Preventing Pediatric Diabetic Ketoacidosis (DKA)

Alba E. Morales, MD

Associate Professor of Pediatrics

Barnstable Brown Diabetes Center/ UK Healthcare

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Faculty Disclosure

- No relevant financial relationships to disclose.

Objectives

Upon completion of this educational activity, you will be able to:

- Describe the diagnostic criteria of pediatric DKA
- List 4 steps in the prevention of DKA in pediatric patients with type 1 diabetes

Expected Outcome

- Participants will become familiar with the pathophysiology, early assessment and prevention of pediatric DKA

Definition of DKA

- 1. Hyperglycemia > 200 mg/dl AND
- 2. Ketonemia (BOHB > 1 mmol/L) AND
- 3. Venous pH < 7.3 or HCO3 < 15 mEq/L
- Classification-

  - **mild** pH <7.3, bicarbonate < 1 5, anion gap >16
  - **moderate** pH <7.2, bicarbonate <10, anion gap >16
  - **severe pH** <7.1, bicarbonate <5, anion gap >16

Source of Metabolic Acidosis in DKA

- Ketonemia (insulin deficiency)
- ALSO-
    - Lactic acidosis (**dehydration**)
    - Renal dysfunction (dehydration)- **loss of bicarbonate in urine**

Who is at risk of DKA?

New onset diabetes

- Age < 4 years
- Children with **NO** 1st degree relative with diabetes
- Lower SE status
- Unusual triggers:
  - Steroids
  - Atypical antipsychotics
  - Diazoxide
  - Immunosuppressive drugs

Established diabetes

- 1-10% per patient/ year= risk of DKA
- Poor metabolic control
- Previous episodes of DKA
- Adolescent girls
- Youth with eating disorders/ other psychiatric illness
- Difficult family circumstances/ low SE status

Risk of DKA is higher in:

- **Prior DKA episodes**
- **Insulin omission (poor adult supervision); poor BG monitoring habits**
- **Adolescent females**
- **Negative Social factors**
- **Recent illness, infection**
- **Psychiatric disorder**
- **Eating disorder**
- **Surgery, trauma, obesity**
- **Use of diabetogenic meds**

Morbidity and Mortality of DKA in Children

- Mortality has been constant at 0.15% (USA)
- Cerebral edema (CE) accounts for 57-87% of all DKA deaths
- Depending on the study, CE incidence in patients with DKA varies from 1-4% approximately and has been stable over last decade or so
- Mortality rates from CE in population studies have been reported as high as 25%

