Diabetic Ketoacidosis (DKA) v5.0: Links and Clinical Tools

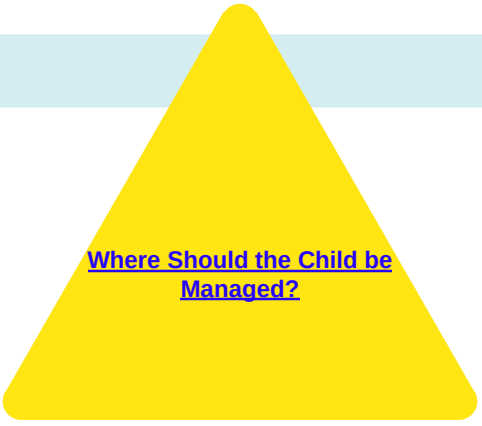
Exclusion and Inclusion Criteria

Pathway Overview

DKA Risk Assessment

ICU Admission Criteria

Cerebral Edema



PHASE 1: Early Electrolyte Adjustment/Rehydration (initial 4-6 hrs)

PHASE 2: Ongoing Electrolyte Adjustment/Rehydration (up to 48 hrs)

Transition Phase

Clinical Tools

GCS Scoring

Clinical Cerebral Edema Risk Tool

Lab Schedule

Guideline Table of Contents

The Two Bag System

Fluid Rate Calculator *(for SCH only)*

Two Bag Clinical Calculator *(for SCH only)*

*** Every recommendation is intended only as a guide for the practitioner and should be adapted to each specific patient based on individual professional judgement and family consideration**

Last Updated: February 2020
Next Expected Review: July 2022

Diabetic Ketoacidosis (DKA) v5.0: Criteria and Overview

Guideline | Summary of Version Changes | Citation Information | Explanation of Evidence Ratings

Inclusion Criteria

DKA is defined as (need all 3 criteria):
(1) Hyperglycemia > 200 mg/dL **AND**
(2) Ketonemia (BOHB > 1 mmol/L) **AND**
(3) Venous pH < 7.3 or HCO3 < 15mEq/L

Exclusion Criteria

(1) Age < 12 months

! If Hyperglycemic Hyperosmolar Syndrome (HHS) is suspected, consult Endocrinology to formulate an individualized management plan for your patient

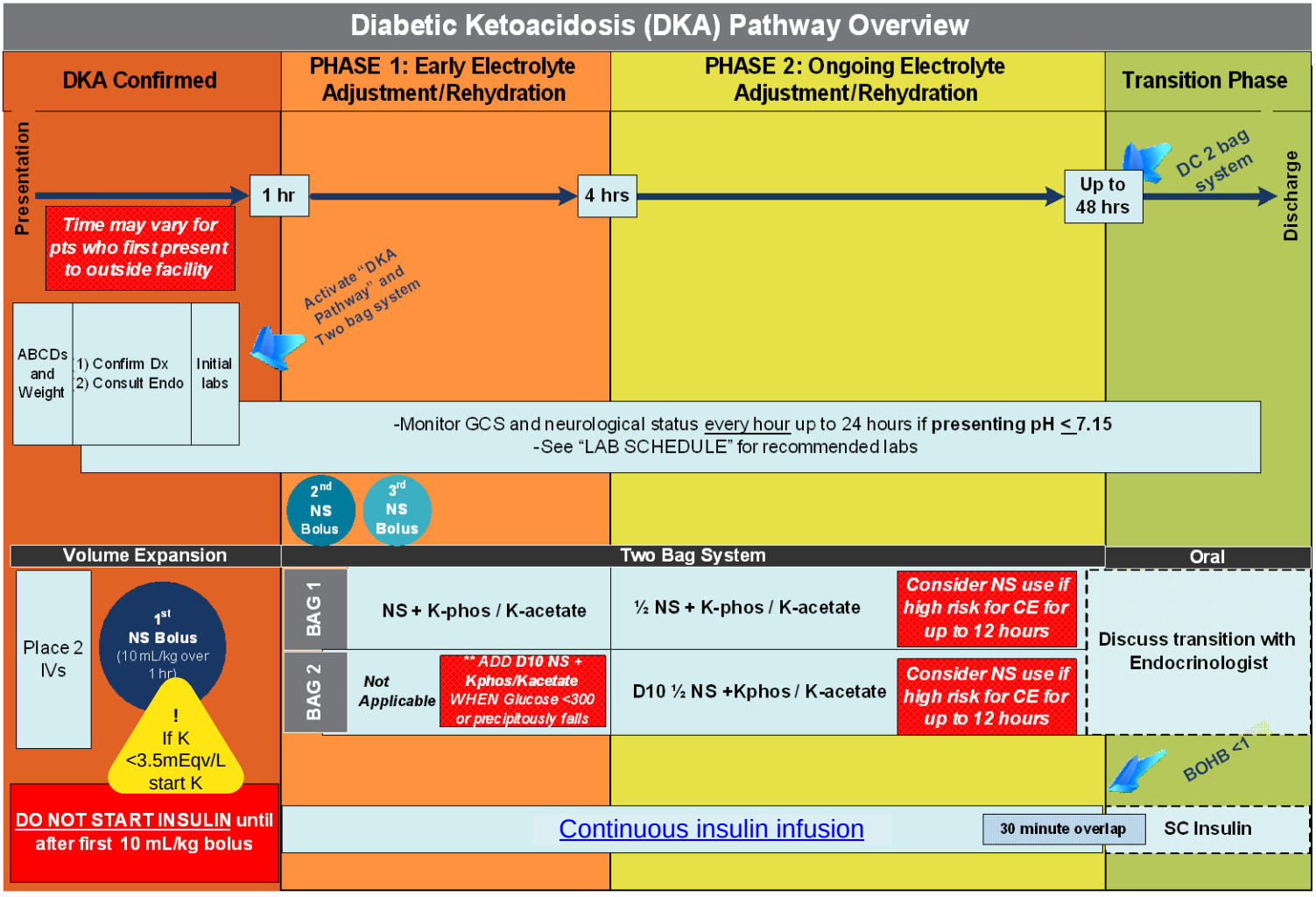
Pathophysiology of DKA

Where Should the Child be Managed?

DKA Severity Definitions

Mild: venous pH <7.3 or serum bicarbonate <15 mmol/L
Moderate: pH <7.2, serum bicarbonate <10 mmol/L
Severe: pH <7.1, serum bicarbonate <5 mmol/L

Diabetic Ketoacidosis (DKA) Pathway Overview



**This intervention is not anticipated for routine management but may be indicated in some circumstances

Seattle Children's HOSPITAL • RESEARCH • FOUNDATION

For questions concerning this pathway, contact: DKA@seattlechildrens.org

Last Updated: February 2020
Next Expected Review: July 2022

Diabetic Ketoacidosis (DKA) v5.0: Assessment & Disposition

Guideline | Summary of Version Changes

Citation Information | Explanation of Evidence Ratings

Assess Neurologic Stability

- GCS Score ≤ 13: Score hourly for up to 24 hours if at high risk for cerebral edema
- Clinical Cerebral Edema Risk Tool and Treatment
- Assess for Cushings Triad (↓ HR, ↑B/P, irregular respiration/widening pulse pressure)
- Anisocoria (unequal pupil size)
- Asymmetric neurological exam
- Non-responsive

! Cerebral Edema

Cerebral Edema

Unstable, admit to ICU

Assess for Clinical Signs and Historical Features Suggestive of DKA
Place PIV and obtain DKA confirmatory labs

! Consult Endocrine once diagnosis is confirmed

DKA Definition
Hyperglycemia >200 mg/dL & Ketonemia (BOHB >1mmol/L) & pH <7.3 or HCO3 <15 mEq/L
If patient is on a home insulin pump, remove it in its entirety, pump and insertion site

! Summary of Complications

Meets DKA Definition?

No → **Consider alternate diagnosis**

Yes

Obtain Second Vascular Access & Initial DKA Labs and new onset Type 1 DM labs, if applicable

1st NS Bolus (10 mL/kg over 1 hr)

DKA Risk Assessment

LOW RISK - Typically Mild DKA: Discharge home

- Established T1DM and improving on therapy
- Overt insulin pump failure, not meeting medium or high risk criteria
- Able to manage DM at home
- Able to tolerate oral fluid

Low → Discharge to home

MEDIUM RISK - Typically Mild to Moderate DKA: Medical Unit Admission

- New onset or established DM not meeting ICU admission criteria
- Unable to manage DM at home

Medium → Admit to Medical Unit

High

HIGH RISK – Typically Moderate to Severe DKA: Admit to ICU
Peak incidence of CE between 4-8 hours (range: prior to presentation up to 24 hours, during DKA)
ICU Admission Criteria (ANY of the following):
Risk does not resolve with improvement of below data within 8 hours

- Age ≤ 24 months
- Corrected Na* < 140 mEq/L or decreasing at 2 hour labs
  Corrected Na = Measured Na + [(Serum glucose – 100)/ 100 X 1.6)]
- Presenting** pH ≤ 7.15
- Presenting** HCO_3 ≤ 5 mEq/L
- Developmental delay or any condition that compromises communication
- GCS ≤ 13 after volume resuscitation
- Abnormal neurological exam after volume resuscitation
- Other organ system dysfunction
- Presenting** PCO_2 < 10 mmHg
- Presenting** BUN > 30 mg/dL
- Patient received IV bicarbonate or insulin bolus
- Calculated mOsm > 350
  2 X Na + (glucose/18) + (BUN/2.8)
- Patient received > 40 mL/kg total initial volume replacement (include fluids received prior to arrival to SCH)

*Serum Na is to be corrected only if abnormal.

**Includes any labs from outside hospital

NOTE: If no ICU beds are available and patient has received extended care outside of SCH, admit to medical unit only if: 2:1 patient to nurse ratio, and after discussion with Endocrinology, ED and ICU attendings, shift administrator, medical and PICU charge RNs, and Risk RN

Last Updated: February 2020
Next Expected Review: July 2022

Diabetic Ketoacidosis (DKA) v5.0: Insulin, Fluid & Electrolytes

Guideline | Summary of Version Changes

Citation Information | Explanation of Evidence Ratings

PHASES 1 & 2

! Never bolus insulin due to risk of cerebral edema

Fluid Calculators

! Early K replacement for presentations with hypokalemia (<3.5mEq/L)

Phase 1: Two Bag System - Early Electrolyte Adjustment/ Rehydration (initial 4-6 hrs)

- **Bag 1:** Start NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate. Add potassium unless hyperkalemia is present K>5.5mEq/L.
- **Bag 2:** D10 NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate. Add potassium unless hyperkalemia. ONLY START Bag 2 IF the plasma glucose falls to <300 mg/dL or if the rate of fall of glucose is precipitous (i.e. >100 mg/dL/hr).
- If the patient received more than 4 hours of treatment at an outside hospital, proceed to Phase 2.

Phase 2: Two Bag System - Ongoing Electrolyte Adjustment/Rehydration (up to 48 hrs)

Low risk for cerebral edema:

- **Bag 1:** Start ½ NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate; Discontinue the NS Bag 1 from Phase 1.
- **Bag 2:** Start D10 ½ NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate; If applicable discontinue D10 NS Bag 2 from Phase 1.

High risk for cerebral edema: (*corrected* Na < 140 or falling rapidly, ICU admit, neurological changes):

- **Bag 1:** Continue NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate.
- **Bag 2:** Continue D10 NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate.
- Continue with NS two-bag system **for up to 12 hours** and then switch to ½ NS two-bag system as described above.

Insulin and Glucose

- **Standard insulin infusion rate: 0.05 units/kg/hour**.
- Use 0.1 unit/kg/hour insulin infusion rate for patients with any of the following: insulin resistance, BMI>85th percentile, pubertal or post-pubertal.
- Use 0.025 units/kg/hour insulin infusion rate with any of the following: <5 years old or insulin sensitive.
- Start regular insulin infusion AFTER completion of first 10 mL/kg bolus of NS that is given over 1 hour.
- Maintain dose of insulin until BOHB<1 mmol/L.
- Do not stop or decrease the insulin infusion if the blood glucose decreases too quickly (> 100 mg/dL/hr) or falls too low (< 300 mg/dL) before DKA has resolved; rather, increase the amount of dextrose administered.
- If glucose is < 125mg/dL, notify provider to order D12.5% with identical saline and electrolyte content to be available.
- When glucose is < 100mg/dL, check BOHB value:
  - Discontinue the two-bag system and instead use D12.5% with saline and electrolyte content.
  - Consult endocrinology and check readiness for transition.

Electrolytes

Sodium

- Use calculated corrected Na to guide subsequent fluid and electrolyte therapy in addition to clinical assessment of dehydration.
  Corrected Na = measured Na + [(Serum glucose as mg/dL – 100)/100] X 1.6
- If corrected Na trends downward and/or falls below 140mEq/L, adjust maintenance fluids to contain NS and increase frequency of serum sodium monitoring.
- If corrected Na decreases to < 130 mEq/L, begin an infusion of 2% saline (peripheral IV) or 3% saline (central line).

Phosphate, Magnesium, and Bicarbonate
Do NOT replace in the routine care of DKA.

Potassium

- Provide sufficient amount of K supplementation as follows
  - If hypokalemia (K<3.5mEq/L) exists at presentation, start potassium at total concentration of 60 mEq/L with the two-bag system.
  - Use combination Kphosphate and Kacetate.
- If presentation of normokalemia, use standard K supplement at total of 40 mEq/L with the start of the two bag system
- If hyperkalemia (two consecutive measures free flowing sample, not hemolyzed), do not begin K replacement until serum K is <5.5mEq/L
- If potassium abnormalities exist, measure serum potassium every 2 hours and place on cardiac monitoring and discuss with attending.

Begin planning for transition to SC insulin when BOHB is < 3 mmol/L

→ **To Transition Phase**

ICU Discharge Criteria

- BOHB ≤ 3 mmol/L (if overnight, consider early morning transfer) and
- GCS = 15 or at premorbid baseline and
- K requirement can be maintained with ≤ 60 mEq/L supplementation and
- No ICU care needed for any other reason
- Exception: hyperosmolar dehydration

Last Updated: February 2020
Next Expected Review: July 2022

Diabetic Ketoacidosis (DKA) v5.0: Transition Phase

Guideline | Summary of Version Changes

Citation Information | Explanation of Evidence Ratings

TRANSITION PHASE

!
Always discuss transition to SC insulin with the Endocrinology fellow or attending regardless of time of day

!
The transition may be complex due to low rate insulin infusions, basal insulin or pump therapy; always consult Endocrinology

Formulate insulin transition plan when BOHB is < 3 mmol/L

↓

Consult Endocrinology

- The dose and type of subcutaneous (SC) insulin should be guided by the on-call Endocrinologist with consideration of age, previous dosing, pubertal state, systemic inflammation, and length of honeymoon period.
- Order transition insulin in “planned state” (do not initiate yet)

↓

Confirm and initiate insulin transition plan as discussed with Endocrinology when BOHB< 1 mmol/L

When ketoacidosis is resolving (BOHB < 1 mmol/L), and the change to SC insulin is planned, the most convenient time to change to SC insulin is just before a mealtime.

↓

- At transition, check glucose within 15 minutes prior to administration of insulin.
- Give subcutaneous basal insulin 30 minutes prior to discontinuing the insulin infusion unless blood glucose <100mg/dL then turn off insulin infusion at the time of sc insulin.
- Initiate **carbohydrate-counted diet;** if eating, give subcutaneous bolus insulin (correction and carbohydrate coverage).
- Recheck glucose 1 hour post insulin dose.

