Maryland ACEP Chapter Educational Conference & Annual Meeting  
March 12, 2020

FACULTY: Mimi Le Lu, MD, FACEP

PRESENTATION
Pediatric DKA: Not Just Little People with Hyperglycemia

DESCRIPTION
The management of diabetic ketoacids (DKA) is one condition that is often managed differently between pediatric and adult patients. The speaker will emphasize pearls and potential pitfalls to avoid peril in the pediatric patient in DKA.

The speaker will discuss differences in management strategies between adult and pediatric patients with DKA and how these differences may affect. She will present the most recent literature and guidelines that address common myths and pitfalls for DKA.

OBJECTIVES
• The similarities and differences between pediatric and adult patients with DKA.
  
• Identify potential management errors that can lead to awareness in pediatric patients.

DISCLOSURE
No significant financial relationships to disclose.
Pediatric DKA: Not just little adults with hyperglycemia ... or ARE they???

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Clinical Assistant Professor
Department of Emergency Medicine
Director, Pediatric EM Education
University of Maryland
No disclosures
Outline

• Compare/ contrast adult and pediatric patients
• Pitfalls in management for the pediatric patient
• Management strategies for insulin pumps
Case #1

45 yo diabetic ♂ with abdominal pain
> nausea, no vomiting, no diarrhea, no fevers

PMHx: Diabetes
Meds: Novolog, Lantus

PEx:
T 37.5, P 118, RR 24, BP 139/81, 100% RA
pale, +tender LUQ and LLQ
**Case #1**

45 yo diabetic ♂ with abdominal pain

- Blood Pressure: 127/93/13
- Pulse: 574
- Temperature: 5
- White Blood Cells: 6
- Hemoglobin: 1.2
- AG: 28

- Lipase: 335 (23-300)
- UA: 3+ ketones
- VBG: 7.098 28/ -21
Case #1

45 yo diabetic ♂ with abdominal pain
- hyperglycemia, ketosis, acidosis

Dx: DKA

Rx: IVF

Pearl

Insulin (bolus?)

Kitabchi, ADA Consensus Statement, *Diabetes Care*, 2009
Goyal, *JEM*, 2010
Case #1

10 yo diabetic ♂ with abdominal pain
> nausea, no vomiting, no diarrhea, no fevers

PMHx: Diabetes
Meds: Novolog, Lantus

PEx:
T 37.5, P 128, RR 35, BP 109/71, 100% RA
pale, +tender LUQ and LLQ
Case #1

10 yo diabetic ♂ with abdominal pain
  > hyperglycemia, ketosis, acidosis

Dx: DKA

Rx: IVF
    Pitfall
    Cerebral edema
    Insulin (bolus?)

Edge, *Diabetologia*, 2006
Diabetic Ketoacidosis (DKA)

- Complex metabolic triad:
  1. Hyperglycemia
     - Glucose > 200 mg/dL (11 mmol/L)
  2. Ketonemia and/or ketonuria
  3. Acidosis
     - Venous pH < 7.3
     - Bicarbonate < 15 mmol/L
Categories

**Adults**

- **Mild:**
  - pH 7.25-7.3
  - Bicarbonate 15-18 mmol/L
- **Moderate**
  - pH 7.0-7.25
  - Bicarbonate 10-15 mmol/L
- **Severe**
  - pH < 7.0
  - Bicarbonate < 10 mmol/L

**Children**

- **Mild:**
  - pH 7.2-7.3
  - Bicarbonate 10-15 mmol/L
- **Moderate**
  - pH 7.1-7.2
  - Bicarbonate 5-10 mmol/L
- **Severe**
  - pH < 7.1
  - Bicarbonate < 5 mmol/L

Kitabchi, *Diabetes Care*, 2009  
Wolfsdorf, *Pediatric Diabetes*, 2014
Hyperosmolar Hyperglycemia State

- Plasma glucose > 600 mg/dL
- Little to no ketoacid accumulation
- Serum osmolality > 320 mOsm/kg
  - $2[\text{measured Na (mEq/L)}] + \text{glucose (mg/dL)/18} + \text{BUN/2.8}$
- Rare in children
Little adults?