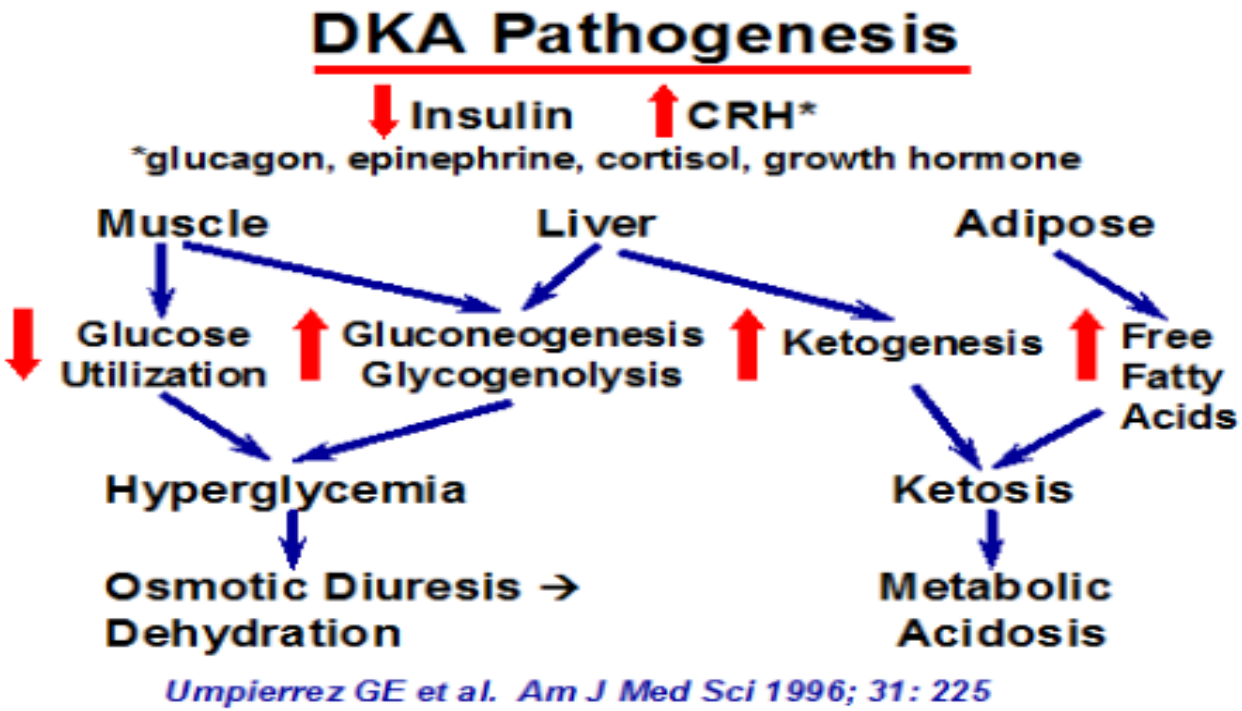
Pathophysiology

- Complete **or relative** insulin deficiency gives rise to accelerated, unchecked ketogenesis and hyperglycemia **(CATABOLIC STATE)**

- Hyperglycemia causes **progressive dehydration** that can lead to renal dysfunction and severe loss of electrolytes

- Volume depletion and acidosis cause **increased production of counter-regulatory hormones** which in turn worsen the above

