Diabetic Ketoacidosis (DKA) & Hyperosmolar Diabetic Ketoacidosis (H-DKA)

Emergency Department

Nationwide Children's — When your child needs a hospital, everything matters.

Center for Clinical Excellence

Pathway Inclusion Criteria:
- Venous pH < 7.3
- Serum glucose ≥ 200 mg/dL
- Serum bicarbonate < 15
- Ketosis (β-OH-Butyrate ≥ 3 mmol/L or moderate urinary ketones ≥ 40)

Exclusion Criteria

Signs and Symptoms:
- Polyuria*
- Polydipsia*
- Fatigue*
- Weight loss
- Anorexia
- Nausea
- Vomiting
- Abdominal pain
- Hyperventilation and deep (Kussmaul) respirations

*Most common

Differential Diagnosis

Initial Assessment
- Obtain: blood gas, Chem 10, β-OH-butyrate, urinalysis
- Assess dehydration, respiratory and neurologic status
- *Address electrolyte abnormalities based on blood gas*

If Inclusion Criteria met:
- NPO
- Obtain IV access x2
- Infectious concerns: CBC, UA, blood & urine cx
- Calculate Corrected Na
  Measured Na+ + 1.6(serum glucose-100)/100

Concerns for Cerebral Edema?

Yes →
1) Administer
3% hypertonic saline (5 mL/kg/dose)
or
Mannitol (1 g/kg/dose)
Beware of diuresis in severely dehydrated patient
2) Consider **CT scan**
(Administer mannitol or hypertonic saline PRIOR)

No ↓

POC glucose > 600 mg/dL or "high" reading?

Yes →
Concerning for Hyperosmolar-DKA
- Requires greater fluid resuscitation than DKA
- Greater risk of complications
- Stabilize circulation prior to initiating insulin

No ↓

Rehydration
- 10-20 mL/kg NS over 30-60 minutes
- Then assess need for an additional IVF boluses (ex: signs of shock)

Rehydration
- 20 mL/kg NS over 30-60 minutes
- *Additional fluid boluses* should be given rapidly if necessary to restore peripheral perfusion

Continued Management
- If insulin pump in place, remove when starting IV insulin
- Check blood glucose (BG) prior to starting insulin

Initiate IV insulin after completing initial rehydration
Start at 0.05 u/kg/hr if ≤ 5 years OR concern for hyperosmolar DKA

Start "2 Bag System" IVF at 1.5 x maintenance rate
Can base on blood gas results

Correct electrolyte abnormalities

Adjust "2 bag system" for changes in BG
- Labs:
  Q 1 hour BG
  Q 2 hours Electrolytes, blood gas

Aim to ↓ BG by 50-100 mg/dL per hour

Not Recommended
- Sodium bicarbonate
- Insulin bolus

Disposition Recommendations

Requires PICU care?

Yes → Admit to PICU

No ↓ Admit to Endocrinology

Inclusion & Exclusion Criteria

Inclusion Criteria for DKA (moderate risk for cerebral edema, requiring intravenous fluids and insulin drip)

- Age 12 months - 21 years
- Blood glucose ≥ 200-600 mg/dL
- Ketosis (β-OH-Butyrate ≥ 3 mmol/L or moderate urinary ketones ≥40)
- Venous pH <7.3 or serum bicarbonate < 15 mEq/L

Inclusion Criteria for Hyperosmolar-DKA (moderate-high risk for cerebral edema, requiring intravenous fluids and insulin drip)

- Age 12 months - 21 years
- Blood glucose > 600 mg/dL
- Ketosis (β-OH-Butyrate ≥ 3 mmol/L or moderate urinary ketones ≥40)
- Venous pH <7.2 or serum bicarbonate < 15 mEq/L
- Serum osmolality > 320 mOsm/kg

*Criteria apply when conditions met at any time during referring facility stay or NCH.

If patient has signs of DKA but does not meet inclusion criteria, off pathway but discuss with Endocrinology Team.

Exclusion Criteria

- Inclusion criteria not met
  (see Sick Day Protocol for patients deemed to be low risk and contact Endocrinology)
- Hyperglycemic Hyperosmolar State (HHS) – must meet all:
  Blood glucose > 600 mg/dL
  Venous pH > 7.25
  Serum bicarbonate ≥ 15 mEq/L
  Absent to small urine ketones
  Serum osmolality > 320 mmol/kg

Algorithm

Initial Assessment

- Airway, Breathing & Circulation (A,B,C's)
- Vital signs
- Hydration status
- Presence of signs of increased intracranial pressure:
  - Pupil asymmetry
  - ↑ blood pressure
  - ↓ heart rate
- Assess for shock as part of circulation assessment

