Diabetic Ketoacidosis (DKA) v.3.0: Links

- Exclusion and Inclusion Criteria
- Pathway Overview
- Initial Assessment: PALS, ISPAD, Neurologic Stability
- ICU Admission Criteria
- Cerebral Edema
- Risk Assessment and Disposition: Low, Medium, High Risk Classifications
- DKA Suspected (ED or Clinic)
- PHASE 1: Early Electrolyte Adjustment/Rehydration (4-6 hrs)
- PHASE 2: Ongoing Electrolyte Adjustment/Rehydration (Up to 48 hrs)
- Transition Phase

Clinical Tools

- GCS Scoring
- The Two Bag System
- Clinical Cerebral Edema Risk Tool
- Fluid Rate Calculator (for SCH only)
- Lab Schedule
- 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.
Diabetic Ketoacidosis (DKA) v.3.0: Criteria and Overview

**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 < 15 mEq/L. [LOE: NC] (1, 20)

**Exclusion Criteria**
1. Age < 12 months

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

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**Pathophysiology of DKA**

**Explanation of Evidence Ratings**

**Summary of Version Changes**

**Test Your Knowledge**

Where Should the Child be Managed?

**Diabetic Ketoacidosis (DKA) Pathway Overview**

- **Assessment**
  - ABCDs and Weight
  - Confirm Dx: Consult Endo
  - Initial labs

- **Fluid & Electrolyte Replacement**
  - Place 2 IVs
  - 1st NS Bolus (10 mL/kg over 1 hr)
  - 2nd NS Bolus
  - 3rd NS Bolus

- **Insulin**
  - Do not start insulin until after first 10 mL/kg bolus

- **Presentation**
  - Time may vary for pts who first present to outside facility

**Diabetic Ketoacidosis (DKA) Pathway Overview**

**Transition Phase**

**Phase 1: Early Electrolyte Adjustment/Rehydration**

- Activate DKA pathway and transition to two bag system
- Monitor GCS and neurological status every hour up to 24 hours if presenting pH ≤ 7.15
- See “LAB SCHEDULE” for recommended labs

**Phase 2: Ongoing Electrolyte Adjustment/Rehydration**

- ½ NS + K-phos / K-acetate
- **Add D10 NS + K-phos/K-acetate when Glucose < 300 or pre-hypokalemia exists**
- D10 ½ NS + K-phos / K-acetate
- **Use NS if corrected Na < 150**

**Transition Phase**

- Oral
- Discuss transition with Endocrinologist

**Continuous Insulin at 0.1 units/kg/hr OR 0.05 units/kg/hr**
- 30 minute overlap
- SC Insulin

**Discharge**

**Time**

- 1 hr
- 4 hrs
- Up to 48 hrs

**This intervention is not anticipated for routine management but may be indicated in some circumstances**
Diabetic Ketoacidosis (DKA) v.3.0: Assessment & Disposition

PALS and ISPAD Assessments
- Assess ABCDs, degree of dehydration
- Measure weight in kilograms [LOE:LC] (1)
- Vital Signs: Temp, HR, BP and RR; q 15 minutes until hemodynamically stable [LOE:LC]
- Notify MD if Cushing’s Triad is present (, HR, 1/BP, widening pulse pressure)
- Cardiorespiratory monitoring [LOE:NC] (1, 13, 14)

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: (one diagnostic criterion, two major, or one major and two minor criteria)
- Anisocoria (unequal pupil size)
- Asymmetric neurological exam
- Non-responsive

Clinical Signs and Historical Features Suggestive of DKA

- Dehydration
- Kussmaul breathing
- Smell of ketones
- Lethargy
- Vomiting
- Abdominal tenderness
- Mental Status Changes
- Polyuria/Polydipsia
- New onset enuresis
- Nocturia
- Weight loss
- Abdominal pain
- Fatigue
- Nausea/vomiting
- Headache
- Confusion
- Candida infection

Meets DKA Definition
Hyperglycemia >200 mg/dl & Ketonemia (BOHB >1mmol/L) & pH <7.3 or HCO3 <15 mEq/L

Obtain Vascular Access & Obtain Initial Labs

- 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
- Initial Labs / Lab Schedule: Serum glucose, Blood gas, Na, K, CI, HCO3, Ca, Mg, Phos, Corrected Na, Serum Osmolality, BUN/Cr, l-hydroxybutyrate (BOHB), Blood Culture and UA (if febrile and concern for infection): 30% will have a microbial co-morbidity [LOE:LC]

LOW RISK: Discharge home [LOE: LC]
- Not new onset
- Overt insulin pump failure, not meeting medium or high risk criteria
- Able to manage DM at home
- Able to tolerate oral fluid

Discharge to home

MEDIUM RISK: Medical Unit Admission [LOE: LC]
- New onset or established DM not meeting ICU admission criteria.
- Unable to manage DM at home.