DKA is caused by insulin deficiency

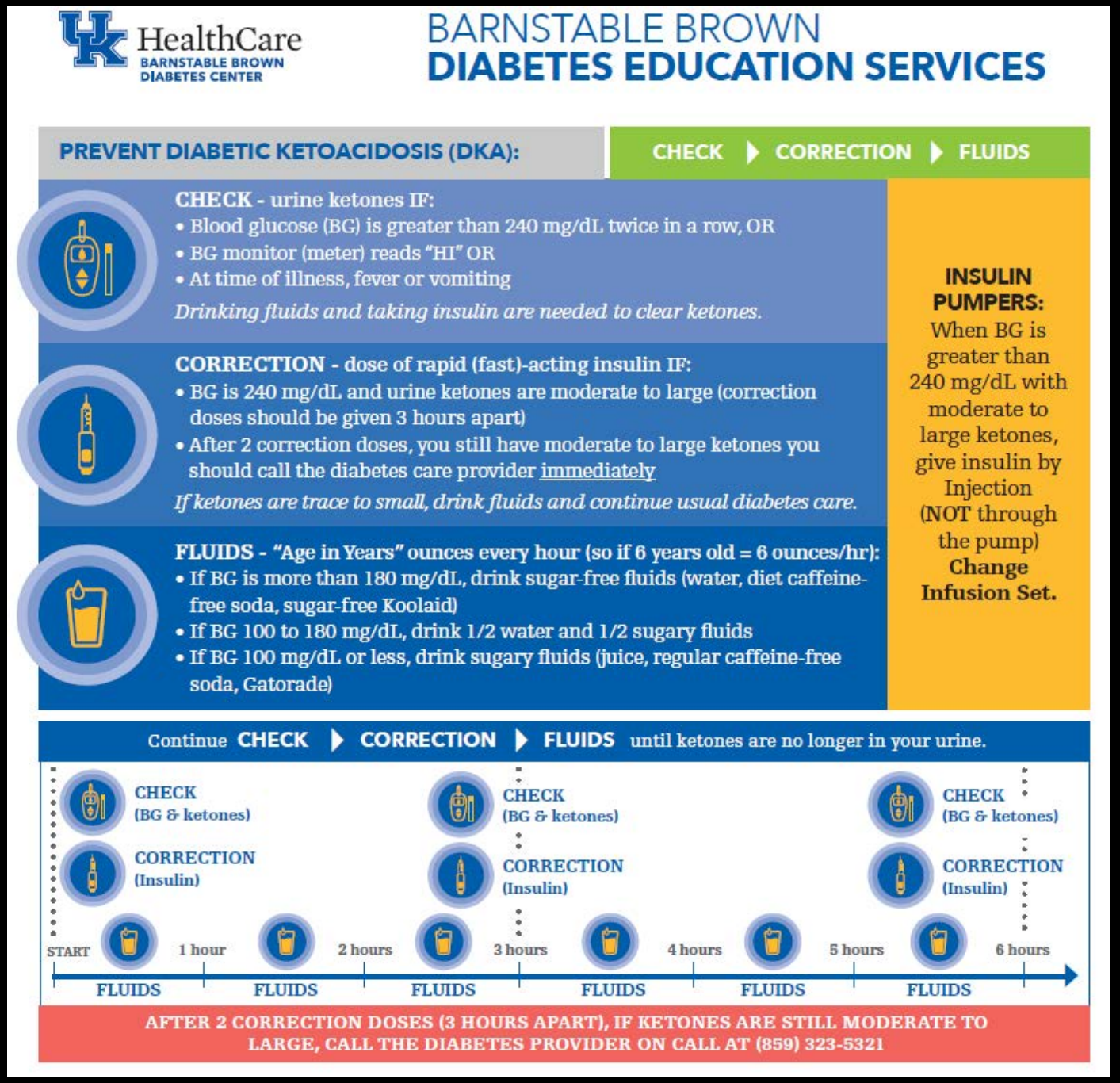


*CRH=Counter Regulatory Hormones

SEVERE DEPLETION OF WATER AND ELECTROLYTES FROM THE INTRA -AND EXTRA-CELLULAR FLUID COMPARTMENTS

Diabetic Ketoacidosis

- PREVENTION is best
- All families with diabetic children are educated on DKA prevention
- Provided with an educational magnet to keep handy



DKA prevention magnet provided to all families

Any acute illness, systemic stress or trauma will cause insulin resistance and temporary, relative insulin deficiency.

Severity and duration of illness will be directly proportionate to the severity / duration of relative insulin deficiency.

HealthCare
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PREVENT DIABETIC KETOACIDOSIS (DKA):

CHECK ▶ CORRECTION ▶ FLUIDS

CHECK - urine ketones IF:

- Blood glucose (BG) is greater than 240 mg/dL twice in a row, OR
- BG monitor (meter) reads "HI" OR
- At time of illness, fever or vomiting

Drinking fluids and taking insulin are needed to clear ketones.

CORRECTION - dose of rapid (fast)-acting insulin IF:

- BG is 240 mg/dL and urine ketones are moderate to large (correction doses should be given 3 hours apart)
- After 2 correction doses, you still have moderate to large ketones you should call the diabetes care provider immediately

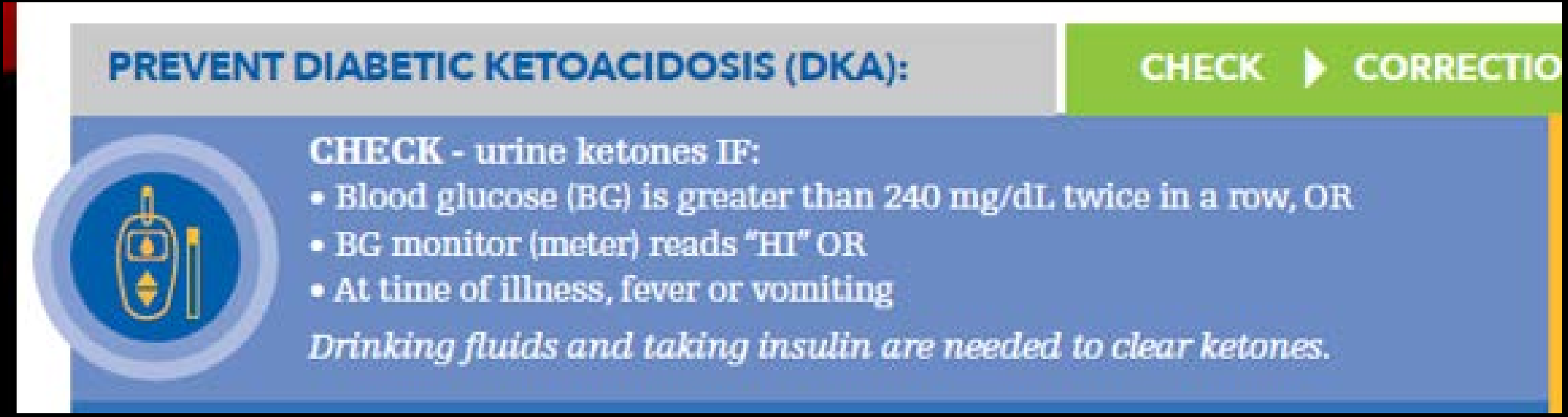
If ketones are trace to small, drink fluids and continue usual diabetes care.

