 3kg lost
  - 3kg = 3L of fluid deficit = 3000ml
Initial 24 hour Therapy

- **Maintenance fluids** = 1700ml (100, 50, 20cc/kg) = 70cc/hr
- Maintenance + deficit = 3000 + 1700 = 4700ml per day required.
- Subtract the boluses 4700 - 1200cc (20cc/kg X 2 in ED) = 3500cc
- Subtract the insulin drip 3U/hr = 3cc/hr (remember 50U insulin in 50cc NSS) over 24 hours = 72cc
- 3500 - 72 = 3428cc required.
- Over a 24 hour period the rate will be roughly 140cc/hr or 2X maintenance.
Sodium considerations

- If Eunatremic 135 to 149 use NSS in a two bag system and replace fluid over 24 hours.
- If Hypernatemetic >150 use 1/2 NSS and replace fluid over 36 hours.
- If Hyponatremic <135 use NSS in a two bag system and replace fluid over 36 hours.
- D5 should be added when the serum glucose falls below 300mg/dL.
**Two bag system**

**Bag A**
- D0
- 0.9NSS
- 20KCl
- 20KPhos

**Bag B**
- D10
- 0.9NSS
- 20KCl
- 20KPhos

<table>
<thead>
<tr>
<th>Glucose</th>
<th>BagA</th>
<th>BagB</th>
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<tbody>
<tr>
<td>D0</td>
<td>140cc/hr</td>
<td>0cc/hr</td>
</tr>
<tr>
<td>D5</td>
<td>70cc/hr</td>
<td>70cc/hr</td>
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<tr>
<td>D7.5</td>
<td>35cc/hr</td>
<td>105cc/hr</td>
</tr>
<tr>
<td>D10</td>
<td>0cc/hr</td>
<td>140cc/hr</td>
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Potassium and bicarbonate considerations

- After urine flow is established and there is no evidence of hyperkalemia 40 meq of potassium should be added to the fluids, 20 meq/L of KCl and 20 meq/L of Kphos.

- Bicarbonate use is not recommended due to its association with an increased risk of cerebral edema.

- An alternative may be THAM (tris-hydroxymethyl-aminomethane) which has been shown to reduce brain tissue acidosis in animals and increase brain lactate export.
**Insulin manipulation**

- Alter insulin infusion rate by 0.025U/kg increments from the baseline 0.1U/kg/hr rate.
- Adjust insulin infusion and dextrose to target a 100mg/dL/hr decline in glucose.
- When serum bicarbonate is >18 and the child demonstrates the desire and ability to orally feed a transition to SQ can occur. It is best to target pre-breakfast or dinner. Continue the infusions (insulin and ivf) until 10 minutes after the SQ shot.
**SQ Insulin**

- New onset
- Lantus - 0.4U/kg (0.2U/kg for toddlers) SQ qHS for older children and in the AM for toddlers. Do not give >1x/day and do not mix with other insulins
- Humalog - 30carbs/1U for older kids, 60carbs/1U for toddlers.
- Correction factor for glucose above 120 = (current BS - target BS)/50. 50 is the # of mg/dL you would expect 1 U of insulin to lower the BS. Divide by 100 or 200 for toddlers who are more sensitive to one unit of insulin.
- Check glucose AC, HS and 1am, if <80mg/dL treat with 4oz of juice and then a substantial snack.
Complications of therapy

- Hypoglycemia - <40 or <60 with symptoms, treat orally if possible or iv 25% 0.5g/kg if NPO. Keep in mind glucagon (0.1-0.3mg/kg) is also an option.
- Hyperkalemia - K > 6mmol/L, treatments include Ca protection of the myocardium, albuterol, kayexalte, but insulin therapy usually is effective.
- Persistent acidemia - if non anion gap usually related to Cl infusion as NaCl, no therapy required.
Complications of therapy

- Mucor - rare but almost universally fatal infection by mucormycosis arising from the respiratory tract or sinuses. Surgical management required.
- Rhabdomyolysis - usually related to hypokalemia and hyperosmolarity. Is rare and treated with alkaninization and diuresis.
- Cerebral edema - more common in children with DKA than adults. Most common in young children with new onset and adolescent females.
SIGNS AND SYMPTOMS OF INTRACEREBRAL CRISIS DURING TREATMENT OF DKA

- Decreasing sensorium
- Sudden and severe headache
- Incontinence
- Vomiting
- Combativeness; disorientation; agitation
- Change in vital signs (hypothermia, hypotension or hypertension, tachycardia or bradycardia or arrhythmia, gasping respirations, or periods of apnea)
- Ophthalmoplegia
- Pupillary changes (asymmetry, sluggish to fixed)
- Papilledema
- Posturing; seizure
Cerebral edema

- Usually occurs between 4-24 hours into therapy.
- Mortality is 50-90%
- Incidence 0.1-1%
- One study lists >4L/m²/d fluid therapy carries increased risk.
- Neurologic monitoring should occur q30minutes in early stages of therapy then hourly.
- Urgent CT should be done when patient is stabilized and CT finding should NOT overrule clinical signs of edema.
Cerebral edema therapies

- Mannitol 1gm/kg infused over 20 minutes. Bottle must be $>37^0C$ to be in solution.
- Intubation and hyperventilation to a PCO2 goal in the mid 30’s.
- Seizure control
- Fluid restriction