- Delay in diagnosis
  - Harder to elicit history
    - polydipsia, polyuria, weight loss
  - “Respiratory problem”
- Precision in fluid regulation
  - Higher basal metabolic rate
  - Larger surface area
- Immature auto-regulatory systems
Initial evaluation

- ABC’s and vital signs (including FS and weight in kg)
- Mental status
- Precipitating cause(s)
  - Infection
  - Non-compliance
  - New-onset
  - Stressors: pregnancy, MI, stroke
Laboratory evaluation

- Capillary glucose
- Serum glucose
- Serum electrolytes
- Complete blood count
- Serum osmolality
- Serum ketone/ beta-hydroxybutyrate
- Urinalysis
- Electrocardiogram
- “Digi-tube”

Et\text{CO}_2

## Similarities: DKA

<table>
<thead>
<tr>
<th>Adults</th>
<th>Pediatrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fluid resuscitation</td>
<td>• Fluid resuscitation</td>
</tr>
<tr>
<td>• Correct electrolytes</td>
<td>• Correct electrolytes</td>
</tr>
<tr>
<td>• Insulin therapy</td>
<td>• Insulin therapy</td>
</tr>
<tr>
<td>• Find the source</td>
<td>• Find the source</td>
</tr>
<tr>
<td>• No bicarbonate!</td>
<td>• No bicarbonate!</td>
</tr>
</tbody>
</table>
### Differences: DKA

#### Adults
- Liberal use of IVF
- Insulin bolus vs infusion
  - 0.1 vs 0.14 units/kg/hr

#### Differences
- (More) conservative IVF
  - 20 ml/kg over 1 hr
- No insulin bolus
  - 0.05-0.1 units/kg/hr
- Two bag system
- Cerebral edema
Cerebral edema

- Leading cause of morbidity and mortality in DKA
  - 0.3 – 1.5% all cases
  - 20% mortality
  - 20% neurologic impairment
- Unclear mechanism
- Low threshold for treatment
- Almost exclusively in peds
Cerebral edema
Measurement of corneal thickness, optic nerve sheath diameter and retinal nerve fiber layer as potential new non-invasive methods in assessing a risk of cerebral edema in type 1 diabetes in children

Krzysztof Jeziorny¹ · Anna Niwald² · Agnieszka Moll² · Katarzyna Piasecka² · Aleksandra Pyziak-Skupien¹ · Arleta Waszczykowska³ · Dobromila Baranska⁴ · Beata Malachowska⁵ · Agnieszka Szadkowska¹ · Wojciech Mlynarski¹ · Agnieszka Zmyslowska¹

Fig. 1 An ultrasonographic image of optic nerve sheath diameter (ONSD) measurement (marked by a dotted arrow)

Jeziorny K, Acta Diabetol, 2018
Kendir OT, J Pediatr Endocrinol Metab, 2019
Cerebral edema risk factors

- Young children
- New onset and newly diagnosed
- Increased BUN
- Severity of acidosis
- Bicarbonate therapy use
- Failure of sodium to rise after therapy

Glaser, NEJM, 2001
Cerebral edema

“There is no convincing evidence of an association between the rate of fluid or sodium administration used in the treatment of DKA and the development of cerebral edema”

Wolfsdorf J, Pediatric Diabetes, 2009
# Pediatric DKA Management

<table>
<thead>
<tr>
<th>Mild</th>
<th>Moderate/ Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Talk to endocrinologist</td>
<td>• Fluids</td>
</tr>
<tr>
<td>• Subcutaneous insulin</td>
<td>• Electrolytes</td>
</tr>
<tr>
<td>• Oral hydration</td>
<td>• Insulin</td>
</tr>
<tr>
<td></td>
<td>• Source</td>
</tr>
</tbody>
</table>
Fluids
Treatment: fluids

- Dehydration on order of 5-10% (“moderate”)
- Correct intravascular volume deficits
- Lowers glucose and plasma osmolality
- Restore renal perfusion
- Better response to insulin therapy
Treatment: fluids

- Initial fluid choice:
  - 20 ml/kg over 1-2 hours
  - Max: 40-50 mL/kg over 4 hours

Peds DKA rarely presents in hypovolemic shock…. find another source!
Treatment: fluids

- Replace deficit over next 48 hours
  - Approximately \(2\times\) maintenance
    - 4 ml/kg/hr for first 10 kg
    - 2 ml/kg/hr for next 10 kg
    - 1 ml/kg/hr for remaining kg

- Example:
  - 35 kg patient = 75 ml/hr
  - Approx 150 ml/hr
Randomized controlled trial
0.9% vs 0.45% NaCl, rapid vs slow
GCS <14: 48/1389 (3.5%)
Clinically apparent brain injury: 12/1389 (0.9%)

Conclusion:
Neither the rate of administration nor the sodium chloride content of intravenous fluids significantly influenced neurologic outcomes in children with diabetic ketoacidosis.
Now what???