!
Basal insulin is used regardless of tolerance of oral intake.

↓

Continue blood glucose monitoring at least 5 times in 24 hours following resolution of DKA.

↓

Discharge Criteria

- Reason for DKA addressed.
- Demonstrated ability to independently administer insulin SC, monitor glucose and determine intervention, and prevent, identify and treat hypoglycemia, hyperglycemia and ketonuria.
- Appointments with Endocrine and primary care provider arranged.
- Glucagon and other supplies addressed.
- Additional education given.
- Additional discharge instructions given.

Last Updated: February 2020
Next Expected Review: July 2022

Seattle Children's
HOSPITAL · RESEARCH · FOUNDATION

Clinical Effectiveness Program

Diabetic Ketoacidosis (DKA)

Guideline
And Implementation Tools

Date of original publication: April 2011
Modified: July 2017

Every recommendation is intended only as a guide for the practitioner and should be adapted to each specific patient based on individual professional judgement and family consideration.

Links and Clinical Tools | **Algorithm** | **Guideline Table of Contents**

GUIDELINE TABLE OF CONTENTS

Implementation Tools

Assessment and Disposition for DKA
DKA Pathway
Lab Schedule
Two-bag system dose calculator
Two-bag system educational materials

DIABETIC KETOACIDOSIS (DKA)
GUIDELINE SUMMARY

Who is this guideline for?

- For use in children greater than 12 months of age with DKA.
  DKA is defined as:
  - hyperglycemia >200 mg/dL *and*
  - ketonemia (β-hydroxybutyrate [BOHB] > 1 mmol/L) *and*
  - venous pH <7.3 *or* HCO_3 < 15 mEq/L
- For use by all providers at Seattle Children's Hospital, trainees, referring hospitals, patients and their families.

What are the goals of DKA management?

- The goals of DKA therapy are to (1) correct dehydration, (2) correct acidosis and reverse ketosis, (3) normalize blood glucose, (4) minimize risk of DKA complications, (5) identify and treat any precipitating event, and (6) provide diabetes education for DKA prevention.

How will the guideline improve the quality of care for DKA patients?

- Decrease risk for adverse outcomes (e.g. medication errors and cerebral edema).
- Decrease variation in management (fluid, electrolyte, and insulin).
- Improve patient flow and collaboration between all providers and sites of care.

What new clinical standard work does the guideline involve?

- **The two-bag system** uses the simultaneous administration of 2 intravenous (IV) fluid bags each with identical electrolytes, but one bag contains 10% dextrose (D10) and the other does not. This system empowers the bedside nurse to adjust the infusion rate of each bag to address fluctuations in the patient's serum glucose without altering the concentration of electrolytes or the rate of fluid or insulin infusion.
- **Cerebral edema** prevention and early recognition, using internationally recommended management strategies (International Society of Pediatric and Adolescent Diabetes ((ISPAD)) guidelines) and standard clinical practice.
- **β-hydroxybutyrate (BOHB) testing** is the best indicator of ketosis in DKA. Normalization (i.e. < 1 mmol/L) indicates resolution of DKA.
- **Hospital wide criteria** for admission, transfer, and discharge.
- **Hospital wide standard documentation** of laboratory tests, neurological assessment [Glasgow Coma Scale (GCS)], fluid and insulin management.
- **Early consultation with Endocrinology** at the time of DKA confirmation.

PRINCIPALS OF MANAGEMENT

FLUIDS

- If needed to restore peripheral circulation, 10 mL/kg of initial fluid resuscitation should be given immediately but over 1 hour. Up to 30 mL/kg can be administered until perfusion is restored.
- Do not give more than 40 mL/kg of initial fluid resuscitation (including fluids at referral center).
- Patients who have received greater than 40 mL/kg of initial fluid resuscitation (including fluids at referral center) require a PICU consultation.

For patients in shock or with severe dehydration, see Guideline Exceptions (page 13)

- Use weight-based clinical calculator (page 39) to determine the total volume requirement and IV fluid rate.
- Use SCH measured weight at presentation for all calculations.
- Replace fluids over 48 hours, starting with the time of initial medical care. Include all fluids administered prior to or during transfer in calculations for fluid replacement.
- Assume 7% dehydration to calculate fluid replacement for the two-bag system (i.e. 0.07 x __kg x 1000 mL/kg = ___mL of dehydration deficit).
- Calculate 48 hour fluid replacement with clinical calculator upon transfer to floor or ICU. This calculation will consider 7% dehydration, maintenance fluids, and volume administered during resuscitation.

INSULIN

- Do not bolus insulin.
- Start regular insulin infusion AFTER completion of first 10 mL/kg bolus of NS or approximately 1 hour after initiation of care.
- MAINTAIN dose of insulin at EITHER 0.025, 0.05 or 0.1 units/kg/hour until BOHB < 1 mmol/L.
- DO NOT DECREASE INSULIN infusion if the blood glucose concentration decreases too quickly (greater than 100 mg/dL/hr) or falls too low (below 300 mg/dL) before DKA has resolved; rather, increase the amount of glucose administered.
- When BOHB is < 1 mmol/L, transition to basal and if eating short acting SC insulin (Transition Phase).
- Discuss the insulin transition plan with Endocrinology once BOHB is <3 mmol/L.

ELECTROLYTES

- Use calculated corrected sodium to guide fluid and electrolyte therapy:
  Corrected Na= measured Na + [(serum glucose mg/dL -100)/100] x1.6
- Use normal saline for the first 4 hours in both bags of the two-bag system (Phase 1).
- Subsequently use ½ NS in both bags of the two-bag system if there is no concern for cerebral edema (Phase 2). If there is concern for cerebral edema (i.e. neurological changes, ICU admission) continue to use normal saline in both bags of the two-bag system for up to the first 12 hours (Phase 2).
- Potassium replacement usually begins with Phase 1 at the time of insulin infusion start; use a total of 40 mEq/L, generally 20 mEq/L of potassium acetate + 20 mEq/L of potassium phosphate.
- Do NOT administer bicarbonate in the routine management of DKA.
- Do NOT replace magnesium in the routine management of DKA.

LABS AND MONITORING

- Perform GCS and neurological assessment **every hour**; continue every hour for up to the first 24 hours for all patients considered high risk for cerebral edema (Table 1).
- Any patient with symptoms of cerebral edema requires PICU care.
- Frequency of laboratory tests is outlined in Table 1.
- All laboratory tests, GCS, and neurological changes are to be recorded by nursing in ClinDoc.

TIMELINE

DKA SUSPECTED: VOLUME EXPANSION ("LIMITED fluid resuscitation")

- Begin fluid replacement before insulin therapy.
- Secure TWO peripheral IV lines and begin fluid replacement immediately with 10 mL/kg using 0.9% normal saline, but administer OVER ONE HOUR unless the patient is in shock.
- Start two-bag system AFTER completion of volume expansion.
- Order the two-bag system under "DKA Pathway Power Plan" and Insulin infusion within the "DKA Pathway Power Plan" in CIS upon confirmation of DKA.

PHASE 1: Early Electrolyte Adjustment/Rehydration

[at least 4 to 6 hours, constant volume rate of administration over 48 hours*]

- Bag 1: Start NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate (add potassium unless hyperkalemia, do not use ½ NS).
- Bag 2: D10 NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate (add potassium unless hyperkalemia, do not use ½ NS). ONLY START Bag 2 IF the plasma glucose falls to <300 mg/dL or if the rate of fall of glucose is precipitous (i.e. > 100 mg/dL/hr).

- If the patient received more than 4 hours of treatment at an outside hospital, then proceed to Phase 2.

PHASE 2: Ongoing Electrolyte Adjustment/Rehydration

[after the first 4-6 hours, constant volume rate of administration over 48 hours]

For patients with low risk for cerebral edema:

- Bag 1: Start ½ NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate; Discontinue the NS Bag 1 from Phase 1.
- Bag 2: Start D10/½ NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate; If applicable discontinue D10 NS Bag 2 from Phase 1.

For patients with increased risk for cerebral edema:

- Bag 1: Continue NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate;
- Bag 2: Continue D10 NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate;
- Continue with NS based fluid two-bag system for up to 12 hours and then switch to ½ NS based fluid two-bag system as described above.

Transition Phase

[when BOHB <1 mmol/L]

- Step 1: Transition to SC insulin when BOHB < 1mmol/L. Administer basal insulin. If patient is eating also administer short acting insulin.
- Step 2: 30 minutes after SC insulin administration, turn off insulin infusion
- Step 3: If patient is tolerating total fluid and carbohydrate needs by mouth, with improving potassium and hydration status, discontinue IV fluids.

If there is any question about overnight transition or need for IV fluids (which may depend upon dextrose delivery, potassium status, overnight transition, poor intake / dehydration), consult with senior resident and / or attending to confirm appropriate orders.

INCREASED RISK OF CEREBRAL EDEMA = ICU ADMISSION CRITERIA

*[if **any** of the following demographic or treatment associated conditions exist]*

HIGH RISK: Admit to ICU
ICU Admission Criteria - any of the following:
Risk does not resolve with improvement of below data within 8 hours
Peak incidence of CE between 4 – 8 hours (range: prior to presentation up to 24 hours, during DKA)

- Age ≤ 24 months
- Corrected Na < 140 mEq/L or decreasing at 2 hour labs
  Corrected Na = Measured Na + [(Serum glucose – 100)/ 100 X 1.6)]
- Presenting** pH ≤ 7.15
- Presenting** HCO_3 ≤ 5 mEq/L
- Developmental delay or any condition that compromises communication
- GCS ≤ 13 after volume resuscitation
- Abnormal neurological exam after volume resuscitation
- Other organ system dysfunction
- Presenting** PCO_2 < 10 mmHg
- Presenting** BUN > 30 mg/dL
- Patient received IV bicarbonate or insulin bolus
- Calculated mOsm > 350
  2 X Na + (glucose/18) + (BUN/2.8)
- Patient received > 40 mL/kg total initial volume replacement (include fluids received prior to arrival to SCH)

*If no ICU beds are available and patient has received extended care outside of SCH, admit to medical unit only if: 2:1 patient to nurse ratio, and after discussion with Endocrinology, ED and ICU attendings, shift administrator, medical and PICU charge RNs, and Risk RN

**Includes any labs from outside hospital

GUIDELINE EXCEPTIONS FOR LESS COMMON CLINICAL SCENARIOS

Shock

- Shock may require more aggressive volume resuscitation to restore end organ perfusion.

Severe dehydration

- Up to three fluid boluses may be required to restore circulation. They should each be administered over 30-60 minutes in 10 mL/kg aliquots to reduce risk of cerebral edema.

Severe electrolyte abnormalities or acidosis

- **Sodium**: If presentation HYPO- or HYPERnatremia or other risks for cerebral edema are present, then use NS (bag 1) and D10 NS (bag 2) for up to 12 hours from therapy initiation or until the corrected sodium has normalized to reduce risk for cerebral edema.
- **Potassium**: Replacement is required for all patients. Initiation of potassium replacement usually begins with Phase 1 at the time of insulin infusion start, unless hyperkalemia is present. Generally replace potassium with 40 mEq/L of potassium unless there is severe hyperkalemia or hypokalemia. If K< 3.5 at presentation, use 60 mEq/L of potassium early. Hyperkalemia: K > 5.5 mEq/L on two consecutive measurements - free flowing sample, not hemolyzed.
- **Chloride**: Hyperchloremic non-anion gap metabolic acidosis can occur with administration of large volumes of high chloride concentration containing fluids. However, a decrease in BOHB to < 1 mmol/L signals resolution of DKA, readiness to transition.
- **Magnesium**: do NOT replace in the routine management of DKA.
- **Phosphate**: do NOT replace in the routine management of DKA; if muscle weakness necessitates, administer potassium phosphate salts and monitor for induced hypocalcemia.
- **Bicarbonate**: do NOT administer in the routine management of DKA; if severe acidosis necessitates, administer 1-2 mEq/kg bicarbonate over 60 minutes; ensure adequate ventilation.

Insulin Sensitivity

- Low dose insulin infusion is the standard of care; a rate less than 0.1 units/kg/hour is indicated in certain cases. Consider starting at 0.025 units/kg/hour for children less than 5 years of age, or decrease rate if patient demonstrates extreme insulin sensitivity. However, avoid discontinuing insulin in the setting of rapid glucose fall and/or evolving hypoglycemia—rather increase the concentration of infused glucose utilizing the two-bag system during ketosis.

ICU Admission Criteria

- If ICU beds are not available, then patients may be transferred to the medical floor **only if** **1:2 nurse to patient ratio** for monitoring is available and after **discussion with** and **approval from all (a) Endocrine f**ellow or attending, (b) ICU attending physician or fellow, (c) medical floor attending (if not Endocrine), (d) Acute Care Charge Nurse, and (e) Shift Administrator.

Transition to subcutaneous insulin other than mealtime when BOHB<1mmol/L.

Discuss with on-call endocrinologist

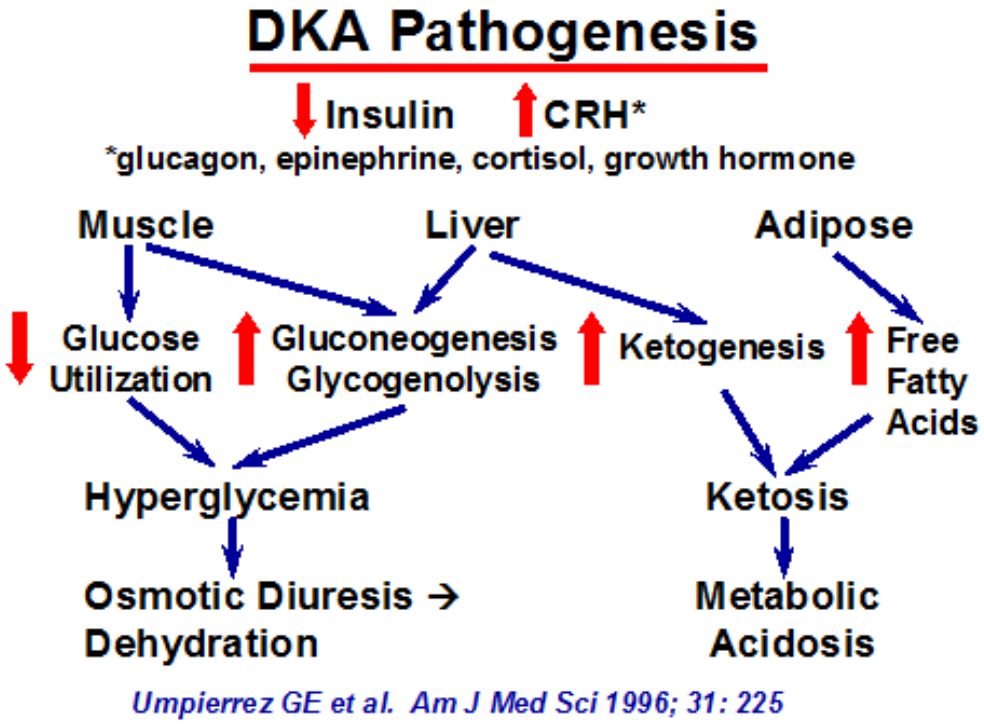
Complications

Please see Complications (page 29) for specific details

GUIDELINE RECOMMENDATIONS

1. BACKGROUND

The cause of DKA is a deficiency of insulin, with resultant unabated gluconeogenesis and lipolysis and impaired muscle glucose utilization. This metabolic milieu generates hyperglycemia and ketosis associated with osmotic diuresis with water and electrolyte losses and metabolic acidosis. DKA is characterized by severe depletion of water and electrolytes from both the intra- and extracellular fluid compartments. The magnitude of specific deficits at presentation varies depending upon the duration and severity of illness and the amount and content of the food and fluids consumed prior to coming to medical attention[1,2].