FLUIDS - "Age in Years" ounces every hour (so if 6 years old = 6 ounces/hr):

- If BG is more than 180 mg/dL, drink sugar-free fluids (water, diet caffeine-free soda, sugar-free Koolaid)
- If BG 100 to 180 mg/dL, drink 1/2 water and 1/2 sugary fluids

INSULIN PUMPERS:
When BG is greater than 240 mg/dL with moderate to large ketones, give insulin by Injection (NOT through the pump) **Change Infusion Set.**

Unexplained hyperglycemia is often the first sign of acute systemic stress, ketonemia follows, ketonuria lags behind ketonemia



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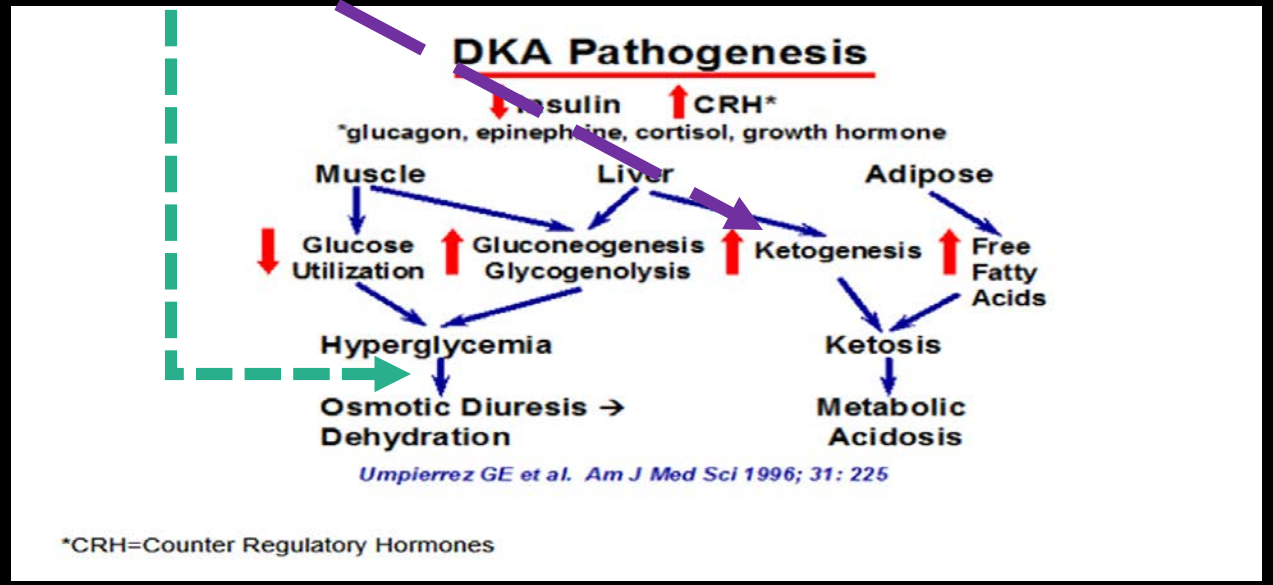
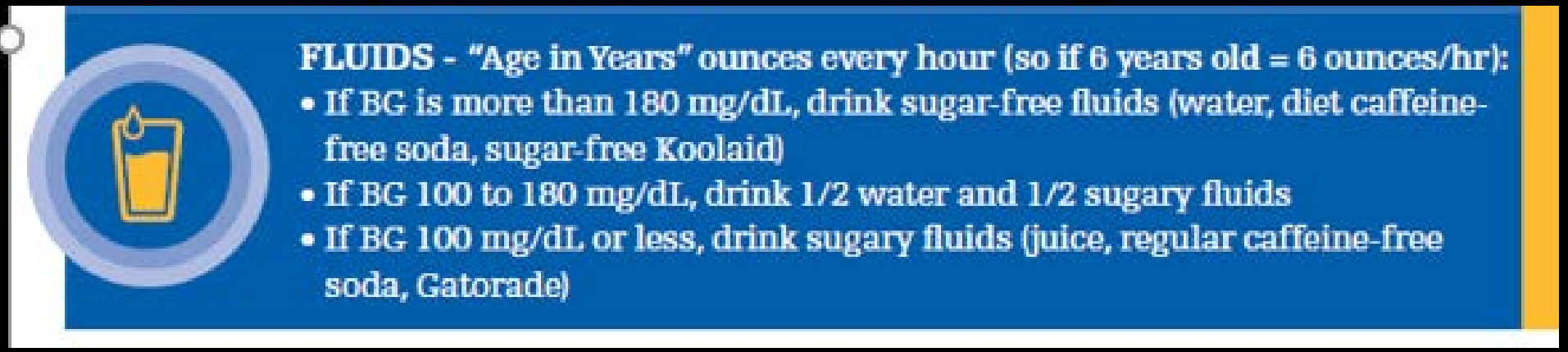
If ketones are trace to small, drink fluids and continue usual diabetes care.