Assessment of Dehydration

Cerebral Edema

Normal Respiratory Rates	
Age	**Rate (breaths per minute)**
Infant	30-53
Toddler	22-37
Preschooler	20-28
School-age	18-25
Adolescent	12-20
2020 American Heart Association Pediatric Advanced Life Support	

Normal Heart Rates		
Age	**Awake Rate (bpm)**	**Sleeping rate (bpm)**
Neonate	100-205	90-160
Toddler	100-180	90-160
Preschooler	80-120	65-100
School-age	75-118	58-90
Adolescent	60-100	50-90
2020 American Heart Association Pediatric Advanced Life Support		

Normal Blood Pressures			
Age	**Systolic (mm Hg)**	**Diastolic (mm Hg)**	**Mean Arterial (mm Hg)**
Neonate	67-84	35-53	45-60
Infant (1-12mo)	72-104	37-56	50-62
Toddler (1-2 y)	86-106	42-63	49-62
Preschooler (3-5 y)	89-112	46-72	58-69
School age (6-9 y)	97-115	57-76	66-72
Preadolescent (10-12 y)	102-120	61-80	71-79
Adolescent	110-131	64-83	73-84
2020 American Heart Association Pediatric Advanced Life Support			

Algorithm

Assessment of Dehydration

Signs and Symptoms	Degree of Dehydration		
	None or Mild	Moderate	Severe
General Condition			
Infants	Thirsty, alert, restless	Lethargic or drowsy	Limp; cold cyanotic extremities; may be comatose
Children	Thirsty, alert, restless	Alert; postural dizziness	Apprehensive; cold, cyanotic extremities; muscle cramps
Quality of radial pulse	Normal	Thready or weak	Feeble or impalpable
Quality of respiration	Normal	Deep	Deep and rapid
Skin elasticity	Pinch retracts immediately	Pinch retracts slowly	Pinch retracts very slowly (> 2 sec)
Eyes	Normal	Sunken	Very sunken
Tears	Present	Absent	Absent
Mucous membranes	Moist	Dry	Very dry
Urine output (parental report)	Normal	Reduced	None passed in many hours

Adapted from Gorelik MH, Shaw KN, Murphy KO. Validity and reliability of clinical signs in the diagnosis of dehydration in children. Pediatrics. 1995;99(5):1-6

Algorithm

Differential Diagnosis

Differential Diagnosis

- Hyperglycemic Hyperosmolar State (HHS)*
- Lactic Acidosis
- Starvation Ketosis
- Alcoholic Ketoacidosis
- Uremic Acidosis
- Toxic Ingestion

***HHS Laboratory Definition**
(Must have all)

- Serum glucose > 600 mg/dL
- Absent to small urine ketones
- Serum osmolality > 320 mmol/kg
- Venous pH > 7.25
- Serum carbon dioxide ≥ 15 mEq/L

Algorithm

Hyperosmolar DKA

For Comparison, Moderate-Severe DKA and Hyperosmolar DKA	
DKA (moderate-severe) • Blood glucose ≥ 200-600 mg/dL • Ketosis (β-OH-Butyrate ≥ 3 mmol/L) • Moderate urinary ketones (≥40+) • Venous pH <7.3 • Serum bicarbonate < 15 mEq/L	**Hyperosmolar DKA (requires greater fluid resuscitation than DKA)** • Blood glucose > 600 mg/dL • Ketosis (β-OH-Butyrate ≥ 3 mmol/L) • Moderate urinary ketones (≥40+) • Venous pH <7.2 • Serum bicarbonate < 15 mEq/L • Serum osmolality > 320 mOsm/kg

Hyperosmolar DKA carries greater risk of complications than DKA:

- Shock with hemodynamic compromise
- Altered mental status
- Severe hypokalemia and hypophosphatemia
- Kidney injury
- Rhabdomyolysis
- Pancreatitis
- Thrombosis
- Malignant hyperthermia-like syndrome (fever, rhabdomyolysis and high mortality rates – can treat with Dantrolene)

Algorithm

Severity Assessment for Risk of Developing Cerebral Edema & Recommended Disposition

Low Risk Criteria

- pH ≥7.2
- serum carbon dioxide ≥15 mEq/L
- Able to tolerate oral fluids.
- Decreasing ketonuria (management initiated at home with sick day protocol)

Disposition*

Able to manage mild acidosis at home (per sick day protocol) if knowledgeable caregiver and able to easily return to main campus, if needed. Call Endocrinology on call provider to discuss disposition to admit versus discharge home.

All patients with suspected New Onset Diabetes Mellitus should be admitted to the endocrinology service.

Medium Risk Criteria

- Not meeting low or high risk criteria
- Progression of ketonuria precluding home management
- Unable to tolerate oral challenge even in mild DKA
- Presence of unstable social situation

Disposition

Admit to Endocrinology Service for IV insulin therapy after discussion with on call Endocrinology Provider.