Admit to Medical Unit

HIGH RISK: Admit to ICU
ICU Admission Criteria: (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 resuscitation
- Other organ system dysfunction
- Presenting pH ≤ 7.15
- Presenting HCO3 ≤ 5 mEq/L
- Presenting PCO2 < 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)
- Corrected Na = 140 mEq/L or decreasing at 2 hour labs. 

*If no ICU beds are available, admit to medical unit only if: 1:2 nurse to patient ratio, and after discussion with attending, charge RN and shift administrator

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**Diabetic Ketoacidosis (DKA) v.3.0: Fluid Resuscitation**

### Fluid Resuscitation

- **Note:** Always begin fluid replacement before insulin therapy.  
  [LOE:NC, C] (1)

- **Note:** Large volume fluid resuscitation and overzealous rehydration may increase the risk of cerebral edema.  
  [LOE:NC] (18,19)

- **Note:** Cerebral edema usually develops 4-12 hours into treatment, but it can occur at any time.

### Assess Fluid Status

Is Patient in Overt Shock?

- **No**
  - **Resuscitate**
    - Begin fluid replacement before insulin therapy.  
      [LOE: NC, C] (1)
    - **If moderately dehydrated:** Give 10 mL/kg of 0.9% normal saline (NS); administered over one hour.  
      [LOE: NC] (1)
    - **If severely dehydrated:** Repeat boluses of 10 mL/kg of 0.9% NS; each bolus administered over 30-60 minutes to restore normal circulation to a maximum of 30 mL/kg [LOE: LC] (1)

- **Yes**
  - **Resuscitate for Overt Shock**
    - Give 20 mL/kg boluses of NS. 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. [LOE:LC]
    - Monitor all I/Os: Include previously administered fluids prior to arrival at SCH, large amounts of oral intake should also be considered [LOE:LC]

Hemodynamically Stable

**To Insulin, Fluid and Electrolyte Management:**  
(Phases 1 & 2)
Diabetic Ketoacidosis (DKA) v.3.0: Insulin, Fluid & Electrolytes

PHASES 1 & 2

Insulin and Glucose
- Start regular insulin infusion AFTER completion of first 10 mL/kg bolus of NS that is given over 1 hour. Typically, this will be after the first hour after presentation to the Emergency Dept. For patients with an insulin pump, physically remove the pump, tubing and sub-cutaneous catheter at onset of insulin infusion.
- Maintain dose of insulin at either 0.1 or 0.05 units/kg/hour until BOHB<1 mmol/L.
- Use 0.05 units/kg/hour for children less than 5 years of age or if patient demonstrates extreme insulin sensitivity. [LOE: A (36,37); 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 not decrease the insulin infusion if the blood glucose concentration decreases too quickly (> 100 mg/dL/hr) or falls too low (< 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 decreased to 0.05 units/kg/hour, or less, provided that metabolic acidosis continues to resolve. Consult Endocrinology.
- If glucose is < 100mg/dL: Discontinue the two-bag system and instead use D12.5% concentration with identical saline and electrolyte content. Consult endocrinology and check readiness for transition.

Low risk for cerebral edema
- Bag 1: Start ½ NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate; If applicable discontinue D10NS Bag 2 from Phase 1. Increased risk for cerebral edema: (corrected Na < 140 or failing rapidly, ICU admit, neuro changes):
  - Bag 1: Start 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 NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate; If applicable discontinue D10NS Bag 2 from Phase 1.
- Continue with NS fluid vehicle two-bag system for up to 12 hours and then switch to ¼ NS fluid vehicle two-bag system as described above.

Fluid Calculators (for SCH only)
- Fluid Rate Calculator
- Two Bag Clinical Calculator

Electrolytes
- Sodium
  - Use calculated corrected Na to guide subsequent fluid and electrolyte therapy in addition to clinical assessment of dehydration. [LOE: NE (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 NS and increase frequency of serum sodium monitoring. [LOE:C:LC]
  - If corrected Na decreases to < 130 mEq/L, begin an infusion of 2% saline through peripheral IV access or 3% saline (if central venous access is available). [LOE:LC]
- Potassium
  - Start potassium at same time of initial fluid resuscitation if hypokalemia (K<3.5 mEq/L) exists at presentation. [LOE:NC] (1)
  - Start potassium following fluid resuscitation unless hyperkalemia exists (K>5.5 mEq/L) on at least two consecutive measures (three 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 (hyperkalemia), monitor ECG. [LOE: LC]
- Phosphate and Calcium
  - Monitor calcium when administering potassium-phosphate as potassium 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]
- Magnesium
  - Do NOT replace magnesium in the routine care of DKA. [LOE:NC] (1)
- Bicarbonate
  - Bicarbonate administration should not be used in the routine management of DKA. [LOE: 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)

To Transition Phase

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

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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 such factors as age, previous dosing, pubertal state, systemic inflammation and length of honeymoon period. [LOE:NC] (1)

Confirm and initiate insulin transition plan as discussed with Endocrine 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. [LOE: NC] (1)

Give the first SC injection of bolus (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.