*CRH=Counter Regulatory Hormones

The goals of DKA therapy are to:

1. Correct the insulin deficiency
2. Reestablish circulating volume and then gradually correct dehydration
3. Reverse the ketosis and resolve the metabolic acidosis
4. Normalize the blood glucose levels
5. Replenish electrolyte losses
6. Identify any precipitating events
7. Avoid complications
8. Prevent further episodes through diabetes education

2. ASSESSMENT AND INITIAL RESUSCITATION IN THE EMERGENCY DEPARTMENT OR CLINIC

➢ **Thoroughly assess all patients with suspected DKA upon patient's arrival. Assess according to PALS guidelines and ISPAD guidelines.** [LOE: PALS Guidelines, NC][1,3,4]

➢ **Assess airway and breathing prior to addressing circulation.** [LOE: PALS Guidelines, NC][4]

Airway

➢ **Assess, ensure, and maintain the patency of the airway.** [LOE: PALS Guidelines, NC][4]
- Secure the airway in standard rapid sequence process if indicated (i.e. GCS < 8).

Breathing

➢ **Assess and monitor integrity of breathing.** [LOE: PALS Guidelines, NC][4]

➢ **Administer oxygen for patients with circulatory, respiratory or neurologic impairment.** [LOE: PALS Guidelines, NC][4]

➢ **Assess for fruity (ketotic) breath and Kussmaul respirations (rapid, deep sighing).** [LOE: NC][1]
- Signs and symptoms suggestive of respiratory insufficiency (including clinical hypoxia and hypoventilation, slowing of respirations, decreased respiratory effort, decreased O_2 saturations or increasing CO_2 on capnography) should lead one to consider airway interventions and/or adjuncts. These can include additional oxygen, oral/nasal airways, bag mask ventilation and intubation.

Circulation

➢ **Assess dehydration severity but recognize that physical assessment is imprecise.** [LOE: C][5,6]
- ≥10% dehydration (and shock) is suggested by the presence of weak or poorly palpable peripheral pulses, hypotension, and oliguria.

- Classic clinical assessment of dehydration may be complicated by comorbidities, coexisting extravascular and intravascular depletion, metabolic acidosis and catabolic state of patient[6].
- In general, the three most useful individual signs for assessing dehydration in young children and predicting at least 5% dehydration are[7]:
  - Prolonged capillary refill time (normal capillary refill is < 2 seconds)
  - Abnormal skin turgor ('tenting' or inelastic skin)
  - Hyperpnea
  - Additional physical signs to use when assessing degree of dehydration include: mental status changes, dry mucus membranes, sunken eyes, absent tears, weak pulses, tachycardia and cool extremities.

Disability/Neurologic Evaluation

⚠ **Suspect cerebral edema in the presence of altered mental status, neurologic changes, and headache.** [LOE: C, B][8,9]

➢ **Assess and document the Glasgow coma scale (GCS) and neurological assessment at admission and every hour for at least the first 12 hours.** [LOE: LC][10]

➢ **A GCS of ≤13 or symptoms of cerebral edema require immediate ICU care.** [LOE: LC][1]
- History of and/or current headache should be noted. [LOE: NC][1]

➢ **Children with compromised communication disorders or developmental disabilities require special consideration when determining altered mental status**. [LOE: LC][11,12]
- Altered mental status may be seen with severe dehydration as well with/from the metabolic effects secondary to severe DKA and cerebral edema.

Glasgow Coma Scale[10]

Eye Opening Response	Spontaneous--open with blinking at baseline	4 points
	Opens to verbal command, speech, or shout	3 points
	Opens to pain, not applied to face	2 points
	None	1 point
Verbal Response	Oriented	5 points
	Confused conversation, but able to answer questions	4 points
	Inappropriate responses, words discernible	3 points
	Incomprehensible speech	2 points
	None	1 point
Motor Response	Obeys commands for movement	6 points
	Purposeful movement to painful stimulus	5 points
	Withdraws from pain	4 points
	Abnormal (spastic) flexion, decorticate posture	3 points
	Extensor (rigid) response, decerebrate posture	2 points
	None	1 point

Verbal response criteria for children under 5 years.

SCORE	2 to 5 years	0 to 23 months.
5	Appropriate words or phrases	Smiles or coos appropriately
4	Inappropriate words	Cries and consolable
3	Persistent cries and/or screams	Persistent inappropriate crying &/or screaming
2	Grunts	Grunts or is agitated or restless
1	No response	No response

Vital Signs

- **Obtain the patient's height in centimeters and weight in kilograms upon presentation to Seattle Children's Hospital (SCH). Do not rely on estimated weight, referral weight, or guardian report.** [LOE: NC][1]

- **Obtain the temperature, heart rate, blood pressure and respiratory rate. Repeat every 15 minutes until hemodynamically stable.** [LOE: LC]

- **Use routine cardiorespiratory monitors.** [LOE: NC][1,13,14]

Fluid replacement, resuscitation and rehydration

- **Obtain vascular access (and laboratory draw) after initial triage and general assessment.**

- **Secure two peripheral IV lines for (1) fluid resuscitation, maintenance fluids, and insulin and (2) access for frequent blood draws. One line should be large bore if needed for shock resuscitation.**

- **Begin fluid replacement before insulin therapy.** [LOE: NC, C][1]

- **Assume moderate (7%) dehydration if not in shock.** [LOE: LC][6,15-17]

- **Begin fluid replacement immediately with 10 mL/kg using 0.9% normal saline (NS); administered over one hour.** [LOE: NC][1]
  - BE AWARE!!! Large volume fluid resuscitation and rehydration may increase the risk of cerebral edema[18,19].

- **Repeat boluses of 10 mL/kg 0.9% NS each bolus administered over 30-60 minutes to restore normal circulation to a maximum of 30 mL/kg**. [LOE: local LC][1]

- **For the rare DKA patient presenting in overt shock, restore circulatory volume with 20 mL/kg boluses of normal saline. Infuse rapidly through a large bore cannula. Reassess the neurologic status, GCS, and physical exam after each bolus.** [LOE: NC][1,3]

- **Patients who have received greater than 40 mL/kg require an ICU consultation to determine disposition since large volumes of fluid may increase risk for cerebral edema. [Note: Include previously administered fluids prior to arrival at SCH.]** [LC]

- ⚠ **Monitor and document all intake and output, taking caution to include any fluids received at referral center or en route when calculating total fluid received. In some instances, large amounts of oral fluid intake should be considered in calculations.**

3. DIAGNOSIS AND RISK ASSESSMENT

[Assessment and Disposition of DKA]

- **DKA is defined as (1) hyperglycemia >200 mg/dL *and* (2) ketonemia (BOHB > 1 mmol/L) *and* (3) venous pH <7.3 *or* HCO_3 < 15.** [LOE: NC][1,20]
  - Clinical signs and symptoms include dehydration, polydipsia, polyuria, new onset enuresis, nocturia, acetonemia ("fruity" breath), Kussmaul breathing, nausea and vomiting, weight loss, abdominal pain, fatigue and decrease in level of consciousness (including coma).
  - Rarely patients might present in DKA with euglycemia or even hypoglycemia. [2017 Periodic Review: Bhakhri 2012]

- **Obtain the following labs following arrival to SCH if suspected DKA: i-stat blood gas and potassium level, point of care (POC) blood glucose and POC beta-hydroxybutyrate (BOHB).**

- **Once confirmed DKA then follow the lab panel: serum glucose, sodium, potassium, bicarbonate, chloride, BUN, creatinine, magnesium, calcium, phosphorus, blood gas, serum BOHB** *[hyperlink to monitoring].* [LOE: NC][1,20-23]

- **Obtain the following labs as indicated for suspected bacterial infections: blood culture, urinalysis, rapid strep test.** [LOE: LC][1]
  - 30% of DKA is associated with microbial co-morbidity. [LOE: LC][24,25]

Clinical Suspicion

- **Use a combination of predisposing risk factors, historical features, clinical exam, and labs to assess risk. [LOE: A, B, NC]1**
  - Risk factors for episodes of DKA in pediatric patients include patients with a prior history of DKA, those with a history of poor metabolic control, inadvertent or deliberately missed doses of insulin, insulin pump therapy interruptions/failures, adolescent females, psychosocial challenges, including lower socio-economic strata and/or lack of healthcare resources. [LOE: A, B, C]26
  - Obese children with type II diabetes mellitus (T2DM), particularly African-American children, are at risk for presentation in DKA27.
  - Additional risk factors include a concomitant illness (particularly infection), psychiatric disorders including eating disorders, surgery, trauma and other social stressors. [LOE: A]1
  - Additionally the use of high dose glucocorticoids, atypical antipsychotics, diazoxide, and some immunosuppressive drugs have been reported to precipitate DKA. [LOE: B]28-32(26)

Consider the following risk factors during initial assessment	Historical Features	Clinical signs	Labs

• *Prior history of DKA*
• *Missed insulin doses*
• *Adolescent females*
• *Lower socio-economic status*
• *Other psychosocial stressors*
• *Recent illness/infection*
• *Psychiatric disorder*
• *Eating disorder*
• *Surgery*
• *Trauma*
• *Obesity*
• *Use of the following medications:*
  ○ *High dose glucocorticoids*
  ○ *Cyclosporine*
  ○ *Tacrolimus*
  ○ *Sirolimus*
  ○ *Mycophenolate*
  ○ *Diazoxide*
  ○ *Atypical antipsychotics*
	• *Polyuria*
	• *Polydipsia*
	• *New onset enuresis*
	• *Nocturia*
	• *Weight loss*
	• *Abdominal pain*
	• *Fatigue*
	• *Nausea/ vomiting*
	• *Headache*
	• *Confusion*
	• *Candida Infection*
		• *Dehydration*
		• *Kussmaul breathing*
		• *Smell of ketones*
		• *Lethargy*
		• *Vomiting*
		• *Abdominal tenderness*
		• *Mental status changes*
			• *Serum Glucose*
			• *Blood gas*
			• *Na, K, Cl, HCO_3, Ca, Mg, Phos*
			• *BUN/Cr*
			• *BOHB*
			• *Blood culture and UA* **if febrile or history of fever**

- **Decide patient's disposition from the ED based on risk of cerebral edema or other adverse events <u>at presentation</u> (e.g. referring hospital or SCH).** [LOE: C, NC][1,20,33]
- **Admit <u>high risk</u> patients to the ICU if any of the following:** [LOE: LC]
  - **Age ≤ 24 months**
  - **Developmental delay or any condition that compromises communication**
  - **GCS ≤ 13 after volume resuscitation**
  - **Abnormal neurological exam after volume**
  - **Other organ system dysfunction**
  - **Presenting pH ≤ 7.15**
  - **Presenting HCO_3 ≤ 5**
  - **Presenting PCO_2 < 10**
  - **Presenting BUN > 30**
  - **Patient received IV bicarbonate or insulin bolus**
  - **Calculated mOsm > 350**
    [Calculated osmolality= 2xNa + (glucose/18) + (BUN/2.8)]
  - **Patient received > 40 mL/kg total initial volume replacement (include fluids received prior to arrival to SCH)**
  - **Corrected Na< 140 mEq/L or decreasing at 2 hour labs**
    [Corrected Na = Measured Na + (Serum glucose – 100)/100 X 1.6)]

- **Admit (or transfer) medium risk patients to the inpatient unit. [LOE: LC]**
  - **New onset or established DM not meeting ICU admission criteria.**
  - **Unable to manage DM at home.**

- **Discharge low risk patients home (with Endocrinology supervision). [LOE: C, NC]1,34,35**
  - **Established diabetes with resolving acidosis and hyperglycemia in the ED, and able to manage diabetes at home.**
  - **Insulin pump failure with resolving acidosis and hyperglycemia in the ED who has access to long acting insulin, and able to manage diabetes at home.**

4. MANAGEMENT (ALL PHASES)

i. Insulin Replacement

⚠ **NEVER GIVE AN INSULIN BOLUS AT THE START OF THERAPY (PRIOR TO FIRST 10 mL/kg BOLUS OF NS) AS IT MAY INCREASE THE RISK OF CEREBRAL EDEMA.** ⚠ [LOE: C][18]

- **Start regular insulin infusion AFTER completion of first 10 mL/kg bolus of NS that is given over 1 hour during.** [LOE: C, E , NC][18]
  - Typically this will be after the first hour after presentation to the Emergency Department.
  - For patients with an insulin pump, physically remove the pump, tubing, and subcutaneous catheter at onset of insulin infusion.

- **Maintain dose of insulin infusion at either 0.1, 0.05 or 0.025 units/kg/hour until BOHB < 1 mmol/L.**
- **Use 0.1 units/kg/hour for patients with BMI > 85th percentile, suspected insulin resistance, pubertal or post-pubertal**

- **Use 0.025 units/kg/hour for children less than 5 years of age or if patient demonstrates extreme insulin sensitivity.** [LOE: A]36,37 [2017 Periodic Review: Kapellen et Nallasamy 2014]
  - Extensive evidence indicates that continuous 'low dose' **intravenous** insulin administration should be the standard of care. [LOE: A][1,36]
  - Although rehydration alone causes some decrease in blood glucose concentration, insulin therapy is essential to normalize blood glucose, suppress lipolysis, ketogenesis and gluconeogenesis and to restore acid base balance. [LOE: A][1,37-39]
- **Do <u>not</u> decrease the insulin infusion if the blood glucose concentration decreases too quickly (greater than 100 mg/dL/hr) or falls too low (below 300 mg/dL) before DKA has resolved; rather, increase the amount of glucose administered.** [LOE: NC][1]
  - If the patient demonstrates marked sensitivity to insulin (e.g. some young children with DKA, patients with HHS, and some older children with established diabetes), and is receiving 10% dextrose (D10) through peripheral IV, the insulin dose may be set at 0.025 units/kg/hour <u>provided that metabolic acidosis continues to resolve</u>. Consult Endocrinology.