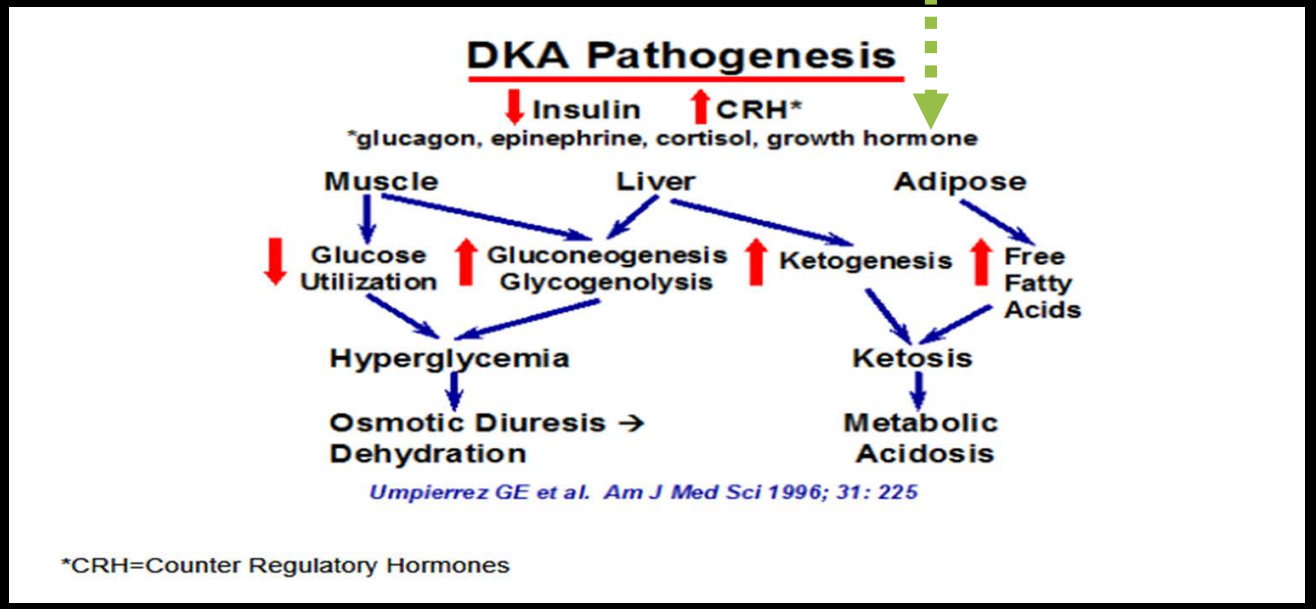
Timely administration of subcutaneous insulin should prevent further ketogenesis, correct hyperglycemia and decrease polyuria (water and electrolyte loss).