Start a carbohydrate-counted (insulin dependent) diet with discontinuation of insulin drip. [LOE: NC] (1)

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

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.
Diabetic Ketoacidosis v.3.0: Cerebral Edema

**Cerebral Edema Risk**
(1 diagnostic criterion, 2 major, or 1 major and 2 minor have a sensitivity of 92% and a specificity of 96% early enough for effective intervention) [LOE: NC] (47,91)

**Diagnostic Criteria:**
- Abnormal motor or verbal response to pain
- Decorticate or decerebrate posturing
- Cranial Nerve Palsy (III, IV, VI), double vision
- Abnormal respiratory pattern (e.g. grunting, central hypoventilation, Cheyne-Stokes, apneusis)

**Major Criteria**
- Altered or fluctuating level of consciousness
- Sustained heart rate deceleration (more than 20 beats/min) not attributable to improved intravascular volume or sleep state
- Age inappropriate incontinence

**Minor Criteria**
- Vomiting, Headache, Lethargy, diastolic BP > 90 mm Hg, Age < 5 yrs

**Additional Risk Factors for Cerebral Edema**

**Treatment** should occur as soon as the condition is suspected in the following hierarchical order:

- **Ensure an adequate airway and assist ventilation initially by manual bag-mask and subsequently by endotracheal intubation only as necessary. [LOE: C] (1)**
- **Ensure adequate circulation; but as possible reduce the rate of fluid administration by one-third. [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 hyperventilating for any reason or if airway protective reflexes are lost. If endotracheal intubation and ventilation are undertaken for patients with DKA, target a PaCO₂ appropriate for estimated [HCO₃]ₐᵥ and treat with great caution those presenting with pHₐᵣᵣ < 7.00 (92).
- **Elevate the head of the bed and keep the head positioned midline. [LOE: NC] (1)**
  - **Administer mannitol:** 1 gram/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)
  - **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]**

**Epidemiology**
- 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)

**ICU Discharge Criteria** [LOE:X]
- **BOHB ≤ 3 mmol/L and**
- **GCS = 15 or at premorbid baseline and**
- **K requirement can be maintained with ≤ 40 mEq/L supplementation and**
- **No ICU care needed for any other reason**
- **For patients with BOHB <3 mmol/L overnight consider early morning transfer**
- **Exception: Hyperosmolar Dehydration**

**Return to Assessment**
Clinical Effectiveness Program

Diabetic Ketoacidosis (DKA)

Guideline
And Implementation Tools

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FINAL
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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.
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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 are encouraged to confirm the information contained herein with other sources.
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DIABETIC KETOACIDOSIS (DKA)
GUIDEライン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
  - ketonemia (β-hydroxybutyrate [BOHB] > 1 mmol/L)
  - venous pH <7.3 or HCO₃ < 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**

- Use weight-based clinical calculator 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 0.05 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 both basal and short acting SC insulin at mealtime (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:

  \[
  \text{Corrected Na} = \text{measured Na} + \frac{[(\text{serum glucose mg/dL} - 100)/100]}{1.6}
  \]

- Use normal saline for the first 4 hours in both bags of the two-bag system (Phase 1).

- Subsequently use \(\frac{1}{2}\) 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** during; 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 Clin. Doc.

**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 \(\frac{1}{2}\) NS).

- Bag 2: D10 NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate (add potassium unless hyperkalemia, do not use \(\frac{1}{2}\) 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: Start 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 NS with 20 mEq/L K-phosphate and 20 mEq/L K-acetate; If applicable discontinue D10 NS Bag 2 from Phase 1.
- Continue with NS fluid vehicle two-bag system for up to 12 hours and then switch to ½ NS fluid vehicle 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 transitioning at mealtime, 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*

- Age ≤ 24 months
- Developmental delay or any condition that compromises communication
- GCS ≤ 13 after volume resuscitation
- Abnormal neurological exam after volume resuscitation
- Other organ system dysfunction
- Presenting pH ≤ 7.15
- Presenting HCO₃⁻ ≤ 5 mEq/L
- Presenting PCO₂ < 10 mmHg
- Presenting BUN > 30 mg/dL
- Patient received IV bicarbonate or insulin bolus
- Corrected Na < 140 mEq/L or falling Na at 2 hour labs
- Calculated mOsm > 350*
- Patient received > 40 mL/kg total initial volume replacement (include fluids received prior to arrival to SCH)