ISPAD Clinical Practice Consensus Guidelines 2018: Diabetic ketoacidosis and the hyperglycemic hyperosmolar state

Joseph I. Wolfsdorf\textsuperscript{1} | Nicole Glaser\textsuperscript{2} | Michael Agus\textsuperscript{1,3} | Maria Fritsch\textsuperscript{4} | Ragnar Hanas\textsuperscript{5} | Arleta Rewers\textsuperscript{6} | Mark A. Sperling\textsuperscript{7} | Ethel Codner\textsuperscript{8}

Fluid treatment for children with diabetic ketoacidosis: How do the results of the pediatric emergency care applied research network Fluid Therapies Under Investigation in Diabetic Ketoacidosis (FLUID) Trial change our perspective?

Nicole Glaser\textsuperscript{1} | Nathan Kuppermann\textsuperscript{1,2}
Type of fluid?

- Retrospective study
- NS vs LR
- Outcomes: cost, LOS, rates of CE

Conclusion:

- Resuscitation with LR compared with NS was associated with lower total cost and rates of CE.

Electrolytes
Treatment: electrolytes

- Potassium
  - Apparent serum hyperkalemia
  - Total body potassium depletion
  - Treatment DKA will cause drop
Treatment: electrolytes

- Potassium
  - Low: replete before starting insulin
  - Normal: add with fluids and insulin
  - High: confirm urine output, then add

Start insulin therapy after obtaining potassium levels
Treatment: electrolytes

- Phosphate
  - Total body phosphate depletion
  - No data showing significant benefit of repletion
  - Concern for hypocalcemia
  - Consider when increasing Cl⁻ or symptomatic
Bicarbonate
Treatment: bicarbonate

- **NOT recommended**
  - Paradoxical intracellular acidosis
  - Worsening tissue perfusion
  - Worsening hypokalemia
  - Worsening hyperosmolality
  - Cerebral edema

- **Exceptions:**
  - Severe acidosis: pH < 6.9 and
  - Cardiac arrhythmia
Insulin
Treatment: insulin

- Continuous infusion (0.05-0.1 units/kg/hr)
- Prime IV tubing
- Start 1-2 hours after initial fluid bolus
- **No bolus** in peds
- Continue until resolution of acidosis
- Maintain glucose > 250-300 mg/dL
Treatment

BAG A
NS + KCl + KPhos

BAG B
D_{10}NS + KCL + KPhos

Insulin
0.05-0.1 units/kg/hr

Total rate (mL/hr)
Cerebral edema management

- Hourly neuro checks
- Immediate treatment
- Reduce fluid administration
- Mannitol
  - 0.5-1 g/kg within 5-10 min
- Hypertonic saline
  - 5-10 ml/kg
- Avoid mechanical hyperventilation

Treat before imaging
Hypertonic solution at bedside
Insulin pumps
Insulin pumps
Insulin pumps

• Self-contained subcutaneous delivery system
  • Only contains short-acting insulin
  • Shorter window before risk DKA
  • Check the tubing for kinks/ breaks
  • Change site (every 3 days)
    • Callous formation
    • Local infection
  • User error/ manipulation
Trouble shooting

- Insulin infusion
  - Severe insulin resistance due to infection
  - Incorrect preparation of insulin infusion
  - Insulin adherent to tubing - Prime the tube!
Management pearls

Example management:

- FS >300
  - Check ketones
  - Give pump bolus and recheck in 1 hour
  - If decreased by 50, give subcutaneous correction dose
  - Change site, recheck in 1 hour
Hopefully in the not too distant future...
Artificial Pancreas Device System

1. Continuous Glucose Monitor
2. Computer-Controlled Algorithm
3. Insulin Pump
4. Patient Effect
DKA Pearls and Pitfalls

- (More) Conservative IV fluids in peds
- Start insulin only after obtaining potassium levels
- No bicarbonate
- No insulin bolus in peds
- Treat before imaging for cerebral edema
Questions?

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