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 emphasis 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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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

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

IVF

IVF

Insulin (bolus?)

Pearl

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
~~IVF~~
~~IVF~~
Insulin ~~(bolus?)~~

Pitfall

Cerebral edema

Edge, *Diabetologia*, 2006
Wolfsdorf, *Pediatr Diabetes* ,2009

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

Kitabchi, *Diabetes Care,* 2009

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

Wolfsdorf, *Pediatric Diabetes,* 2014

Hyperosmolar Hyperglycemia State

- Plasma glucose > 600 mg/dL
- Little to no ketoacid accumulation
- Serum osmolality > 320 mOsm/kg
  - 2[measured Na (mEq/L)] + glucose (mg/dL)/18 + 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

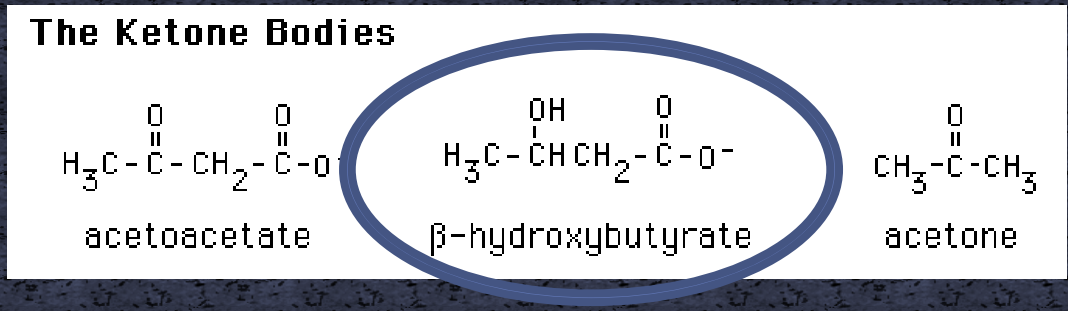
Wolfsdorf, *Diabetes Care*, 2006

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”



$EtCO_2$

Bou Chebl R, *BMC Emerg Med*, 2016
Gilhotra Y, *J Paediatr Child Health*, 2007

Similarities: DKA

Adults

- Fluid resuscitation
- Correct electrolytes
- Insulin therapy
- Find the source
- No bicarbonate!

Pediatrics

- Fluid resuscitation
- Correct electrolytes
- Insulin therapy
- Find the source
- No bicarbonate!

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 Jeziorny[1] · Anna Niwald[2] · Agnieszka Moll[2] · Katarzyna Piasecka[2] · Aleksandra Pyziak-Skupien[1] · Arleta Waszczykowska[3] · Dobromiła Baranska[4] · Beata Malachowska[5] · Agnieszka Szadkowska[1] · Wojciech Mlynarski[1] · Agnieszka Zmyslowska[1]

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

Mild

- Talk to endocrinologist
- Subcutaneous insulin
- Oral hydration

Moderate/ Severe

- Fluids
- Electrolytes
- Insulin
- Source

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 hour
  - 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 2x 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


STOP


DEBATE

Clinical Trial of Fluid Infusion Rates for Pediatric Diabetic Ketoacidosis

Nathan Kuppermann, M.D., M.P.H., Simona Ghetti, Ph.D., Jeff E. Schunk, M.D., Michael J. Stoner, M.D., Arleta Rewers, M.D., Ph.D., Julie K. McManemy, M.D., M.P.H., Sage R. Myers, M.D., M.S.C.E., Lise E. Nigrovic, M.D., M.P.H., Aris Garro, M.D., M.P.H., Kathleen M. Brown, M.D., Kimberly S. Quayle, M.D., Jennifer L. Trainor, M.D., et al., for the PECARN DKA FLUID Study Group*

- 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.

NEJM, 2018

Now what???

ISPAD CLINICAL PRACTICE CONSENSUS GUIDELINES

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

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

REVIEWS AND COMMENTARIES

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[1] | Nathan Kuppermann[1,2]

Pediatric Diabetes, 2018

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.

Bergmann KR, *Pediatr Emerg Care,* 2018

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!

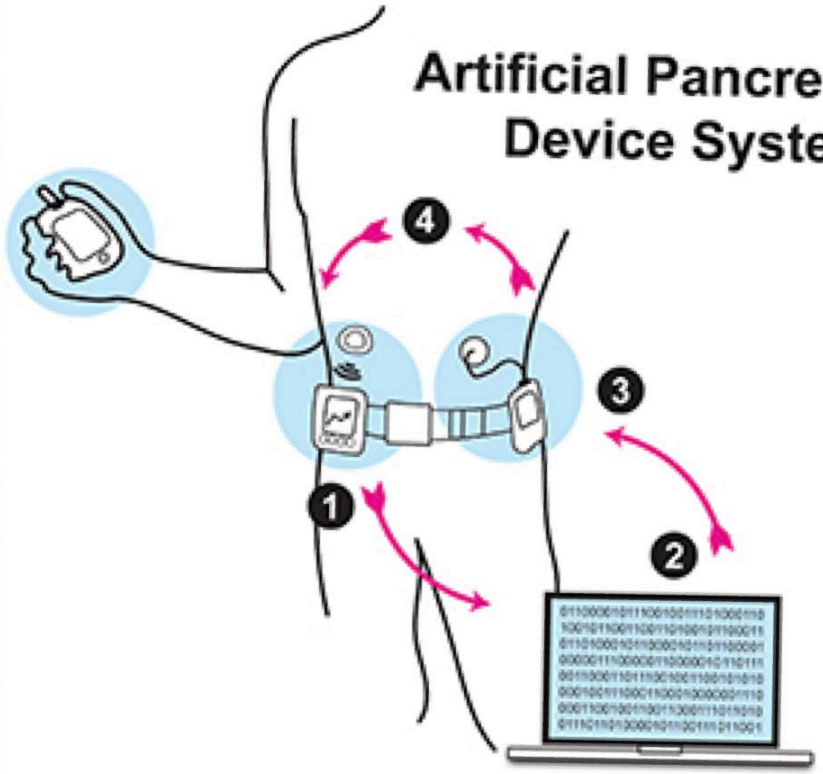
Management pearls

Example management:

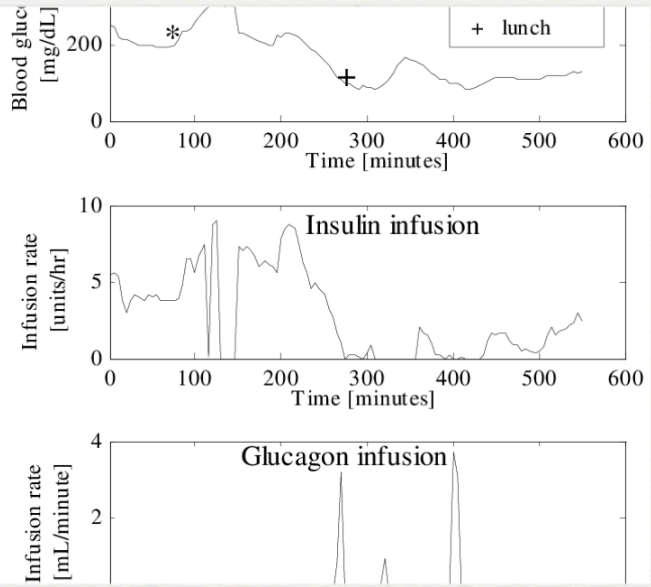
- FS >300
  - Check ketones
  - Give pump bolus and recheck in 1 hour
  - If decreased by 50, give subcutaneous correction dose
  - Change site, recheck in 1 hour

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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