*Calculated osmolality = 2xNa + (glucose/18) + (BUN/2.8)*
**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 HYPO- or HYPER-natremia 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.
  - Hyperkalemia: $K > 5.5 \text{ mEq/L}$ 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 $<1 \text{ mmol/L}$ 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 0.05 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 fellow 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 $< 1 \text{ mmol/L}$.
- Discuss with on-call endocrinologist

**Complications**
- Please [Complications](#) for specific details

**Assessment and Disposition for DKA**
- [DKA Pathway](#)
- [Lab Schedule](#)
B. 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

DKA Pathogenesis

\[\downarrow \text{Insulin} \quad \uparrow \text{CRH*}\]

*glucagon, epinephrine, cortisol, growth hormone

Muscle: Glucose Utilization, Hyperglycemia, Osmotic Diuresis → Dehydration

Liver: Gluconeogenesis, Glycogenolysis, Ketogenesis, Metabolic Acidosis

Adipose: Ketogenesis, Free Fatty Acids


*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

1. 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 O₂ saturations or increasing CO₂ 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\(^{10}\)

<table>
<thead>
<tr>
<th>Eye Opening Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous--open with blinking at baseline</td>
<td>4 points</td>
</tr>
<tr>
<td>Opens to verbal command, speech, or shout</td>
<td>3 points</td>
</tr>
<tr>
<td>Opens to pain, not applied to face</td>
<td>2 points</td>
</tr>
<tr>
<td>None</td>
<td>1 point</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verbal Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oriented</td>
<td>5 points</td>
</tr>
<tr>
<td>Confused conversation, but able to answer questions</td>
<td>4 points</td>
</tr>
<tr>
<td>Inappropriate responses, words discernible</td>
<td>3 points</td>
</tr>
<tr>
<td>Incomprehensible speech</td>
<td>2 points</td>
</tr>
<tr>
<td>None</td>
<td>1 point</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Motor Response</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obeys commands for movement</td>
<td>6 points</td>
</tr>
<tr>
<td>Purposeful movement to painful stimulus</td>
<td>5 points</td>
</tr>
<tr>
<td>Withdraws from pain</td>
<td>4 points</td>
</tr>
<tr>
<td>Abnormal (spastic) flexion, decorticate posture</td>
<td>3 points</td>
</tr>
<tr>
<td>Extensor (rigid) response, decerebrate posture</td>
<td>2 points</td>
</tr>
<tr>
<td>None</td>
<td>1 point</td>
</tr>
</tbody>
</table>

Verbal response criteria for children under 5 years.

<table>
<thead>
<tr>
<th>SCORE</th>
<th>2 to 5 years</th>
<th>0 to 23 Months.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Appropriate words or phrases</td>
<td>Smiles or coos appropriately</td>
</tr>
<tr>
<td>4</td>
<td>Inappropriate words</td>
<td>Cries and consolable</td>
</tr>
<tr>
<td>3</td>
<td>Persistent cries and/or screams</td>
<td>Persistent inappropriate crying &amp;/or screaming</td>
</tr>
<tr>
<td>2</td>
<td>Grunts</td>
<td>Grunts or is agitated or restless</td>
</tr>
<tr>
<td>1</td>
<td>No response</td>
<td>No response</td>
</tr>
</tbody>
</table>

**Vital Signs**

- Obtain the patient's 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 edema¹⁸,¹⁹.

- 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.
1. 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 HCO₃⁻ < 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.

- Obtain the following labs following arrival to SCH if suspected DKA: i-stat blood gas, 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
### Consider the following risk factors during initial assessment

- 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

### Historical Features

- Polyuria
- Polydipsia
- New onset enuresis
- Nocturia
- Weight loss
- Abdominal pain
- Fatigue
- Nausea/ vomiting
- Headache
- Confusion
- Candida Infection

### Clinical signs

- Dehydration
- Kussmaul breathing
- Smell of ketones
- Lethargy
- Vomiting
- Abdominal tenderness
- Mental status changes

### Labs

- Serum Glucose
- Blood gas
- Na, K, Cl, HCO₃, 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 at presentation (e.g. referring hospital or SCH). [LOE: C, NC]¹,²⁰,³³

• Admit high risk 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 HCO₃ ≤ 5
  - Presenting PCO₂ < 10
  - Presenting BUN > 30
  - Patient received IV bicarbonate or insulin bolus
  - Calculated mOsm > 350
    \[\text{Calculated osmolality}= 2\times \text{Na} + (\text{glucose}/18) + (\text{BUN}/2.8)\]
  - 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
    \[\text{Corrected Na} = \text{Measured Na} + \left[(\text{Serum glucose} – 100)/100 \times 1.6\right]\]

• 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 at either 0.1 or 0.05 units/kg/hour until BOHB < 1 mmol/L.