- **Transition to SC insulin when BOHB is < 1 mmol/L. Administer basal and if eating short acting insulin as well** (Transition Phase). [LOE: B][21-23]

ii. Electrolytes and Acidosis

- **Replace electrolyte deficiencies <u>AFTER restoring circulating volume and starting the insulin infusion</u>.** [LOE: NC] [1]

- **The clinician should be familiar with the principles of fluid and electrolyte replacement therapy.** [LOE: LC]
  - There are no data to support the use of colloid in preference to crystalloid in the treatment of DKA. [LOE: NC][1]

- Sodium and the extracellular and intracellular fluid deficit of water must be replaced. [LOE: A][1]
- Improvement of glomerular filtration will enhance clearance of glucose and ketones from the blood.
- Hyperglycemia in a DKA state causes an increased osmolality that result in osmotic diuresis with resultant loss of water. [LOE: NC][1]
- Water, sodium, potassium, phosphate and glucose are lost in the urine with diuresis. [LOE: NC][1]
- Hyperosmolality results in a shift of water from the intracellular to the extracellular compartment.
- Administration of large amounts of 0.9% saline has been associated with the development of hyperchloremic metabolic acidosis that may complicate identification of the resolution of DKA. [LOE: NC][40,41]. Accordingly volume replacement is changed from normal saline to 0.45% saline after four hours unless hyponatremia is developing or there is concern for clinically significant, overt cerebral edema. [LOE: LC][1,20]
- No treatment strategy can be definitively recommended as being superior based on evidence. However, ICP increases with IV fluid administration, and the rise is greater with use of hypotonic fluids, suggesting that use of isotonic saline at a slower rate may be prudent if there are no signs of frank shock. [LOE: NC][1]

SODIUM

- ➢ **Use calculated corrected sodium to guide subsequent fluid and electrolyte therapy in addition to clinical assessment of dehydration.** [LOE: NC][42-44]

Corrected Na = measured Na + [(Serum glucose as mg/dL – 100)/100] X 1.6

- **If corrected Na is trending downward and/or falls below 140 mEq/L, adjust maintenance fluids to contain normal saline and increase frequency of serum sodium monitoring.** [LOE: C, LC]

- **If corrected sodium decreases to < 130 mEq/L, begin an infusion of 2% or 3% saline through peripheral IV access (if central venous access is available).** [LOE: LC]

- **Switch to 0.45% saline (0.45 S) after 0.9% normal saline (NS) is complete (first 4 hours) unless hyponatremia exists (corrected sodium < 140 mEq/L) or there is ongoing concern for cerebral edema.** [LOE: C, NC][42,43]
  - Most commonly sodium levels are low secondary to the shift of water from the intracellular compartment into the extracellular fluid compartment. However, serum Na can be normal or elevated due to osmotic diuresis from an increased loss of water in excess of sodium.
  - Sodium levels should increase once fluid resuscitation begins, and as the serum glucose concentration decreases. [LOE: A][1]
  - Uncorrected serum sodium levels are not a reliable way to monitor sodium levels due to elevated glucose and lipids[1,44]. Instead, sodium should be corrected as detailed above and corrected serum sodium maintained $\geq$ 140 mEq/L.

- A failure of uncorrected serum sodium levels to rise as glucose falls (resulting in a fall of effective serum osmolality) with treatment may represent a risk factor for the development of cerebral edema. [LOE: NC][8,45-49]

POTASSIUM

- **Start potassium at same time of initial volume expansion if hypokalemia (K< 3.5 mEq/L) exists at presentation with 60 mEq/L of potassium salts.** [LOE: NC][1]

- **Generally start potassium following fluid resuscitation unless hyperkalemia exists (K > 5.5 mEq/L on two consecutive measures (free flowing sample, not hemolyzed) at presentation.** [LOE: NC][1]

- **If potassium abnormalities exist, measure serum potassium every 2 hours.**

- **If severe potassium abnormalities exist (especially hyperkalemia), monitor ECG for potassium-associated changes.** [LOE: LC]

- **Replace potassium with 40 mEq/L of potassium salts unless there is severe hyperkalemia or hypokalemia. Use a combination of 20 mEq/L of potassium acetate and 20 mEq/L of potassium phosphate to avoid unnecessary chloride administration.** [LOE: C, NC][1]
  - Potassium replacement therapy is eventually required regardless of the serum potassium concentration. [LOE: NC][1,50,51]
  - Potassium replacement generally should start at the same time as the insulin infusion.
  - Due to cellular shifts of intracellular potassium, the child in DKA has a total body potassium deficit. The patient often presents with hyperkalemia due to concomitant acidosis but may also present with hypokalemia. Once insulin is started, potassium levels can drop rapidly. Replacement therapy is required regardless of the serum potassium concentration. [LOE: A , NC][1,13,14].

PHOSPHATE AND CALCIUM

- **Monitor calcium when administering potassium-phosphate as phosphate replacement may induce hypocalcemia.** [LOE: C][52,53]

- **If severe hypocalcemia exists, monitor ECG for calcium-associated changes.** [LOE: LC]

- **Treat severe hypophosphatemia if in conjunction with unexplained weakness.** [LOE: NC]
  - DKA patients may be depleted of intracellular phosphate. However, there is no proven clinical benefit from phosphate replacement, but potassium phosphate can be given safely. [LOE: A] [54,55]

MAGNESIUM

- **Do not replace magnesium in the routine care of the DKA patient [LOE: NC]1.**
  - Initial magnesium levels assist in interpreting calcium homeostasis.

- There is no proven clinical benefit from magnesium replacement.
- Magnesium replacement is unnecessary because levels are often erroneously low and normalize with DKA treatment and introduction of diet.

ACIDOSIS: (ß-hydroxybutyrate (BOHB) and bicarbonate)

- **BOHB levels should be monitored every 2 hours until < 1mmol/L.** [LOE: C][54].
  - There are two major ketone bodies that cause acidosis in DKA – BOHB and acetoacetate. Beta-hydroxybutyrate is the predominant ketone body in DKA but is not detected with urine ketone measurements. Acetoacetate is detected in urinary ketone measurements. Acetone, which results in fruity-smelling breath, does not contribute to acidosis.
  - Beta-hydroxybutyrate levels represent the best indicator of ketosis and resolution of DKA. [LOE: LC, B, D][1,23,56-64]
  - Beta-hydroxybutyrate levels reflect the impact of fluid resuscitation and insulin administration on the child's ketosis; as pH and PCO_2 levels increase, BOHB levels decrease[22,23].
  - Bedside BOHB meters can provide real-time results to dictate treatment changes, simultaneously with bedside electrolyte, blood gas, and glucose measurements.
  - Use of site-of-care BOHB testing has been associated with decreased ICU length of stay and laboratory costs[62].
  - Normalization of BOHB levels is a strong indicator for transition to subcutaneous insulin. Discontinue the insulin drip and begin SC insulin when BOHB is < 1 mmol/L. [LOE: LC, B][22,23]

Comparison of Urine and Blood Ketones [LOE: D][65]

Urine Ketones		Blood BOHB
Negative	< 0.5 mmol/L	≤ 0.5 mmol/L
Trace	0.5 mmol/L	0.6-0.9 mmol/L
Small	1.5 mmol/L	1.0-1.4 mmol/L
Moderate	4.0 mmol/L	1.5-2.4 mmol/L
Large	8.0 mmol/L	2.5-2.9 mmol/L
Very Large	16 mmol/L	≥ 3.0 mmol/L

- **Bicarbonate administration should NOT be used in the routine management of DKA. [LOE: NC. A]1**
  - If the acidosis is profound and thought to be adversely affecting cardiac contractility during resuscitation, bicarbonate may be considered. [LOE: A][1,66]
  - Controlled trials have shown no clinical benefit from bicarbonate administration and its use is contraindicated. [LOE: B, C][67-69]

iii. Two-Bag System and Ongoing Fluid Management (after restoration of circulation)

- **Utilize the Two-Bag System for correction of DKA dehydration. [LOE: B, C]44,70-72**

- The two-bag system:
  - Uses the simultaneous administration of two intravenous (IV) fluid bags each with identical electrolytes, but one bag contains 10% dextrose (D10) and the other does not.
  - Empowers the bedside nurse to adjust the infusion rate of each bag to address fluctuations in the patient's serum glucose without altering the insulin rate.
  - Reliably meets the changing glucose of a child with DKA on an insulin drip. [LOE: LC]
  - Prevents waiting for rehydration fluid decisions, pharmacy delivery, and nurse administration.
  - Relies on a calculation of percentage of fluids to be administered based on the fluid administration rate.

- **Order the two-bag system in the ED or ICU upon confirmation of DKA following the recommended timeline and Phases. Use weight-based clinical calculator to determine IV fluid rate**. [LOE: local LC]

- **Utilizing the Clinical Calculator determine the total volume requirement, after subtracting out initial resuscitation fluids (including those received at transferring hospital or en route), and replace over 48 hours.** [LOE: C, NC][1]

- **Include all fluids administered prior to or during transfer in calculations for fluid replacement.**
  - In some instances consideration may need to be given to large amount of oral fluids consumed prior to medical therapy. [LOE: NC][1]

- **Assume 7% dehydration to calculate fluid replacement for the two-bag system (i.e. 0.07 x __kg x 1000 mL/kg= ___mL of dehydration deficit)**[6,15,17,73].
  - May need to increase percent dehydration for the rare patient with DKA and hypovolemic shock.

- **Generally institute the two-bag system employing normal saline for DKA volume replacement during the first 4-6 hours following DKA diagnosis. This typically would occur following initial normal saline bolus(es).** [LOE: C, NC][20,46,74-77]

- **Generally institute the two-bag system employing 0.45% saline following 4 hours[1] of the two-bag system employing normal saline, unless there is particular concern for development or progression of cerebral edema. In this case continued use of the two-bag system employing normal saline is warranted.**

- **Rate of total volume administration during use of the two-bag system includes: [(maintenance fluid for 2 days + 7% deficit volume) – resuscitation fluid received in the ED and prior to arrival at the ED] / 48 hours. This is calculated utilizing the Clinical Calculator.**

- **Insulin rate does not typically change and the dose is to remain at 0.025 or 0.05 or0.1 units/kg/hour.** [LOE: B][22,23,78-80] Please see further details in Section 4.

- **Patient is to remain NPO while on insulin infusion.** [LOE: NC][1] However, Endocrinology may approve a NON-carbohydrate containing snack.
- **D10% should be turned on with the two-bag system when the plasma glucose falls to <300 mg/dL, or sooner if the rate of fall is precipitous (i.e. > 100 mg/dL/hour) to prevent a rapid decrease in plasma glucose concentration and hypoglycemia. In the case of precipitous glucose fall, discuss management with Endocrinology fellow or attending.** [LOE: B][1]
- **If the patient's corrected sodium has fallen below 140 mEq/L or there is serious concern for evolving cerebral edema, 0.9% saline should be used instead of the 0.45% saline for replacement fluid.** [LOE: LC]
- **If blood glucose < 100 mg/dL, continue the IV fluid component total rate of infusion of the two-bag system, but administer as 12.5% dextrose with appropriate potassium supplement and decrease the insulin infusion to 0.05 units/kg/hr or less following discussion with Endocrinology fellow or attending.** [LOE: LC].
- **If 12.5% dextrose is started or the insulin infusion needs to be decreased the Endocrinologist on call must be notified.** Check BOHB results and consider readiness for transition off insulin infusion. [LOE: LC]
- **Once on subcutaneous (SC) insulin and the insulin infusion has been discontinued the intravenous fluids of the two-bag system can be turned off unless further potassium and/or dextrose supplementation or intravenous rehydration is required.**

EXAMPLE of determination of total volume of fluid replacement over 48 hours

- ❑ Calculate the fluid deficit (assumed to be 7%)
- ❑ Calculate and add the maintenance fluid for two days
- ❑ Determine and subtract the amount of fluid received prior to arrival
- ❑ Determine and subtract the amount of "initial" fluid received in ED or ICU
- ❑ Administer the net fluid volume over 48 hours starting from initial presentation.

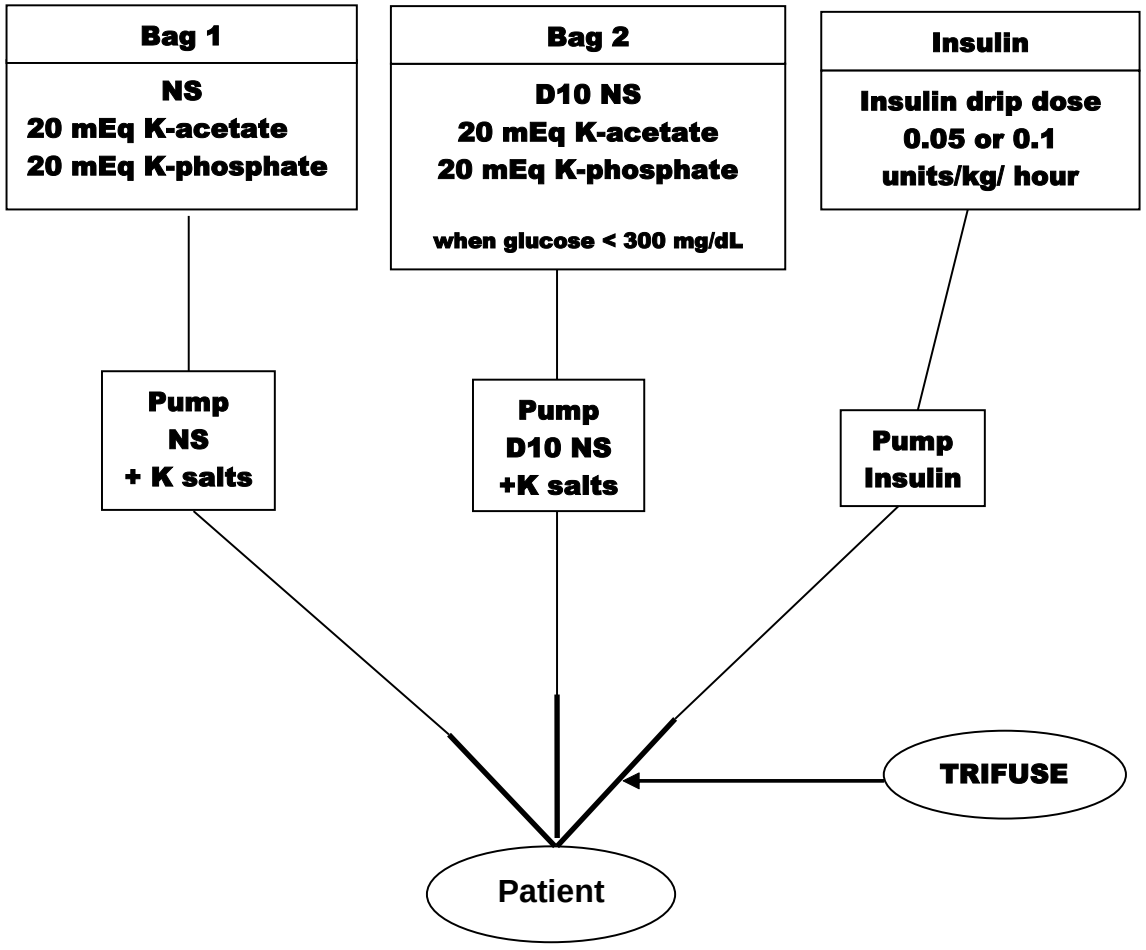
For example, for an 18 kg child with DKA:

With assumed 7% dehydration, the deficit is 70 mL/kg or 1260 mL.
Calculated maintenance fluid is 1400 mL/day or 2800 mL for 2 days.
Total fluid needs are 1260 (deficit) + 2800 (2 days of maintenance) or 4060 mL for two days.
Subtract from this total, all fluid administered during the initial volume resuscitation and administer the difference over 48 hours. If 10 mL/kg (180 mL) were administered at an outside hospital and 20 mL/kg of normal saline boluses (360 mL) were administered at presentation to SCH, 4060-180-360 = 3520 mL/48 hours or 73 mL/hr.