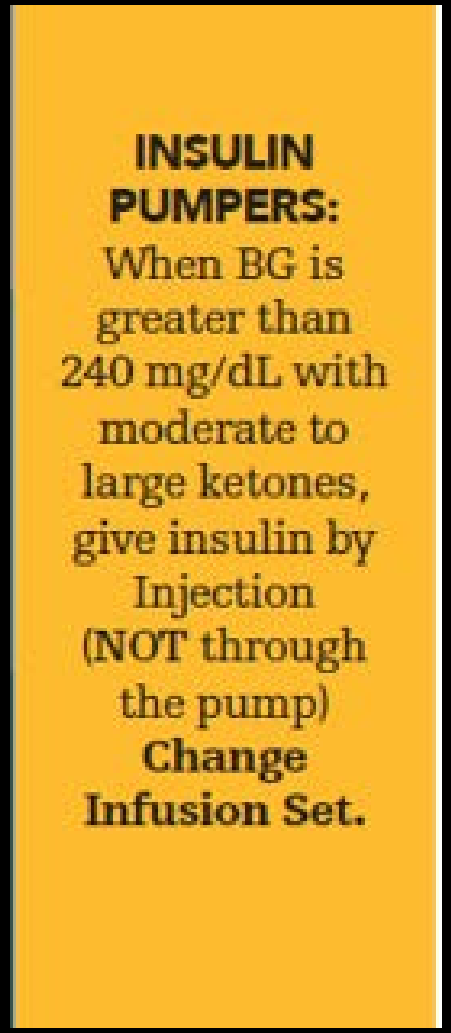
Fluid intake to prevent dehydration, replace losses, prevent excessive counter-regulatory hormone production

Drinking glucose will allow child to take extra insulin doses if needed to continue to prevent ketogenesis



Summary for families/ patients:

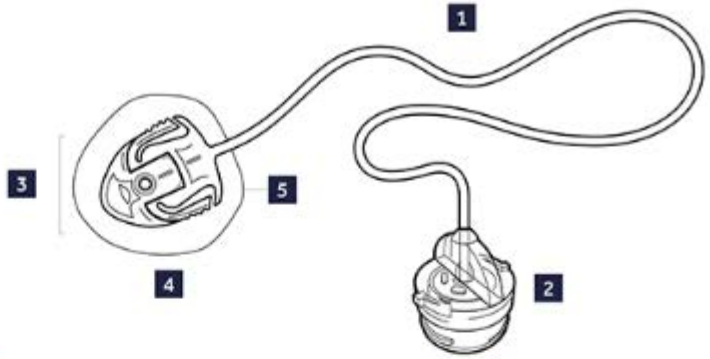
- Your (child's) body needs more insulin during illnesses
- High blood sugar is often the first sign of illness
- Higher insulin need can lead to ketone acids production in blood – can easily be detected in urine
- Giving extra insulin doses will stop the body from making more ketones
- Giving extra fluids will replenish urine losses from high BG and will prevent dehydration
- Extra insulin and fluid needs can persist as long as the viral/ acute illness is present



Ketonuria/ ketonemia while using insulin pumps VERY OFTEN signal a problem with the tubing, infusion site, insulin delivery mechanism.

If a pump user develops ketonuria it is mandatory that insulin reservoir, tubing and site be replaced and pump mechanism should be checked for malfunction.

Insulin administration should be done with pens/ syringes while ketonuria/ ketonemia persists.