- Use 0.05 units/kg/hour for children less than 5 years of age or if patient demonstrates extreme insulin sensitivity. [LOE: A]³⁶,³⁷
  - 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]¹,³⁶-³⁹

- Do not 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 decreased to 0.05 units/kg/hour, or less, provided that metabolic acidosis continues to resolve. Consult Endocrinology.

- Transition to SC insulin at mealtime when BOHB is < 1 mmol/L. Administer both basal and short acting insulin (Transition Phase). [LOE: B]²¹-²³

ii. Electrolytes and Acidosis

- Replace electrolyte deficiencies AFTER restoring circulating volume and starting the insulin infusion. [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

\[
\text{Corrected Na} = \text{measured Na} + \left[\left(\text{Serum glucose as mg/dL} - 100\right)/100\right] \times 1.6
\]

- 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 lipids¹,⁴⁴. Instead, sodium should be corrected as detailed above and corrected serum sodium maintained > 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
POTASSIUM

- Start potassium at same time of initial fluid resuscitation if hypokalemia (K< 3.5 mEq/L) exists at presentation. [LOE: NC]¹

- 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 decrease 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 presents most commonly 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: (β-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}**

<table>
<thead>
<tr>
<th>Urine Ketones</th>
<th>Blood BOHB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>&lt; 0.5 mmol/L</td>
</tr>
<tr>
<td>Trace</td>
<td>0.5 mmol/L</td>
</tr>
<tr>
<td>Small</td>
<td>1.5 mmol/L</td>
</tr>
<tr>
<td>Moderate</td>
<td>4.0 mmol/L</td>
</tr>
<tr>
<td>Large</td>
<td>8.0 mmol/L</td>
</tr>
<tr>
<td>Very Large</td>
<td>16 mmol/L</td>
</tr>
</tbody>
</table>

- **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.
  o 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. \(0.07 \times \_\_\text{kg} \times 1000 \text{ mL/kg} = \_\_\text{mL of dehydration deficit}\))⁶,¹⁵,¹⁷,⁷³.
  o 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 hours¹ 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: \([\text{maintenance fluid for 2 days } + 7\% \text{ deficit volume} ] – \text{resuscitation fluid received in the ED and prior to arrival at the ED} \) / 48 hours. This is calculated utilizing the Clinical Calculator.

➢ Insulin rate does not typically change and the dose is to remain at 0.05 or 0.1 units/kg/hour. [LOE: B]²²,²³,⁷⁸-⁸⁰ Please see further details in Section 4.
- Patient is to remain NPO while on insulin drip. [LOE: NC] However, Endocrinology may approve a NON-carbohydrate containing snack.

- D10 should be turned on with either two-bag systems 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]

- 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 20 mEq/L each of potassium acetate and potassium phosphorus, 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 drip needs to be decreased the Endocrinologist on call must be notified. Check BOHB results and consider readiness for transition off insulin drip. [LOE: LC]

- Once on subcutaneous (SC) insulin and the insulin drip 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.

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

- 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

<table>
<thead>
<tr>
<th>Bag 1</th>
<th>Bag 2</th>
<th>Insulin</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS</td>
<td>D10 NS</td>
<td>Insulin drip dose 0.05 or 0.1 units/kg/hour</td>
</tr>
<tr>
<td>20 mEq K-acetate</td>
<td>20 mEq K-acetate</td>
<td></td>
</tr>
<tr>
<td>20 mEq K-phosphate</td>
<td>20 mEq K-phosphate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>when glucose &lt; 300 mg/dL</td>
<td></td>
</tr>
</tbody>
</table>

- **Pump**: NS + K salts
- **Pump**: D10 NS + K salts
- **Pump**: Insulin

**Patient**

**TRIFUSE**
**Phase 2 of Two-bag System**

<table>
<thead>
<tr>
<th>Blood Glucose (mg/dL)</th>
<th>% of Rate From NS or 0.45% saline with 20 mEq/L KAc 20 mEq/L KPO₄ Bag</th>
<th>% of Rate From D10/NS or D10/0.45% NS with 20 mEq/L KAc 20 mEq/L KPO₄ Bag</th>
<th>Final Dextrose Concentration (%)</th>
<th>Insulin Infusion Rate (units/kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;300</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>299-250</td>
<td>75</td>
<td>25</td>
<td>2.5</td>
<td>0.1</td>
</tr>
<tr>
<td>249-200</td>
<td>50</td>
<td>50</td>
<td>5</td>
<td>0.1</td>
</tr>
<tr>
<td>199-150</td>
<td>25</td>
<td>75</td>
<td>7.5</td>
<td>0.1</td>
</tr>
<tr>
<td>149-100</td>
<td>0</td>
<td>100</td>
<td>10</td>
<td>0.1</td>
</tr>
</tbody>
</table>
| < 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. | 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                              |}

*Note: Connect insulin and maintenance fluids at patient using a biorefuse connector to the IV catheter. 