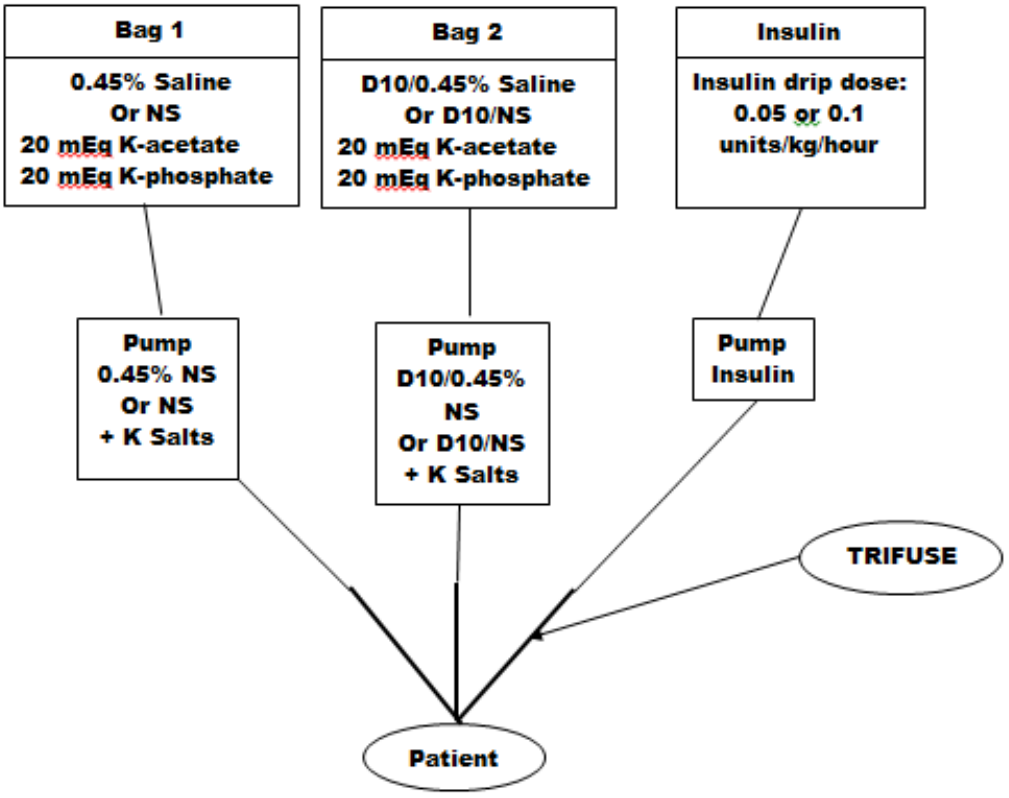
SCH Weight	Fluids received prior to arrival	Fluids received during volume resuscitation	Calculate Fluid Deficit	Calculate Maintenance Fluids for 2 days	Total fluid needs for 48 hrs	Subtract Fluids received	Volume for IVF administration over next 48 hr
18kg	10 mL/kg at outlying ED	10 mL/kg x 2 in SCH ED	7% =70 mL/kg	= 1400 mL/day x 2 days	2800+1260	4060 -540	3520/48
	= 180 mL	= 360 mL	= 1260 mL	= 2800 mL	=4060 mL	= 3520 mL	=73 mL/hr

- ➢ **The Phase 1 of Two-bag system is to commence following DKA diagnosis.**
- ➢ **The Phase 2 of Two-bag system is to commence following the initial four hours of normal saline administration.**

Phase 1 of Two-bag System



Phase 2 of Two-bag System



**Note:* Connect insulin and maintenance fluids at patient using a bior tri-fuse connector to the IV catheter.

EXAMPLE calculation for of two-bag system with 0.1 units/kg/hour insulin

Blood Glucose (mg/dL)	% of Rate From NS or 0.45% saline with 20 mEq/L KAc 20 mEq/L KPO_4 Bag	% of Rate From D10/NS or D10/0.45% NS with 20 mEq/L KAc 20 mEq/L KPO_4 Bag	Final Dextrose Concentration (%)	Insulin Infusion Rate (units/kg/hr)
>300	100	0	0	0.1
299-250	75	25	2.5	0.1
249-200	50	50	5	0.1
199-150	25	75	7.5	0.1
149-100	0	100	10	0.1
< 100	Discontinue the two-bag system and instead use D12.5% concentration with identical saline and electrolyte content Discuss with Attending. Check BOHB results and consider readiness to transition off insulin infusion.			0.1

iv. Transition Phase

Formulate insulin transition plan when BOHB <3 mmol/L in consultation with endocrinology. [LOE: local LC]

- **Discontinue the insulin infusion and begin SC insulin when BOHB is < 1 mmol/L.** [LOE: B, C]
  - The dose and type of SC insulin should be guided by the on-call Endocrinologist according to local preferences and circumstances with consideration to such factors as age, previous dosing, pubertal state, systemic inflammation and length of honeymoon period. [LOE: NC][1]

- **Plan transition to SC insulin at breakfast or dinner time.** [LOE: NC][1]
  - When ketoacidosis is resolving (BOHB < 1 mmol/L), oral intake is tolerated, and the change to SC insulin is planned, the most convenient time to change to SC insulin is just before a mealtime. [LOE: NC][1]
  - If not at mealtime basal insulin can be given at the time of transition
  - If eating; also give short acting insulin

- **Give the first SC injection of short acting insulin (if taking oral diet) and basal insulin 30 minutes prior to discontinuing the insulin drip.** [LOE: NC][1]
  - Prevents rebound hyperglycemia and allows sufficient time for the insulin to be absorbed.
  - If blood glucose <100 mg/dl at transition; do not overlap for 30 minutes, stop insulin infusion

- **Start an "Insulin Dependent (carbohydrate counted)" diet with discontinuation of insulin infusion.** [LOE: NC][1]

- **Discuss other mealtime and overnight transitions with the on-call endocrinologist as this may be complex with considerations of low rate insulin infusion, basal insulin or pump therapy.** [LOE: local LC]

- **Monitor blood glucose at least 5 times in 24 hours following resolution of DKA.** [LOE: E, NC][1]
  - Fasting morning, pre-lunch, pre-dinner, before bed, 3 am overnight [LOE: local LC] and any additional as needed to avoid marked hyperglycemia and hypoglycemia after transitioning to SC insulin. [LOE: E, NC][1]

5. MONITORING CLINICAL STATUS AND BLOOD CHEMISTRIES

- **Obtain the following labs upon confirmation of DKA: serum glucose, sodium, potassium, bicarbonate, chloride, BUN, creatinine, magnesium, calcium, phosphorus, blood gas, beta-hydroxybutyrate (BOHB).** [LOE: NC][1,22,23]

- **Obtain the laboratory tests as indicated in the table below. For suspected bacterial infections obtain as clinically indicated: blood culture, urinalysis, and rapid strep test.** [LOE: local LC].
  - ~30% of DKA is associated with viral or bacterial condition[24,25].

Lab Schedule

	Confirmed DKA:NS 10 ml/kg begins. Hour 0	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hour 7	Hour 8	Hour 9	Hour 10	Hour 11	Hour 12
TIME													
Glucose	X	X	X	X	X	X	X	X	X	X	X	X	X
Sodium	X		X		X		X		X		X		X
Potassium	X		X		X				X				X
Chloride	X		X		X				X				X
Bicarbonate	X		X		X				X				X
BUN	X												
Creatinine	X												
Magnesium	X				X				X				
Calcium	X				X				X				
Phosphorus	X				X				X				
Blood Gas (CBG, VBG, ABG)					X								
ß-hydroxybutyrate	X		X		X		X		X		X		X
New T1IDM diagnosis labs if indicated	X												
Blood culture if indicated	X												
Urinalysis if indicated	X												

- **In most patients, it is not necessary to continue follow sodium, potassium, chloride, bicarbonate, magnesium, calcium, phosphorus after 8 hours from presentation UNLESS they have not normalized.**

- **Glasgow coma scale (GCS) and neurological assessment will be performed at admission and then <u>every hour for at least the first 12 hours</u>, up to 24 hours.**

- **A GCS of ≤ 13 or symptoms of cerebral edema should prompt a rapid response team (RRT) call or a Code Blue if the patient is not already admitted to the PICU.**

- **Peripheral perfusion should be assessed upon presentation to the Emergency Department, before and after all fluid boluses, and then hourly until restored to normal.**

6. COMPLICATIONS

Cerebral Edema

- **All care providers should be aware of signs and symptoms of cerebral edema:**
  - headache
  - alterations in neurological status (restlessness, irritability, increased drowsiness, incontinence, deterioration of GCS)
  - specific neurological signs including cranial nerve palsies, anisocoria, asymmetric facies or posture, double vision
  - progressive heart rate slowing, rising blood pressure, widening pulse pressure (Cushing's triad)
  - decreasing oximetry saturations

  - Mortality associated with DKA ranges 0.15-0.3% with cerebral edema accounting for the vast majority of these fatalities. [LOE: C, B][8,81,82].
  - Incidence of cerebral edema among patients with DKA ranges 0.5–0.9% with an associated mortality of 21–24% and significant morbidity among survivors. [LOE: C, B][8,82-84]
  - Demographic factors associated with an increased risk of cerebral edema (all of which likely reflect DKA severity at presentation) include:
    - young age [LOE: C][1,8,82]
    - new onset diabetes mellitus [LOE: C, B][8,82]
  - Cerebral edema may develop at any time during the treatment of DKA, although typically occurs 4-12 hours into DKA treatment. [LOE: C, B]8,83,85-87
  - In addition several potential cerebral edema risk factors related to DKA treatment have also been suggested [LOE: C]18,19,45,88,89:
    - greater hypocapnia after adjusting for degree of acidosis at presentation8,90
    - increased BUN at presentation8,83
    - severity of acidosis at presentation18,83
    - use of bicarbonate for treatment of acidosis8
    - attenuated rise in serum sodium concentration during treatment associated with a decrease in effective plasma osmolality45
    - greater volumes of fluid administration during the first 4 hours18
    - administration of insulin in the first hour of fluid resuscitation18

DETERMINING CLINICAL CEREBRAL EDEMA RISK		
Diagnostic Criteria*	**Major Criteria**	**Minor Criteria**
Abnormal motor or verbal response to pain	Altered mentation/fluctuating level of consciousness	Vomiting
Decorticate or decerebrate posture	Sustained heart rate deceleration (more than 20 beats/min) not attributable to improved intravascular volume or sleep state	Headache
Cranial nerve palsy (especially III, IV, and VI) may result in double vision	Age-inappropriate incontinence	Lethargy; not easily aroused
Abnormal neurogenic respiratory pattern (e.g. grunting, central hyperventilation, Cheyne-Stokes respiration, apneusis)		Diastolic blood pressure >90 mm Hg
		Age <5 years

*** One diagnostic criterion, or two major criteria, or one major criteria and two minor criteria have a sensitivity of 92%, a specificity of 96% and a false positive rate of only 4% for the recognition DKA cerebral edema early enough for effective intervention.** [LOE: NC][1,47,91]

Treatment for DKA-associated cerebral edema should occur as soon as the condition is suspected in the following hierarchical order:

- **Ensure adequate circulation; but as possible reduce the rate of fluid administration by one-third.** [LOE: C][1]
- **Ensure an adequate airway and assist ventilation initially by manual bag-mask and subsequently by endotracheal intubation only as necessary.** [LOE: C][1]
- **Avoid maneuvers and drugs likely to increase intracranial pressure if tracheal intubation is undertaken**.
- *In general, avoid endotracheal intubation and ventilation unless the patient is exhausted or hypoventilating for any reason or if airway protective reflexes are lost. If endotracheal intubation and ventilation are undertaken for patients with DKA, target a $PaCO_2$ appropriate for estimated $[HCO_3]_{CSF}$ and treat with great caution those presenting with $pH_{Art} < 7.00$*[92].
- **Elevate the head of the bed and keep the head positioned midline.** [LOE: NC][1]
- **Administer mannitol, 1 g/kg IV over 20 minutes and repeat if there is no initial response (improvement in neurological status) in 30 minutes**. [LOE: C, NC][93-96] [2017 Periodic Review, Decourcey 2013]

- **Alternatively, provide a bolus of 3% saline (central line required) , 5 mL/kg, (if there is no response to mannitol) and initiate a continuous infusion of 3% saline targeting a serum Na of 150-160 mEq/L**. [LOE: C][97,98]

- Consult Neurosurgery for placement of an intracranial pressure monitor. [LOE: LC]

- **After the patient has been stabilized, obtain a CT scan of the head to assess for cerebral edema, thrombosis and intracranial hemorrhage** [LOE: NC][99-102] [2017 Periodic Review, Soto-Rivera 2017]**.** Generally, central nervous system (CNS) imaging should be considered when neurological status has not improved following cerebral edema therapy and/or other CNS complication is suspected.

- **Rule out hypoglycemia and hyponatremia in all cases of altered neurologic status associated with DKA**. [LOE: LC]

See also Increased Intracranial Pressure Treatment *(for SCH only)*

Complication	Association	Treatment
Hypokalemia [2017 Periodic Review, Carlotti 2013, Koves 2014]	Inadequate potassium replacement; ongoing potassium losses. Severe hypokalemia may cause intestinal invagination REF: Akruyek et al, include evidence rating	Increase K replacement; may require concentrated K infusion at 0.1-0.3 mEq/kg/hr
Hyperkalemia	Renal failure	Reduce/eliminate K in IV fluids; continuous renal replacement therapy as necessary
Hypophosphatemia	Renal losses	Will normalize with re-establishment of nutritional support. Severe hypophosphatemia in conjunction with unexplained weakness should be treated [LOE: NC][55]
Hypoglycemia	Failure to add glucose to IV fluids when serum glucose declines below 300 mg/dL	Addition of 5-12.5% dextrose to IV fluids when serum glucose declines below 300 mg/dL
Disseminated intravascular coagulation	Infection, tissue necrosis	Monitor for infection, thrombosis
Central venous thrombosis or stroke[103,104]	Prolonged dehydration; DKA represents a hypercoagulable state[99-102] [2017 Periodic Review, Bilici 2011]	Avoid central venous catheterization, if occurs with CVC anticoagulate
Dural sinus, basilar artery thrombosis or stroke[84,101]	Prolonged dehydration; DKA represents a hypercoagulable state[99-102]	If underlying coagulopathy suspected, anticoagulate[105]
Sepsis	Impaired immunity associated with diabetes mellitus. Antecedent for DKA	Antimicrobials
Mucormycosis[106]	Infection specifically associated with DKA, especially rhinocerebral or pulmonary infections.	Infectious Disease, Otolaryngology consultations. Caspofungin, liposomal amphotericin B[107]
Rhabdomyolysis[108]	Hypophosphatemia, anemia, thrombocytopenia. High osm on admission; more frequent in hyperglycemic hyperosmolar state	Preserve good renal blood flow.
Pancreatitis[109,110]	Associated with abdominal pain but not always, often associated with elevated BUN	Chemical pancreatitis is common in DKA, but clinical pancreatitis is rare. Check lipase, amylase, lipids and calcium levels.

Hyperglycemic Hyperosmolar syndrome [2017 Periodic Review, Wetterl 2012]	Higher risk of thrombosis, rhabdomyolysis, malignant hyperthermia, cerebral edema.	Generally requires more careful fluid therapy, careful Na, K and GCS monitoring. Insulin at 0.05-0.1 units/kg/hr.
Hyperchloremic metabolic acidosis[111] [2017 Periodic Review, Prashanth 2014]	Large volume resuscitation with normal saline.	Use potassium as K acetate and K phosphate to replace K.
Granuloma annulare [2017 Periodic Review, Agrawal 2012]		
Extrapontine myelinolysis [2017 Periodic Review, Gencipar 2014]		
Neuropsychological sequelae [2017 Periodic Review, Cameron 2014]		
Hypertriglyceridemia lipemic serum [2017 Periodic Review, Lufti 2012, Williamson 2012]		

7. EDUCATION

- **Prevention of DKA is paramount for diabetes care.** [LOE: NC][1]
  - Every episode of DKA in patients with previously diagnosed diabetes is preventable.