INFUSION SET*

1 **Tubing:** carries insulin from the pump to you

2 **Reservoir Connector:** end of the tubing that attaches the reservoir which holds the insulin

3 **Insertion Site Section:** other end of the tubing that attaches to you

4 **Cannula:** tiny flexible tube placed into your body** by the insertion needle included in the insertion site section

5 **Adhesive:** holds the infusion set in place

6 **Reservoir Compartment:** part of the pump where the reservoir fits

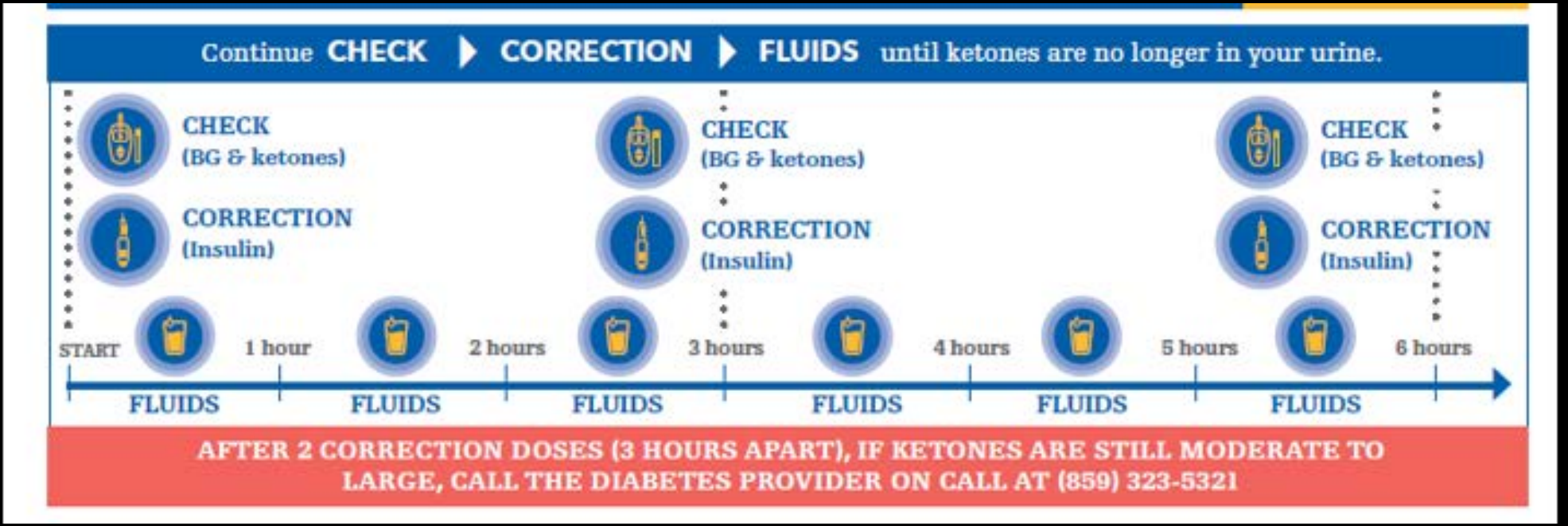
RESERVOIR

PUMP

You should replace both the infusion set and the reservoir every 2 to 3 days.

*Mio® infusion set shown in illustration.

**Some infusion sets do not use a cannula but have a small needle that remains inserted in the body.



Check, correct and fluid intake steps should be repeated as long as acute illness lasts or as long as it takes to resolve ketonuria (if there was another for insulin interruption found).