**EXAMPLE calculation for of two-bag system with 0.1 units/kg/hour insulin**
iv. Transition Phase

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

- **Discontinue the insulin drip 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]

- **Plan transition to SC insulin at breakfast or dinner time.** [LOE: NC]
  - 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]

- **Give the first SC injection of bolus (if taking oral diet) and basal insulin 30 minutes prior to discontinuing the insulin drip.** [LOE: NC]
  - Prevents rebound hyperglycemia and allows sufficient time for the insulin to be absorbed.

- **Start an “Insulin Dependent (carbohydrate counted)” diet with discontinuation of insulin drip.** [LOE: NC]

- **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]
  - 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]
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: NC1,22,23]

- 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 condition24,25.

<table>
<thead>
<tr>
<th>Laboratory analysis</th>
<th>DKA confirmed</th>
<th>Hour 1</th>
<th>Hour 2</th>
<th>Hour 3</th>
<th>Hour 4</th>
<th>Hour 5</th>
<th>Hour 6</th>
<th>Hour 7</th>
<th>Hour 8</th>
<th>Hour 9</th>
<th>Hour 10</th>
<th>Hour 11</th>
<th>Hour 12</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Glucose</em></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Sodium</strong></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>****Potassium</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Chloride</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>BUN</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Creatinine</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>****Magnesium</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>****Calcium</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>****Phosphorus</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Blood Gas (CBG, VBG, ABG)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>ß-hydroxybutyrate</strong></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>†Blood culture</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>†Urinalysis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

* Repeat glucose every hour while on insulin drip, send first glucose to the lab as well for serum glucose
** Repeat sodium and BOHB every 2 hours while on insulin drip
**** May repeat these labs every 4 hours until normalized, especially while on insulin drip
† Only if febrile or concern for infection and do not repeat if done at referral hospital
‡ Repeat if done at referral hospital

- 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 every hour for at least the first 12 hours, up to 24 hours.

- A GCS of $\leq 13$ 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 presentation^{8,90}
  - increased BUN at presentation^{8,83}
  - severity of acidosis at presentation^{18,83}
  - use of bicarbonate for treatment of acidosis^{8}
  - attenuated rise in serum sodium concentration during treatment associated with a decrease in effective plasma osmolality^{45}
  - greater volumes of fluid administration during the first 4 hours^{18}
  - administration of insulin in the first hour of fluid resuscitation^{18}
## DETERMINING CLINICAL CEREBRAL EDEMA RISK

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

* 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]

### 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]

- **Ensure an adequate airway and assist ventilation initially by manual bag-mask and subsequently by endotracheal intubation only as necessary.** [LOE: C]

- **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.

- **Elevate the head of the bed and keep the head positioned midline.** [LOE: NC]

- **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]
- 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}. 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)
<table>
<thead>
<tr>
<th>Complication</th>
<th>Association</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypokalemia</td>
<td>Inadequate potassium replacement; ongoing potassium losses</td>
<td>Increase K replacement; may require concentrated K infusion at 0.1-0.3 mEq/kg/hr</td>
</tr>
<tr>
<td>Hyperkalemia</td>
<td>Renal failure</td>
<td>Reduce/eliminate K in IV fluids; continuous renal replacement therapy as necessary</td>
</tr>
<tr>
<td>Hypophosphatemia</td>
<td>Renal losses</td>
<td>Will normalize with re-establishment of nutritional support. Severe hypophosphatemia in conjunction with unexplained weakness should be treated [LOE: NC][55]</td>
</tr>
<tr>
<td>Hypoglycemia</td>
<td>Failure to add glucose to IV fluids when serum glucose declines below 300 mg/dL</td>
<td>Addition of 5-12.5% dextrose to IV fluids when serum glucose declines below 300 mg/dL</td>
</tr>
<tr>
<td>Disseminated intravascular coagulation</td>
<td>Infection, tissue necrosis</td>
<td>Monitor for infection, thrombosis</td>
</tr>
<tr>
<td>Central venous thrombosis or stroke[103,104]</td>
<td>Prolonged dehydration; DKA represents a hypercoagulable state[99-102]</td>
<td>Avoid central venous catheterization, if occurs with CVC anticoagulate</td>
</tr>
<tr>
<td>Dural sinus, basilar artery thrombosis or stroke[84,101]</td>
<td>Prolonged dehydration; DKA represents a hypercoagulable state[99-102]</td>
<td>If underlying coagulopathy suspected, anticoagulate[105]</td>
</tr>
<tr>
<td>Sepsis</td>
<td>Impaired immunity associated with diabetes mellitus. Antecedent for DKA</td>
<td>Antimicrobials</td>
</tr>
<tr>
<td>Mucormycosis[106]</td>
<td>Infection specifically associated with DKA, especially rhinocerebral or pulmonary infections.</td>
<td>Infectious Disease, Otolaryngology consultations. Caspofungin, liposomal amphotericin B[107]</td>
</tr>
<tr>
<td>Rhabdomyolysis[108]</td>
<td>Hypophosphatemia, anemia, thrombocytopenia. High osm on admission; more frequent in hyperglycemic hyperosmolar state</td>
<td>Preserve good renal blood flow.</td>
</tr>
<tr>
<td>Pancreatitis[109,110]</td>
<td>Associated with abdominal pain but not always, often associated with elevated BUN</td>
<td>Chemical pancreatitis is common in DKA, but clinical pancreatitis is rare. Check lipase, amylase, lipids and calcium levels.</td>
</tr>
<tr>
<td>Hyperglycemic Hyperosmolar syndrome</td>
<td>Higher risk of thrombosis, rhabdomyolysis, malignant hyperthermia, cerebral edema.</td>
<td>Generally requires more careful fluid therapy, careful Na, K and GCS monitoring. Insulin at 0.05-0.1 units/kg/hr.</td>
</tr>
<tr>
<td>Hyperchloremic metabolic acidosis[111]</td>
<td>Large volume resuscitation with normal saline.</td>
<td>Use potassium as K acetate and K phosphate to replace K.</td>
</tr>
</tbody>
</table>
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 Diabetes¹¹³ 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](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.