- **Education for the newly diagnosed patient begins when ketoacidosis (DKA) is resolved and should focus on the primary education of the patient (if possible based on age) and family about diabetes.** [LOE: NC][112]
  - Education is an important aspect in management of diabetes and aids in glucose control.
- **Provide written materials for reference (local preference: Understanding Diabetes[113], by Dr. Peter Chase).**
- **Exceptions to standard inpatient education for newly diagnosed diabetes patients recovering from DKA will only be made at the discretion of the endocrinology attending.**
- **The length and intensity of education of the patient with established diabetes who has recovered from DKA should focus on preventing future occurrences and should be determined by the endocrinology attending but should emphasize the following:** [LOE: LC]

  - **Need for increased parental supervision.**
  - **Need for routine administration of basal insulin or the need to use backup injectable insulin in the case of pump malfunction.**
  - **Need to routinely measure ketones either in the blood or urine.**
  - **Need to administer additional insulin during times of illness. Patients should be referred to the Division of Endocrinology sick day management guidelines at http://www.seattlechildrens.org/pdf/PE288.pdf**

- **A psychosocial evaluation by a skilled interviewer (such as a social worker) should be performed if there is a concern from the diabetes team that other factors may influence the development of DKA.**

8. DISCHARGE

- Hospital discharge criteria are as follows [LOE: LC]:
  - Resolution of metabolic acidosis (pH >7.29 or bicarbonate >15).
  - Mental status is at baseline.
  - Appropriate follow up has been arranged.
  - A clinic visit for diabetes provider must be scheduled no later than three months from the time of discharge for patients with established diabetes and 4 weeks for a newly diagnosed patient. Patients must have ready phone access to a health care provider who can help adjust insulin doses if needed prior to the clinic visit.
  - The cause of DKA, if identified, has been adequately addressed through education.
  - The patient and family have demonstrated knowledge to recognize the signs and symptoms of hyperglycemia with ketones/DKA, have demonstrated that they can check blood/urine ketones, and how to institute appropriate management.

- All patients should be given written materials about management of diabetes while ill (either from, Understanding Diabetes, by Dr. Peter Chase or from the Division of Endocrinology sick day management guidelines found at **http://www.seattlechildrens.org/pdf/PE288.pdf**
- All patients should be asked to call into the diabetes nurses' line at 206-987-5452 to review blood glucoses within 48 hours after discharge unless follow up with another health care provider is arranged.

- Call the diabetes phone line at (206) 987-5452 to review blood glucoses. For urgent diabetes-related questions, call (206) 987-2000 and ask for the on-call nurse Mon-Fri from 7 am to 5:30 pm, and the on-call doctor after hours.

1. ORDER SETS
TWO-BAG SYSTEM WEIGHT BASED DOSE CALCULATOR

IV fluid rate for patients with Diabetic Ketoacidosis

Fill in the yellow boxes and everything else will be calculated.

Weight of patient	100	kg
Maximum calculation weight used is 80 kg.		
Severity of Dehydration - assume:	7	percent
Fluid deficit = weight (max: 80 kg) * percentage dehydrated	5600	ml
VOLUME RESUSCITATION		
TOTAL fluids administered during resuscitation phase	4000	ml = 50 ml/kg
This is greater than 40 ml/kg, contact ICU for evaluation.		
Maintenance fluids for one day:	2700	ml
Total fluids to administer over 48 hours (maintenance * 2 + deficit - resuscitation)	7000	ml
NOTE: Formula is such that we never provide less than 1 x maintenance fluids.		
TOTAL IV FLUID RATE:	146	ml / hr

TWO-BAG SYSTEM EDUCATION MATERIALS

Instructions for use of the Two-bag System

Generally institute the two-bag system following initial normal saline resuscitation. Rate of total volume administration during use of the two-bag system is the maintenance/deficit fluid infusion rate calculated as: [(maintenance fluid for 2 days + 7% deficit volume) – resuscitation fluid received in the ED and prior to arrival at the ED] / 48.

The two-bag system delivers 0.9% normal saline or 0.45% saline, with 20 mEq/L potassium acetate (KAc) and 20 mEq/L potassium phosphate (KPhos) and variable dextrose. If the patient's corrected sodium has fallen below 140 mEq/L or there is serious concern for evolving cerebral edema, 0.9% saline should be used instead of the 0.45% saline for replacement fluid. If the patient has hyperkalemia with K > 5.5 mEq/L, potassium replacement should be monitored and delayed until normokalemia.

Blood Glucose (mg/dL)	% of Rate From 0.45% saline 20 mEq/L KAc 20 mEq/L KPhos Bag	% of Rate From **10%** Dextrose 0.45% saline 20 mEq/L KAc 20 mEq/L KPhos Bag	Final Dextrose Concentration (%)	Insulin Infusion Rate (units/kg/hr)
>300	100	0	0	0.1
299-250	75	25	2.5	0.1
249-200	50	50	5	0.1
199-150	25	75	7.5	0.1
149-100	0	100	10	0.1
< 100	Discontinue the two-bag system and instead use D12.5% concentration with identical saline and electrolyte content Discuss with Attending. Check BOHB results and consider readiness to transition off insulin infusion.			0.1

APPENDIX

ICU discharge criteria:
(These criteria were developed by agreement of stakeholders based on local service provision and there is no evidence base behind these criteria.)

1. BOHB ≤ 3 mmol/L and

2. GCS =15 or at premorbid baseline and

3. K requirement can be maintained with ≤ 60 mEq/L supplementation and

4. No ICU care needed for any other reason

For patients with BOHB ≤ 3 mmol/l overnight consider early morning transfer. Discuss the transition period with Endocrinologist.

Exception: Hyperosmolar Dehydration.

Where Should the Child be Managed?

The child should receive care in a unit that has:

- Experienced nursing staff trained in monitoring and management
- Written guidelines for DKA management in children
- Access to laboratories that can provide frequent and timely measurements of biochemical variables
- A specialist/consultant pediatrician with training and expertise in the management of DKA should direct inpatient management.

Children with severe DKA (long duration of symptoms, compromised circulation, or depressed level of consciousness) or those who are at increased risk for cerebral edema (e.g., < 5 years of age, severe acidosis, low pCO_2, high blood urea nitrogen) should be considered for immediate treatment in an intensive care unit (pediatric, if available) or in a unit that has equivalent resources and supervision, such as a children's ward specializing in diabetes care (C,E) (5, 42).

Reference:

ISPAD International Consensus:
Wolfsdorf J[1], Craig ME, Daneman D, Dunger D, Edge J, Lee W, Rosenbloom A, Sperling M, Hanas R. (2009). Diabetic ketoacidosis in children and adolescents with diabetes. *Pediatr Diabetes,* 10 Suppl 12:118-33, Page 121. doi: 10.1111/j.1399-5448.2009.00569.x

Evidence Ratings

2011 KEY TO LEVELS OF EVIDENCE

M =Meta-analysis or Systematic Review
A =Randomized controlled trial: large sample
B =Randomized controlled trial: small sample
C=Prospective trial or large case series
D= Retrospective analysis
O= Other evidence
S=Review article
LC =Expert opinion or consensus
NC = National consensus
F =Basic Laboratory Research
X= No evidence

This will appear in the text as [LOE: M]

2017 KEY TO LEVELS OF EVIDENCE

This Periodic Review was developed through local consensus based on published evidence and expert opinion as part of Clinical Standard Work at Seattle Children's. Pathway teams include representatives from Medical, Subspecialty, and/or Surgical Services, Nursing, Pharmacy, Clinical Effectiveness, and other services as appropriate.

When possible, we used the GRADE method of rating evidence quality. Evidence is first assessed as to whether it is from randomized trial or cohort studies. The rating is then adjusted in the following manner (from: Guyatt G et al. J Clin Epidemiol. 2011;4:383-94.):

Quality ratings are *downgraded* if studies:

- Have serious limitations
- Have inconsistent results
- If evidence does not directly address clinical questions
- If estimates are imprecise OR
- If it is felt that there is substantial publication bias

Quality ratings are *upgraded* if it is felt that:

- The effect size is large
- If studies are designed in a way that confounding would likely underreport the magnitude of the effect OR
- If a dose-response gradient is evident

Guideline – Recommendation is from a published guideline that used methodology deemed acceptable by the team.

Expert Opinion – Our expert opinion is based on available evidence that does not meet GRADE criteria (for example, case-control studies).

Quality of Evidence:
✪✪✪✪ High quality
✪✪✪○ Moderate quality
✪✪○○ Low quality
✪○○○ Very low quality
Guideline
Expert Opinion

Return to Algorithm

To Bibliography

Summary of Version Changes

Version 1.0 (4/1/2011): Go live

Version 2.0 (2/27/2013): Algorithm introduced, CIS Powerplan added, BOHB point of care testing initiated, Transition Phase (IV to subcutaneous insulin) revised

Version 2.1 (3/13/2013): Corrected language around blood glucose <100 mg/dL recommendation.

Version 2.2 (12/17/2014): Changes made to add language to warning triangle regarding where patients should be managed.

Version 3.0 (4/19/2016): Yellow triangle added to the transition phase to provide guidance on the transition from insulin drip to subcutaneous.

Version 4.0 (7/12/17): Changes include

General Enhancements to the DKA Pathway include:

- CIS enhancements to the Power Plan to simplify ordering into three phases: suspected, confirmed and transition
- Simplified appearance of the algorithm for improved usability
- More conservative approach to initial fluid administration
- Improved lab schedule in the treatment of DKA in each phase, now including the transition phase
- Earlier replacement of potassium in phase 1 & 2 to prevent hypokalemia
- Hypokalemia for DKA is defined as less than 3.5 mEq/L
- Updated language to clarify admission criteria to the PICU and Medical Unit
- Expanding the use of point of care BOHB to other areas of care, such as the PICU and Medical unit (FY18)
- More conservative insulin administration

Insulin Management Recommendations

- Use 0.05 units/kg/hour insulin infusion rate as the standard starting dose
  - New
- Start insulin infusion therapy 1 hour after fluid resuscitation.
  - Current state
- Do not use insulin bolus therapy.
  - Current state
- Use 0.1 unit/kg/hour insulin infusion rate for patients with any of the following: insulin resistance, BMI>85th percentile, pubertal or post-pubertal.

  NOTE: 30% increase in insulin requirement with puberty.
- Use 0.025 units/kg/hour insulin infusion rate with any of the following:<5 years old or insulin sensitive.
- Avoid added glargine (basal insulin) during insulin infusion therapy as it is described to increase the risk of hypokalemia.
- Avoid subcutaneous short acting insulin used to replace insulin infusion therapy during DKA management in children as there is no evidence to support superiority of this practice.

Return to Algorithm

Summary of Version Changes page 2

Version 5.0 (2/4/2020): Changes include

- Added Mild, Moderate, and Severe DKA definitions (from ISPAD Guidelines) to Criteria and Overview Page
- Added footnote to High Risk/ICU Criteria, indicating that “Serum Na is to be corrected only if abnormal”
- On Insulin, Fluid & Electrolytes - Phase 1 & 2 page, corrected K to ≤ 60 mEq/L (previously said <40)
- On Transition Phase page, a reference to the Nursing Job Aid was added

Return to Algorithm

Medical Disclaimer

Medicine is an ever-changing science. As new research and clinical experience broaden our knowledge, changes in treatment and drug therapy are required.

The authors have checked with sources believed to be reliable in their efforts to provide information that is complete and generally in accord with the standards accepted at the time of publication.

However, in view of the possibility of human error or changes in medical sciences, neither the authors nor Seattle Children's Healthcare System nor any other party who has been involved in the preparation or publication of this work warrants that the information contained herein is in every respect accurate or complete, and they are not responsible for any errors or omissions or for the results obtained from the use of such information.

Readers should confirm the information contained herein with other sources and are encouraged to consult with their health care provider before making any health care decision.

Return to Algorithm

2011 Diabetic Ketoacidosis (DKA) Citation

Approved by the CSW Diabetic Ketoacidosis (DKA) team for April, 2011

CSW Diabetic Ketoacidosis Team 2011:

CSW Owner	**Ildiko H. Koves, MD, FRACP**
ED Clinical Nurse Specialist	**Elaine Beardsley, RN, MN**
Pediatric Intensive Care	**Heather Hawk, RN, DNP**
Clinical Nurse Specialist	**Kristi Klee, MSN, RN-BC**
Pharmacy	**Gretchen A. Linggi Irby, PharmD**
Emergency Medicine	**Russ Migita, MD**
Clinical & Translational Research	**Joel Tieder, MD, MPH**
Clinical & Translational Research	**Tony Woodward, MD, MBA**
Clinical & Translational Research	**Jerry Zimmerman, MD**

Clinical Effectiveness Team:

Consultant:	**Jean Popalisky, DNP**
Project Manager:	**Kate Drummond, MS, MPA**
Project Manager:	**Jennifer Magin, MBA**
CE Analyst:	
CIS Informatician:	**Michael Leu, MD, MS, MPA**
CIS Analyst:	**Heather Marshall**
Librarian:	**Susan Klawansky**
Program Coordinator:	**Ashlea Tade**

Executive Approval:

Sr. VP, Chief Medical Officer	Mark Del Beccaro, MD
Sr. VP, Chief Nursing Officer	Madlyn Murrey, RN, MN
Surgeon-in-Chief	Bob Sawin, MD

Return to Algorithm

2017 Diabetic Ketoacidosis (DKA) Periodic Review Citation

Approved by the CSW Diabetic Ketoacidosis (DKA) Periodic Update team for July 13, 2017

CSW Diabetic Ketoacidosis Periodic Review Team 2017:

CSW Owner	**Ildiko H. Koves, MD, FRACP**
ED Clinical Nurse Specialist	**Elaine Beardsley, RN, MN**
Pediatric Intensive Care Clinical Nurse Specialist	**Hector Valdivia, RN, MN**
Clinical Nurse Specialist	**Rebecca Engberg, BSN, RN, CPN**
Clinical Nurse Specialist	**Coral Ringer, RN**
Pharmacy	**Gretchen A. Irby, PharmD**
Emergency Medicine	**Anne Slater, MD**
Emergency Medicine	**Stanford Heath Ackley, MD**
Critical Care, PICU	**Lauren Rakes, MD**
Critical Care, PICU	**Elaine Albert, MD, MHA**
Critical Care, PICU	**Jerry Zimmerman, MD**

Clinical Effectiveness Team:

Consultant:	**Jean Popalisky, DNP**
Project Manager:	**Dawn Hoffer**
CE Analyst:	**Holly Clifton**
CIS Informatician:	**Michael Leu, MD, MS, MPA**
CIS Analyst:	**Heather Marshall**
Librarian:	**Peggy Cruse, MLIS**
Program Coordinator:	**Kristyn Simmons**
Literature Reviewer:	**Eileen Reichert, ARNP**

Retrieval Website: http://www.seattlechildrens.org/pdf/DKA-pathway.pdf

Please cite as:
Seattle Children's Hospital, Koves IH, Ackley, H, Albert EJ, Beardsley E, Engberg R, Irby GA, Leu M, Popalisky JC, Rakes L, Reichert E, Ringer C, Slater A, Valdivia H, Zimmerman JJ. 2017 July. Diabetic Ketoacidosis (DKA) Pathway. Available from: http://www.seattlechildrens.org/pdf/DKA-pathway.pdf