Contact provider on call if no improvement or worsening picture, can discuss need for ER visit

Remote assessment

Consider RISK factors	HPI	*Concerning Signs*
▪ Prior DKA episodes ▪ Insulin omission (poor adult supervision) ▪ Adolescent females ▪ Negative Social factors ▪ Recent illness, infection ▪ Psychiatric disorder ▪ Eating disorder ▪ Surgery, trauma, obesity ▪ Use of diabetogenic meds	▪ Polyuria ▪ Polydipsia ▪ Signs of dehydration ▪ Abdominal pain ▪ Severe fatigue ▪ Nausea ▪ Weakness ▪ Headache ▪ Confusion ▪ Drowsiness	▪ Kussmaul breathing ▪ Repeated emesis ▪ Abdominal tenderness (diffuse) ▪ Mental status changes ▪ Lethargy ▪ Child will most likely need ED assessment ▪ Mild illness leads to mild DKA ▪ Severe illness leads to severe DKA

Steps in DKA prevention

- Know your (your child's) risk of developing DKA
- Check for ketonuria or ketonemia if BG > 240 more than once or feeling sick
- Give insulin every 3 hours (using BG correction factor)
- Replace fluid losses, increase hydration and prevent hypoglycemia by drinking extra fluids based on age
- Awareness---
  - Insulin pump tubing and mechanism malfunction can cause DKA

Thank-you!

- Questions?

- Amo278@uky.edu

Hospital management of DKA

Rehydrate

- 1st HOUR:
  - resuscitation fluids (10-20 ml/kg 0.9%NS bolus, repeat if needed up to 30 ml/kg total)
  - Overt shock- 20 ml/kg 0.9% NS bolus
- Subsequent fluids need to be calculated to replace deficit and provide maintenance fluids using body weight as reference

Stop ketogenesis

- INSULIN
  - No bolus needed and may be associated with increased risk for cerebral edema
- 0.1 unit/ kg/hour regular insulin is default rate

New since 2018-

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]

TABLE 1 FLUID trial treatment protocols

Protocol Components	Protocol A1	Protocol A2	Protocol B1	Protocol B2
Standard initial fluid bolus	10 cc/kg bolus of 0.9% saline	10 cc/kg bolus of 0.9% saline	10 cc/kg bolus of 0.9% saline	10 cc/kg bolus of 0.9% saline
Additional intravenous fluid bolus	Additional 10 cc/kg of 0.9% saline	Additional 10 cc/kg of 0.9% saline	No additional bolus	No additional bolus
Assumed fluid deficit	10% of body weight	10% of body weight	5% of body weight	5% of body weight
Replacement of deficit	Replace half of fluid deficit + maintenance fluids over initial 12 h, remaining deficit + maintenance fluids over subsequent 24 h	Replace half of fluid deficit + maintenance fluids over initial 12 h, remaining deficit + maintenance fluids over subsequent 24 h	Replace deficit + maintenance fluids evenly over 48 h	Replace deficit + maintenance fluids evenly over 48 h
Fluid used for deficit replacement	0.45% saline	0.9% saline	0.45% saline	0.9% saline

Abbreviation: FLUID, Fluid Therapies Under Investigation in DKA.
Modified from Glaser N. et al.[23]. Reprinted with permission.

Pediatric Diabetes. 2019;20:10–14.

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The PECARN FLUID Trial found no significant differences
between study arms in either mental status changes (assessed by GCS
and digit span scores) during DKA treatment, clinical diagnoses of
brain injury, or cognitive testing scores at follow-up

In plain terms:

- ***Fast*** administration rate of fluids= 2X maintenance for initial 12 hours, then 1.5 maintenance over next 24 hours (given after 20 cc/kg/NS bolus)
  - NS vs ½ NS to replace deficit
- ***Slow*** administration of fluids= 1.5 maintenance for 48 hours duration of IV fluids (given after a 10 cc/kg bolus)
  - NS vs ½ NS to replace deficit
- No difference in GCS outcomes; brain injury; or short term memory after DKA episode
- Children with severe DKA who were rehydrated at a faster rate improved their short term memory sooner than those who were rehydrated at the slower rate (not significant).

Fluids- modern take

- In summary, the PECARN FLUID Trial provided the first high-quality data investigating the effects of fluid infusion rates and NaCl content on neurological outcomes of DKA in children. The FLUID Trial data suggest that a range of fluid infusion protocols can be used safely in children with DKA and intravenous fluids should not be restricted unnecessarily due to concerns about causing brain injuries. Children with DKA should receive fluid resuscitation similar to children with other conditions involving similar degrees of dehydration.