- Instruct patients to contact the endocrinologist on call at 206-987-2000 for urgent questions about their blood glucose before their phone follow-up with their primary diabetes care provider or their designee.
C. IMPLEMENTATION TOOLS

1. Algorithms
   a. Assessment and Disposition for DKA
   b. DKA Pathway
   c. Lab Schedule

2. Two-bag system dose calculator (paper and electronic version)
3. Two-bag system education materials
1) ABCD’s and Weight

Weight on Admission

2) Confirm Diagnosis

Clinical Signs
- Dehydration
- Kussmaul breathing
- Smell of ketones
- Lethargy
- Vomiting
- Abdominal tenderness
- Mental Status Changes

Historical Features
- Polyuria
- Polydipsia
- New onset enuresis
- Nocturia
- Weight loss
- Abdominal pain
- Fatigue
- Nausea/vomiting
- Headache
- Confusion
- Candida infection

Initial Labs
- Serum Glucose
- Blood gas
- Na, K, Cl, HCO₃, Ca, Mg, Phos
- Corrected Na and serum osmolality
- BUN/Cr
- BOHB
- Blood culture and UA if febrile or concern for infection

Neurologically Unstable
- Anisocoria
- Asymmetric Neuro Exam
- Non-responsive
- GCS ≤ 13

Neurologically Stable

3) Assess Risk and Initial Disposition

Call Endocrine

Assess Cerebral Edema Risk

ICU Consultation
If at high risk for cerebral edema

Low (Home)
- Not new onset
- Overt insulin pump failure, not meeting medium or high risk criteria
- Able to manage DM at home
- Able to tolerate oral fluid

Medium (Floor)
- New onset DM not meeting ICU criteria
- Unable to manage DM at home

High (ICU)
- Age ≤ 24 months
- Development delay or any condition that compromises communication
- GCS ≤ 13 after volume resuscitation
- Abnormal neurological exam after volume resuscitation
- Other organ system dysfunction
- Presenting pH < 7.15
- Presenting HCO₃ ≤ 5 mEq/L
- Presenting PCO₂ < 10 mmHg
- Presenting BUN > 30 mg/dL
- Patient received IV bicarbonate or insulin bolus
- Na < 140 mEq/L (corrected) or falling Na at 2 hour labs
- Calculated mOsm > 350
- Patient received > 40 mL/kg total initial volume replacement (include all fluids received prior to arrival to SCH)

4) Discharge Criteria

Discharge to Home
- 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
- Glucagon and other supplies addressed.