Return to Algorithm

Seattle Children's
HOSPITAL • RESEARCH • FOUNDATION

Bibliography 2011

1. Wolfsdorf J, Craig ME, Daneman D, et al. Diabetic ketoacidosis in children and adolescents with diabetes. Pediatr Diabetes 2009;10 Suppl 12:118-33.
2. Umpierrez GE, Khajavi M, Kitabchi AE. Review: diabetic ketoacidosis and hyperglycemic hyperosmolar nonketotic syndrome. Am J Med Sci 1996;311:225-33.
3. Association AH. Pediatric Advanced Life Support. Dallas, TX: American Heart Association; 2006.
4. AH A. Pediatric Advanced Life Support. 2006.
5. Mackenzie A, Barnes G, Shann F. Clinical signs of dehydration in children. Lancet 1989;2:605-7.
6. Koves IH, Neutze J, Donath S, et al. The accuracy of clinical assessment of dehydration during diabetic ketoacidosis in childhood. Diabetes Care 2004;27:2485-7.
7. Steiner MJ, DeWalt DA, Byerley JS. Is this child dehydrated? JAMA 2004;291:2746-54.
8. Glaser N, Barnett P, McCaslin I, et al. Risk factors for cerebral edema in children with diabetic ketoacidosis. The Pediatric Emergency Medicine Collaborative Research Committee of the American Academy of Pediatrics. N Engl J Med 2001;344:264-9.
9. Edge JA. Cerebral oedema during treatment of diabetic ketoacidosis: are we any nearer finding a cause? Diabetes Metab Res Rev 2000;16:316-24.
10. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet 1974;2:81-4.
11. Mestrovic J, Kardum G, Polic B, et al. The influence of chronic health conditions on susceptibility to severe acute illness of children treated in PICU. Eur J Pediatr 2006;165:526-9.
12. Dosa NP, Boeing NM, Ms N, Kanter RK. Excess risk of severe acute illness in children with chronic health conditions. Pediatrics 2001;107:499-504.
13. Malone JI, Brodsky SJ. The value of electrocardiogram monitoring in diabetic ketoacidosis. Diabetes Care 1980;3:543-7.
14. Soler NG, Bennett MA, Fitzgerald MG, Malins JM. Electrocardiogram as a guide to potassium replacement in diabetic ketoacidosis. Diabetes 1974;23:610-5.
15. Fagan MJ, Avner J, Khine H. Initial fluid resuscitation for patients with diabetic ketoacidosis: how dry are they? Clin Pediatr (Phila) 2008;47:851-5.
16. Ugale J, Mata A, Meert KL, Sarnaik AP. A measured degree of dehydration in children and adolescents with type 1 diabetic ketoacidosis. Pediatr Crit Care Med 2011.
17. Ugale J, Mata A, Meert KL, Sarnaik AP. Measured degree of dehydration in children and adolescents with type 1 diabetic ketoacidosis*. Pediatr Crit Care Med 2012;13:e103-7.
18. Edge JA, Jakes RW, Roy Y, et al. The UK case-control study of cerebral oedema complicating diabetic ketoacidosis in children. Diabetologia 2006;49:2002-9.
19. Hom J, Sinert R. Evidence-based emergency medicine/critically appraised topic. Is fluid therapy associated with cerebral edema in children with diabetic ketoacidosis? Ann Emerg Med 2008;52:69-75 e1.
20. Dunger DB, Sperling MA, Acerini CL, et al. ESPE/LWPES consensus statement on diabetic ketoacidosis in children and adolescents. Arch Dis Child 2004;89:188-94.
21. Wiggam MI, O'Kane MJ, Harper R, et al. Treatment of diabetic ketoacidosis using normalization of blood 3-hydroxybutyrate concentration as the endpoint of emergency management. A randomized controlled study. Diabetes Care 1997;20:1347-52.
22. Ham MR, Okada P, White PC. Bedside ketone determination in diabetic children with hyperglycemia and ketosis in the acute care setting. Pediatr Diabetes 2004;5:39-43.
23. Rewers A, McFann K, Chase HP. Bedside monitoring of blood beta-hydroxybutyrate levels in the management of diabetic ketoacidosis in children. Diabetes Technol Ther 2006;8:671-6.
24. Flood RG, Chiang VW. Rate and prediction of infection in children with diabetic ketoacidosis. Am J Emerg Med 2001;19:270-3.
25. Mbugua PK, Otieno, C.F., Kayima, J.K., Amayo, A.A., McLigeyo, S.O. Diabetic ketoacidosis: clinical presentation and precipitating factors at Kenyatta National Hospital, Nairobi. East Afr Med J 2005;82:S191-S6.

Return to Algorithm

To Bibliography, Pg 2

Bibliography 2011

25. Mbugua PK, Otieno, C.F., Kayima, J.K., Amayo, A.A., McLigeyo, S.O. Diabetic ketoacidosis: clinical presentation and precipitating factors at Kenyatta National Hospital, Nairobi. East Afr Med J 2005;82:S191-S6.
26. Rewers M, LaPorte RE, King H, Tuomilehto J. Trends in the prevalence and incidence of diabetes: insulin-dependent diabetes mellitus in childhood. World Health Stat Q 1988;41:179-89.
27. Pinhas-Hamiel O, Dolan LM, Zeitler PS. Diabetic ketoacidosis among obese African-American adolescents with NIDDM. Diabetes Care 1997;20:484-6.
28. Bangstad HJ, Danne T, Deeb L, Jarosz-Chobot P, Urakami T, Hanas R. Insulin treatment in children and adolescents with diabetes. Pediatr Diabetes 2009;10 Suppl 12:82-99.
29. Rosilio M, Cotton JB, Wieliczko MC, et al. Factors associated with glycemic control. A cross-sectional nationwide study in 2,579 French children with type 1 diabetes. The French Pediatric Diabetes Group. Diabetes Care 1998;21:1146-53.
30. Smith CP, Firth D, Bennett S, Howard C, Chisholm P. Ketoacidosis occurring in newly diagnosed and established diabetic children. Acta Paediatr 1998;87:537-41.
31. Morris AD, Boyle DI, McMahon AD, Greene SA, MacDonald TM, Newton RW. Adherence to insulin treatment, glycaemic control, and ketoacidosis in insulin-dependent diabetes mellitus. The DARTS/MEMO Collaboration. Diabetes Audit and Research in Tayside Scotland. Medicines Monitoring Unit. Lancet 1997;350:1505-10.
32. Rewers A, Chase HP, Mackenzie T, et al. Predictors of acute complications in children with type 1 diabetes. JAMA 2002;287:2511-8.
33. Monroe KW, King W, Atchison JA. Use of PRISM scores in triage of pediatric patients with diabetic ketoacidosis. Am J Manag Care 1997;3:253-8.
34. Chase HP, Garg SK, Jelley DH. Diabetic ketoacidosis in children and the role of outpatient management. Pediatr Rev 1990;11:297-304.
35. Linares MY, Schunk JE, Lindsay R. Laboratory presentation in diabetic ketoacidosis and duration of therapy. Pediatr Emerg Care 1996;12:347-51.
36. Kitabchi AE. Low-dose insulin therapy in diabetic ketoacidosis: fact or fiction? Diabetes Metab Rev 1989;5:337-63.
37. Waldhausl W, Kleinberger G, Bratusch-Marrain P, Komjati M. [Pathophysiology and therapy of diabetic ketoacidosis and of non-ketoacidotic hyperosmolar diabetic coma]. Wien Klin Wochenschr 1984;96:309-19.
38. Owen OE, Licht JH, Sapir DG. Renal function and effects of partial rehydration during diabetic ketoacidosis. Diabetes 1981;30:510-8.
39. Luzi L, Barrett EJ, Groop LC, Ferrannini E, DeFronzo RA. Metabolic effects of low-dose insulin therapy on glucose metabolism in diabetic ketoacidosis. Diabetes 1988;37:1470-7.
40. Adrogue HJ, Eknoyan G, Suki WK. Diabetic ketoacidosis: role of the kidney in the acid-base homeostasis re-evaluated. Kidney Int 1984;25:591-8.
41. Oh MS, Carroll HJ, Uribarri J. Mechanism of normochloremic and hyperchloremic acidosis in diabetic ketoacidosis. Nephron 1990;54:1-6.
42. Katz MA. Hyperglycemia-induced hyponatremia--calculation of expected serum sodium depression. N Engl J Med 1973;289:843-4.
43. Hillier TA, Abbott RD, Barrett EJ. Hyponatremia: evaluating the correction factor for hyperglycemia. Am J Med 1999;106:399-403.
44. Metzger D. Diabetic ketoacidosis in children and adolescents: An update and revised treatment protocol. BC Medical Journal 2010;52:24-31.
45. Hoorn EJ, Carlotti AP, Costa LA, et al. Preventing a drop in effective plasma osmolality to minimize the likelihood of cerebral edema during treatment of children with diabetic ketoacidosis. J Pediatr 2007;150:467-73.
46. Harris GD, Fiordalisi I, Harris WL, Mosovich LL, Finberg L. Minimizing the risk of brain herniation during treatment of diabetic ketoacidemia: a retrospective and prospective study. J Pediatr 1990;117:22-31.

Return to Algorithm

To Bibliography, Pg 3

Bibliography 2011

47. Hale PM, Rezvani I, Braunstein AW, Lipman TH, Martinez N, Garibaldi L. Factors predicting cerebral edema in young children with diabetic ketoacidosis and new onset type I diabetes. Acta Paediatr 1997;86:626-31.
48. Duck SC, Wyatt DT. Factors associated with brain herniation in the treatment of diabetic ketoacidosis. J Pediatr 1988;113:10-4.
49. Bohn D. Understanding the pathophysiology of cerebral edema in diabetic ketoacidosis: another brick in the wall? Pediatr Crit Care Med 2010;11:421-3.
50. Tattersall RB. A paper which changed clinical practice (slowly). Jacob Holler on potassium deficiency in diabetic acidosis (1946). Diabet Med 1999;16:978-84.
51. Nabarro JD, Spencer AG, Stowers JM. Treatment of diabetic ketosis. Lancet 1952;1:983-9.
52. Zipf WB, Bacon GE, Spencer ML, Kelch RP, Hopwood NJ, Hawker CD. Hypocalcemia, hypomagnesemia, and transient hypoparathyroidism during therapy with potassium phosphate in diabetic ketoacidosis. Diabetes Care 1979;2:265-8.
53. Winter RJ, Harris CJ, Phillips LS, Green OC. Diabetic ketoacidosis. Induction of hypocalcemia and hypomagnesemia by phosphate therapy. Am J Med 1979;67:897-900.
54. Association A. Pediatric Advanced Life Support. 2006.
55. Bohannon NJ. Large phosphate shifts with treatment for hyperglycemia. Arch Intern Med 1989;149:1423-5.
56. Gibby OM, Veale KE, Hayes TM, Jones JG, Wardrop CA. Oxygen availability from the blood and the effect of phosphate replacement on erythrocyte 2,3-diphosphoglycerate and haemoglobin-oxygen affinity in diabetic ketoacidosis. Diabetologia 1978;15:381-5.
57. Keller U, Berger W. Prevention of hypophosphatemia by phosphate infusion during treatment of diabetic ketoacidosis and hyperosmolar coma. Diabetes 1980;29:87-95.
58. Wilson HK, Keuer SP, Lea AS, Boyd AE, 3rd, Eknoyan G. Phosphate therapy in diabetic ketoacidosis. Arch Intern Med 1982;142:517-20.
59. Becker DJ, Brown DR, Steranka BH, Drash AL. Phosphate replacement during treatment of diabetic ketosis. Effects on calcium and phosphorus homeostasis. Am J Dis Child 1983;137:241-6.
60. Fisher JN, Kitabchi AE. A randomized study of phosphate therapy in the treatment of diabetic ketoacidosis. J Clin Endocrinol Metab 1983;57:177-80.
61. Clerbaux T, Reynaert M, Willems E, Frans A. Effect of phosphate on oxygen-hemoglobin affinity, diphosphoglycerate and blood gases during recovery from diabetic ketoacidosis. Intensive Care Med 1989;15:495-8.
62. Vanelli M, Chiari G, Capuano C, Iovane B, Bernardini A, Giacalone T. The direct measurement of 3-beta-hydroxy butyrate enhances the management of diabetic ketoacidosis in children and reduces time and costs of treatment. Diabetes Nutr Metab 2003;16:312-6.
63. Noyes KJ, Crofton P, Bath LE, et al. Hydroxybutyrate near-patient testing to evaluate a new end-point for intravenous insulin therapy in the treatment of diabetic ketoacidosis in children. Pediatr Diabetes 2007;8:150-6.
64. Laffel L. Ketone bodies: a review of physiology, pathophysiology and application of monitoring to diabetes. Diabetes Metab Res Rev 1999;15:412-26.
65. Brink S, Laffel L, Likitmaskul S, et al. Sick day management in children and adolescents with diabetes. Pediatr Diabetes 2009;10 Suppl 12:146-53.
66. Narins RG, Cohen JJ. Bicarbonate therapy for organic acidosis: the case for its continued use. Ann Intern Med 1987;106:615-8.
67. Morris LR, Murphy MB, Kitabchi AE. Bicarbonate therapy in severe diabetic ketoacidosis. Ann Intern Med 1986;105:836-40.
68. Okuda Y, Adrogue HJ, Field JB, Nohara H, Yamashita K. Counterproductive effects of sodium bicarbonate in diabetic ketoacidosis. J Clin Endocrinol Metab 1996;81:314-20.

Return to Algorithm

To Bibliography, Pg 4

Bibliography 2011

69. Green SM, Rothrock SG, Ho JD, et al. Failure of adjunctive bicarbonate to improve outcome in severe pediatric diabetic ketoacidosis. Ann Emerg Med 1998;31:41-8.
70. Grimberg A, Cerri RW, Satin-Smith M, Cohen P. The "two bag system" for variable intravenous dextrose and fluid administration: benefits in diabetic ketoacidosis management. J Pediatr 1999;134:376-8.
71. Poirier MP, Greer D, Satin-Smith M. A prospective study of the "two-bag system" in diabetic ketoacidosis management. Clin Pediatr (Phila) 2004;43:809-13.
72. Rewers A. Current controversies in treatment and prevention of diabetic ketoacidosis. Adv Pediatr 2010;57:247-67.
73. Mackenzie A, Shann F, Barnes G. Clinical signs of dehydration in children. Lancet 1989;2:1529-30.
74. Harris GD, Fiordalisi I. Physiologic management of diabetic ketoacidemia. A 5-year prospective pediatric experience in 231 episodes. Arch Pediatr Adolesc Med 1994;148:1046-52.
75. Adrogue HJ, Barrero J, Eknoyan G. Salutary effects of modest fluid replacement in the treatment of adults with diabetic ketoacidosis. Use in patients without extreme volume deficit. JAMA 1989;262:2108-13.
76. Mel JM, Werther GA. Incidence and outcome of diabetic cerebral oedema in childhood: are there predictors? J Paediatr Child Health 1995;31:17-20.
77. Wagner A, Risse A, Brill HL, et al. Therapy of severe diabetic ketoacidosis. Zero-mortality under very-low-dose insulin application. Diabetes Care 1999;22:674-7.
78. Soler NG, FitzGerald MG, Wright AD, Malins JM. Comparative study of different insulin regimens in management of diabetic ketoacidosis. Lancet 1975;2:1221-4.
79. Al Hanshi S, Shann F. Insulin infused at 0.05 versus 0.1 units/kg/hr in children admitted to intensive care with diabetic ketoacidosis. Pediatr Crit Care Med 2011;12:137-40.
80. Puttha R, Cooke D, Subbarayan A, et al. Low dose (0.05 units/kg/h) is comparable with standard dose (0.1 units/kg/h) intravenous insulin infusion for the initial treatment of diabetic ketoacidosis in children with type 1 diabetes-an observational study. Pediatr Diabetes 2010;11:12-7.
81. Curtis JR, To T, Muirhead S, Cummings E, Daneman D. Recent trends in hospitalization for diabetic ketoacidosis in ontario children. Diabetes Care 2002;25:1591-6.
82. Edge JA, Ford-Adams ME, Dunger DB. Causes of death in children with insulin dependent diabetes 1990-96. Arch Dis Child 1999;81:318-23.
83. Lawrence SE, Cummings EA, Gaboury I, Daneman D. Population-based study of incidence and risk factors for cerebral edema in pediatric diabetic ketoacidosis. J Pediatr 2005;146:688-92.
84. Rosenbloom AL. Hyperglycemic crises and their complications in children. J Pediatr Endocrinol Metab 2007;20:5-18.
85. Rosenbloom AL. Intracerebral crises during treatment of diabetic ketoacidosis. Diabetes Care 1990;13:22-33.
86. Glasgow AM. Devastating cerebral edema in diabetic ketoacidosis before therapy. Diabetes Care 1991;14:77-8.
87. Couch RM, Acott PD, Wong GW. Early onset fatal cerebral edema in diabetic ketoacidosis. Diabetes Care 1991;14:78-9.
88. Carlotti AP, Bohn D, Halperin ML. Importance of timing of risk factors for cerebral oedema during therapy for diabetic ketoacidosis. Arch Dis Child 2003;88:170-3.
89. Brown TB. Cerebral oedema in childhood diabetic ketoacidosis: is treatment a factor? Emerg Med J 2004;21:141-4.
90. Mahoney CP, Vlcek BW, DelAguila M. Risk factors for developing brain herniation during diabetic ketoacidosis. Pediatr Neurol 1999;21:721-7.
91. Muir AB, Quisling RG, Yang MC, Rosenbloom AL. Cerebral edema in childhood diabetic ketoacidosis: natural history, radiographic findings, and early identification. Diabetes Care 2004;27:1541-6.
92. Tasker RC, Lutman D, Peters MJ. Hyperventilation in severe diabetic ketoacidosis. Pediatr Crit Care Med 2005;6:405-11.