Meets DKA Definition
1) Hyperglycemia > 200 mg/dL &
2) Ketonemia (BOHB > 1 mmol/L) &
3) pH ≤ 7.3 or HCO₃ < 15 mEq/L

Initial Labs

Weight on Admission

ASSESSMENT AND DISPOSITION FOR DKA
Diabetic Ketoacidosis (DKA) Pathway Overview

**DKA Suspected**
- ABCDs and Weight
- 1) Confirm Dx
- 2) Consult Endo
- Initial labs

**PHASE 1: Early Electrolyte Adjustment/Rehydration**
- Activate "DKA" Primary and Two Bag system
- Monitor GCS and neurological status every hour up to 24 hours if presenting pH < 7.15
- See "LAB SCHEDULE" for recommended labs

**Volume Expansion**
- Place 2 IVs
- 1st NS Bolus (10mL/kg over 1 hr)

**2nd NS Bolus**
- NS + K-phos / K-acetate

**3rd NS Bolus**
- ½ NS + K-phos / K-acetate

**PHASE 2: Ongoing Electrolyte Adjustment/Rehydration**
- **Use NS if corrected Na >150**

**Oral**
- **Use NS if corrected Na >150**

**Not Applicable**
- **ADD D10 NS + Kphos/Kacetate WHEN Glucose <200 or precociously labs
- D10 ½ NS +Kphos / K-acetate

**Fluid & Electrolyte Replacement**
- Continuous Insulin at 0.1 units/kg/hr OR 0.05 units/kg/hr
- 30 minute overlap

**Insulin**
- SC Insulin

**Time**
- 1 hr
- 4 hrs
- Up to 48 hrs

**Presentation**
- Time may vary for pts who first present to outside facility

**Transition Phase**
- Discharge

**Bohr et al**

**This intervention is not anticipated for routine management but may be indicated in some circumstances**
Table 1. Lab schedule

<table>
<thead>
<tr>
<th>Laboratory analysis</th>
<th>DKA confirmed</th>
<th>Hour 1</th>
<th>Hour 2</th>
<th>Hour 3</th>
<th>Hour 4</th>
<th>Hour 5</th>
<th>Hour 6</th>
<th>Hour 7</th>
<th>Hour 8</th>
<th>Hour 9</th>
<th>Hour 10</th>
<th>Hour 11</th>
<th>Hour 12</th>
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<tr>
<td><em>Glucose</em></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>Sodium</strong></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>****Potassium</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>Chloride</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>Bicarbonate</td>
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<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>BUN</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Creatinine</td>
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<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>****Magnesium</td>
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<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>****Calcium</td>
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<td>X</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>****Phosphorus</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
</tr>
<tr>
<td>Blood Gas (CBG, VBG, ABG)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>X</td>
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</tr>
<tr>
<td><strong>ß-hydroxybutyrate</strong></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>†Blood culture</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>†Urinalysis</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

* Repeat glucose every hour while on insulin drip, send first glucose to the lab as well for serum glucose
** Repeat sodium and BOHB every 2 hours while on insulin drip
**** May repeat these labs every 4 hours until normalized, especially while on insulin drip
† Only if febrile or concern for infection and do not repeat if done at referral hospital
‡ Repeat if done at referral hospital
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
Maximum calculation weight used is 80 kg.
Severity of Dehydration - assume:
Fluid deficit = weight (max: 80 kg) * percentage dehydrated

VOLUME RESUSCITATION
TOTAL fluids administered during resuscitation phase
This is greater than 40 ml/kg, contact ICU for evaluation.
Maintenance fluids for one day:
Total fluids to administer over 48 hours (maintenance * 2 + deficit - resuscitation)
NOTE: Formula is such that we never provide less than 1 x maintenance fluids.

TOTAL IV FLUID RATE:
**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.

<table>
<thead>
<tr>
<th>Blood Glucose (mg/dL)</th>
<th>% of Rate From 0.45% saline 20 mEq/L KAc 20 mEq/L KPhos Bag</th>
<th>% of Rate From 10% Dextrose 0.45% saline 20 mEq/L KAc 20 mEq/L KPhos Bag</th>
<th>Final Dextrose Concentration (%)</th>
<th>Insulin Infusion Rate (units/kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;300</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>299-250</td>
<td>75</td>
<td>25</td>
<td>2.5</td>
<td>0.1</td>
</tr>
<tr>
<td>249-200</td>
<td>50</td>
<td>50</td>
<td>5</td>
<td>0.1</td>
</tr>
<tr>
<td>199-150</td>
<td>25</td>
<td>75</td>
<td>7.5</td>
<td>0.1</td>
</tr>
<tr>
<td>149-100</td>
<td>0</td>
<td>100</td>
<td>10</td>
<td>0.1</td>
</tr>
<tr>
<td>&lt; 100</td>
<td>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.</td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
</tbody>
</table>
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 ≤ 40 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.
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]
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.
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.
Diabetic Ketoacidosis (DKA) Citation

Title: Diabetic Ketoacidosis (DKA)

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- Tony Woodward, MD, MBA
- Jerry J. Zimmerman, MD

Date: April 2011

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

Example:
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 pCO₂, 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:
<table>
<thead>
<tr>
<th>Number</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>80.</td>
<td>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.</td>
</tr>
</tbody>
</table>