Return to Algorithm

To Bibliography, Pg 5

Bibliography 2011

93. Fiordalisi I, Novotny WE, Holbert D, Finberg L, Harris GD. An 18-yr prospective study of pediatric diabetic ketoacidosis: an approach to minimizing the risk of brain herniation during treatment. Pediatr Diabetes 2007;8:142-9.
94. Franklin B, Liu J, Ginsberg-Fellner F. Cerebral edema and ophthalmoplegia reversed by mannitol in a new case of insulin-dependent diabetes mellitus. Pediatrics 1982;69:87-90.
95. Shabbir N, Oberfield SE, Corrales R, Kairam R, Levine LS. Recovery from symptomatic brain swelling in diabetic ketoacidosis. Clin Pediatr (Phila) 1992;31:570-3.
96. Roberts MD, Slover RH, Chase HP. Diabetic ketoacidosis with intracerebral complications. Pediatr Diabetes 2001;2:109-14.
97. Curtis JR, Bohn D, Daneman D. Use of hypertonic saline in the treatment of cerebral edema in diabetic ketoacidosis (DKA). Pediatr Diabetes 2001;2:191-4.
98. Kamat P, Vats A, Gross M, Checchia PA. Use of hypertonic saline for the treatment of altered mental status associated with diabetic ketoacidosis. Pediatr Crit Care Med 2003;4:239-42.
99. Kanter RK, Oliphant M, Zimmerman JJ, Stuart MJ. Arterial thrombosis causing cerebral edema in association with diabetic ketoacidosis. Crit Care Med 1987;15:175-6.
100. Roe TF, Crawford TO, Huff KR, Costin G, Kaufman FR, Nelson MD, Jr. Brain infarction in children with diabetic ketoacidosis. J Diabetes Complications 1996;10:100-8.
101. Keane S, Gallagher A, Ackroyd S, McShane MA, Edge JA. Cerebral venous thrombosis during diabetic ketoacidosis. Arch Dis Child 2002;86:204-5.
102. Rosenbloom AL. Fatal cerebral infarctions in diabetic ketoacidosis in a child with previously unknown heterozygosity for factor V Leiden deficiency. J Pediatr 2004;145:561-2.
103. Gutierrez JA, Bagatell R, Samson MP, Theodorou AA, Berg RA. Femoral central venous catheter-associated deep venous thrombosis in children with diabetic ketoacidosis. Crit Care Med 2003;31:80-3.
104. Worly JM, Fortenberry JD, Hansen I, Chambliss CR, Stockwell J. Deep venous thrombosis in children with diabetic ketoacidosis and femoral central venous catheters. Pediatrics 2004;113:e57-60.
105. Carvalho KS, Bodensteiner JB, Connolly PJ, Garg BP. Cerebral venous thrombosis in children. J Child Neurol 2001;16:574-80.
106. Moye J, Rosenbloom AL, Silverstein J. Clinical predictors of mucormycosis in children with type 1 diabetes mellitus. J Pediatr Endocrinol Metab 2002;15:1001-4.
107. Voitl P, Scheibenpflug C, Weber T, Janata O, Rokitansky AM. Combined antifungal treatment of visceral mucormycosis with caspofungin and liposomal amphotericin B. Eur J Clin Microbiol Infect Dis 2002;21:632-4.
108. Casteels K, Beckers D, Wouters C, Van Geet C. Rhabdomyolysis in diabetic ketoacidosis. Pediatr Diabetes 2003;4:29-31.
109. Quiros JA, Marcin JP, Kuppermann N, et al. Elevated serum amylase and lipase in pediatric diabetic ketoacidosis. Pediatr Crit Care Med 2008;9:418-22.
110. Haddad NG, Croffie JM, Eugster EA. Pancreatic enzyme elevations in children with diabetic ketoacidosis. J Pediatr 2004;145:122-4.
111. Taylor D, Durward A, Tibby SM, et al. The influence of hyperchloraemia on acid base interpretation in diabetic ketoacidosis. Intensive Care Med 2006;32:295-301.
112. Swift PG. Diabetes education in children and adolescents. Pediatr Diabetes 2009;10 Suppl 12:51-7.
113. Chase HP MD. Understanding Diabetes Barbara Davis center for Childhood Diabetes 2011.

Return to Algorithm

To Bibliography, Pg 6

Bibliography 2017

Agrawal AK, Kammen BF, Guo H, Donthineni R. An unusual presentation of subcutaneous granuloma annulare in association with juvenile-onset diabetes: Case report and literature review. *Pediatr Dermatol*. 2012;29(2):202-205.

Akyurek N, Atabek ME, Eklioglu BS. Intestinal invagination in diabetic ketoacidosis: Case report. *J Pediatr Endocrinol Metab*. 2015;28(1-2):73-74.

Bakes K, Haukoos JS, Deakyne SJ, et al. Effect of volume of fluid resuscitation on metabolic normalization in children presenting in diabetic ketoacidosis: A randomized controlled trial. *J Emerg Med* [DKA]. 2016;50(4):551-559.

Basnet S, Venepalli PK, Andoh J, Verhulst S, Koirala J. Effect of normal saline and half normal saline on serum electrolytes during recovery phase of diabetic ketoacidosis. *J Intensive Care Med* [DKA]. 2014;29(1):38-42. Accessed 20140106; 11/3/2016 2:17:21 PM. http://dx.doi.org/10.1177/0885066612467149.

Bergmann KR, Milner DM, Voulgaropoulos C, Cutler GJ, Kharbanda AB. Optic nerve sheath diameter measurement during diabetic ketoacidosis: A pilot study. *West J Emerg Med* [DKA]. 2016;17(5):531-541.

Bhakhri BK. Normal blood glucose level at presentation does not rule out diabetic ketoacidosis in a sick child. *CJEM*. 2012;14(2):72-73.

Bilici M, Tavil B, Dogru O, Davutoglu M, Bosnak M. Diabetic ketoasidosis is associated with prothrombotic tendency in children. *Pediatr Hematol Oncol* [DKA]. 2011;28(5):418-424. Accessed 20110708; 11/3/2016 2:17:21 PM. http://dx.doi.org/10.3109/08880018.2011.558568.

Cameron FJ, Scratch SE, Nadebaum C, et al. Neurological consequences of diabetic ketoacidosis at initial presentation of type 1 diabetes in a prospective cohort study of children. *Diabetes Care* [DKA]. 2014;37(6):1554-1562. Accessed 20140523; 11/3/2016 2:17:21 PM. http://dx.doi.org/10.2337/dc13-1904.

Carlotti,Ana Paula de Carvalho Panzeri, St George-Hyslop C, Bohn D, Halperin ML. Hypokalemia during treatment of diabetic ketoacidosis: Clinical evidence for an aldosterone-like action of insulin. *J Pediatr* [DKA]. 2013;163(1):207-12.e1. Accessed 20130626; 11/3/2016 2:17:21 PM. http://dx.doi.org/10.1016/j.jpeds.2013.01.007.

Cebeci AN, Guven A, Kirmizibekmez H, Yildiz M, Dursun F. Clinical features and management of diabetic ketoacidosis in different age groups of children: Children less than 5 years of age are at higher risk of metabolic decompensation. *J Pediatr Endocrinol* [DKA]. 2012;25(9-10):917-925.

Cohen M, Leibovitz N, Shilo S, Zuckerman-Levin N, Shavit I, Shehadeh N. Subcutaneous regular insulin for the treatment of diabetic ketoacidosis in children. *Pediatr Diabetes* [DKA]. 2016.

Decourcey DD, Steil GM, Wypij D, Agus MSD. Increasing use of hypertonic saline over mannitol in the treatment of symptomatic cerebral edema in pediatric diabetic ketoacidosis: An 11-year retrospective analysis of mortality*. *Pediatr Crit Care Med* [DKA]. 2013;14(7):694-700.

Durward A, Ferguson LP, Taylor D, Murdoch IA, Tibby SM. The temporal relationship between glucose-corrected serum sodium and neurological status in severe diabetic ketoacidosis. *Arch Dis Child* [DKA]. 2011;96(1):50-57. Accessed 20101220; 11/3/2016 2:17:21 PM. http://dx.doi.org/10.1136/adc.2009.170530.

Return to Algorithm

To Bibliography, Pg 7

Bibliography 2017

Gencpinar P, Tekguc H, Senol AU, Duman O, Dursun O. Extrapontine myelinolysis in an 18-month-old boy with diabetic ketoacidosis: Case report and literature review. J Child Neurol. 2014;29(11):1548-1553.

Glaser NS, Tancredi DJ, Marcin JP, et al. Cerebral hyperemia measured with near infrared spectroscopy during treatment of diabetic ketoacidosis in children. J Pediatr [DKA]. 2013;163(4):1111-1116. Accessed 20130927; 11/3/2016 2:17:21 PM. http://dx.doi.org/10.1016/j.jpeds.2013.06.008.

Glaser NS, Wootton-Gorges SL, Buonocore MH, et al. Subclinical cerebral edema in children with diabetic ketoacidosis randomized to 2 different rehydration protocols. Pediatrics [DKA]. 2013;131(1):e73-80. Accessed 20130102; 11/3/2016 2:17:21 PM. http://dx.doi.org/10.1542/peds.2012-1049.

Harrison VS, Rustico S, Palladino AA, Ferrara C, Hawkes CP. Glargine co-administration with intravenous insulin in pediatric diabetic ketoacidosis is safe and facilitates transition to a subcutaneous regimen. Pediatric Diabetes. 2016. Accessed 20161103; 2/3/2017 5:22:20 PM. https://dx.doi.org/10.1111/pedi.12462.

Houshyar J, Bahrami A, Aliasgarzadeh A. Effectiveness of insulin glargine on recovery of patients with diabetic ketoacidosis: A randomized controlled trial. Journal of clinical and diagnostic research : JCDR [DKA]. 2015;9(5):01.

Kapellen T, Vogel C, Telleis D, Siekmeyer M, Kiess W. Treatment of diabetic ketoacidosis (DKA) with 2 different regimens regarding fluid substitution and insulin dosage (0.025 vs. 0.1 units/kg/h). Exp Clin Endocrinol Diabetes [DKA]. 2012;120(5):273-276. Accessed 20120522; 11/3/2016 2:17:21 PM. http://dx.doi.org/10.1055/s-0031-1299706.

Koves IH, Leu MG, Spencer S, et al. Improving care for pediatric diabetic ketoacidosis. Pediatrics. 2014;134(3):e848-56. Accessed 20140903; 2/3/2017 5:22:20 PM. https://dx.doi.org/10.1542/peds.2013-3764.

Lutfi R, Huang J, Wong HR. Plasmapheresis to treat hypertriglyceridemia in a child with diabetic ketoacidosis and pancreatitis. Pediatrics. 2012;129(1):e195-8.

Nallasamy K, Jayashree M, Singhi S, Bansal A. Low-dose vs standard-dose insulin in pediatric diabetic ketoacidosis: A randomized clinical trial. Jama, Pediatr [DKA]. 2014;168(11):999-1005. Accessed 20141104; 11/3/2016 2:17:21 PM. http://dx.doi.org/10.1001/jamapediatrics.2014.1211.

Petzold S, Kapellen T, Siekmeyer M, et al. Acute cerebral infarction and extra pontine myelinolysis in children with new onset type 1 diabetes mellitus. Pediatr Diabetes [DKA]. 2011;12(5):513-517. Accessed 20110728; 11/3/2016 2:17:21 PM. http://dx.doi.org/10.1111/j.1399-5448.2010.00732.x.
Prashanth GP, Bellad RM, Inamdar PR. Diabetic ketoacidosis with normal anion gap--to use or not to use normal saline? Indian Pediatr. 2014;51(3):234-235.

Prashanth GP, Bellad RM, Inamdar PR. Diabetic ketoacidosis with normal anion gap--to use or not to use normal saline? Indian Pediatr. 2014;51(3):234-235.

Return to Algorithm

To Bibliography, Pg 8

Bibliography 2017

Rosner EA, Strezlecki KD, Clark JA, Lieh-Lai M. Low thiamine levels in children with type 1 diabetes and diabetic ketoacidosis: A pilot study. Pediatr Crit Care Med [DKA]. 2015;16(2):114-118.

Soto-Rivera CL, Asaro LA, Agus MS, DeCourcey DD. Suspected cerebral edema in diabetic ketoacidosis: Is there still a role for head CT in treatment decisions? Pediatr Crit Care Med. 2017;18(3):207-212.

Vavilala MS, Marro KI, Richards TL, et al. Change in mean transit time, apparent diffusion coefficient, and cerebral blood volume during pediatric diabetic ketoacidosis treatment. Pediatr Crit Care Med [DKA]. 2011;12(6):e344-9.

Wetter J, Gohlke BC, Woelfle JF. Hyperglycemic hyperosmolar state as initial manifestation of pediatric insulin-dependent diabetes. Klin Padiatr. 2012;224(1):32-33.

Williamson S, Alexander V, Greene SA. Severe hyperlipidaemia complicating diabetic ketoacidosis. Arch Dis Child. 2012;97(8):735-2012-301810. Epub 2012 Mar 23.

Wolfsdorf JI, Allgrove J, Craig ME, et al. ISPAD clinical practice consensus guidelines 2014. diabetic ketoacidosis and hyperglycemic hyperosmolar state. Pediatr Diabetes [DKA]. 2014;15(Suppl 20):154-179. Accessed 20140903; 11/3/2016 2:17:21 PM. http://dx.doi.org/10.1111/pedi.12165.

Yung M, Letton G, Keeley S. Controlled trial of hartmann's solution versus 0.9% saline for diabetic ketoacidosis. J Paediatr Child Health. 2017;53(1):12-17. Accessed 20170110; 2/23/2017 4:39:52 PM. https://dx.doi.org/10.1111/jpc.13436.

Return to Algorithm

To Bibliography, Pg 1