High Risk Criteria

- Lowest pH < 7.1 age < 3 years
- Lowest pH < 7.0 age ≥ 3 years
- Blood glucose > 600 mg/dL
- Corrected Serum Sodium > 155 mEq/L
- New onset neurological deficit
- Clinical or radiographic concerns for cerebral edema

Cerebral Edema

Disposition

Consider pediatric intensive care unit (PICU) for IV insulin therapy and ongoing monitoring. Strongly consider PICU admission based on labs at initial presentation.

Algorithm

Cerebral Edema
Risk Factors & Clinical Signs & Management

Risk Factors for Cerebral Edema

- Age < 3 years
- Administration of bicarbonate
- Low PaCO2 levels at presentation
- Excessive fluid resuscitation (≥ 40 mL/kg bolus)

Clinical Signs of Cerebral Edema

- Concerning or deteriorating mental status
- Headache
- Abnormal pupils
- Bradycardia or lower heart rate than expected for degree of dehydration*
- Hypertension*
- Altered breathing pattern (grunting, Cheyne-Stokes, apneusis)*

*When seen together are late signs and concerning for herniation

Management of Suspected or Confirmed Cerebral Edema

1) Administer:
3% hypertonic saline (5 mL/kg/dose)
or
Mannitol (1 g/kg/dose) *Beware of diuresis in severely dehydrated patient.*

2) Elevate head of bed

3) Discuss indications for **CT scan with PICU** (administer mannitol or hypertonic saline **PRIOR**)

Algorithm

Electrolyte Management

Sodium (Na^+)	
Corrected sodium calculation Measured Na + 1.6 (serum glucose – 100)/100	Useful for monitoring response to fluid therapy during DKA when hyperglycemia exists (glucose >100 mg/dL)
For corrected Na^+ < 140 mEq/L	Maintenance fluid containing Normal Saline should be used if not started prior
For corrected Na^+ < 125 mEq/L	Consider 3% Sodium Chloride

Potassium (K^+)

- For potassium < 3.0, give KCL 0.2-1 mEq/kg/dose (max 40 mEq) during initial fluid resuscitation. Recheck potassium level via poc blood gas to ensure ≥ 3.0 *prior to stating insulin drip*
- Include K^+ in continuous IV fluids at the time of initiation, unless true hyperkalemia (> 6 mmol/L) exists
- Adequate urine output should be demonstrated prior to initiating K^+ replacement

For K^+ replacement, administer as KPhos and KCl^- preferably	If KPhos unavailable, use K^+ acetate

Suggested potassium components for continuous IV fluids

Serum K^+	KPhos (mEg/L)	KCL^- (mEg/L)
<4.5	30	30
4.5-6	20	20
>6	None	None

For hyper or hypokalemia, have patient on continuous ECG monitoring

For hyperkalemia, please refer to the ED Hyperkalemia Clinical Pathway

Calcium (Ca^{++}), Phosphorous (PO_4^{3-})

Closely observe calcium levels with KPhos administration since hypocalcemia may be induced

Treat severe hypophosphatemia (Phos <1mg/dl)	Important especially if this is accompanied by clinical features (muscle weakness, cardiac dysfunction specifically, left ventricular dysfunction, symptomatic anemia, or respiratory depression)

Bicarbonate ($HCO3^-$)

Avoid routine $HCO3^-$ administration since paradoxical CNS acidosis may develop & hypokalemia may be precipitated

In life threatening hyperkalemia bicarbonate therapy may be administered

Algorithm

Recommended Treatments for Medium or High Risk Patients

Intravenous Fluid (IVF) Administration & IV Insulin Phase

Fluid administration and IV insulin therapy occurs simultaneously

IVF administration:

- 1.5 X maintenance rate

For potassium < 3.0, give KCL 0.2-1 mEq/kg/dose (max 40 mEq) during initial fluid resuscitation. Recheck potassium level via POC blood gas to ensure ≥ 3.0 *prior to starting insulin drip*

Two-Bag system:

- 10% Dextrose in NS
- NS

Calculation of maintenance IVF by 4, 2, 1 rule:

- 4 mL/kg/hour for first 10 kg
- 2 mL/kg/hour for second 10 kg mL/kg
- 1mL/kg/1mL/kg/hour for each kg over 20kg

Insulin drip:

- Children ≤ 5 years of age OR concern for hyperosmolar DKA start insulin at rate of 0.05 unit/kg/hour
  - *Insulin drip rate may need to be adjusted for those children > 5yo if initial serum BG or electrolytes (serum osmolality < 320 mOsm/kg) do not support hyperosmolar DKA.*
- Children > 5 years of age start insulin drip at rate of 0.1 unit/kg/hour
- Aim to maintain BG between 150-250 mg/dL while patient is receiving insulin drip

Adjust IVF composition based on BG:

- If BG decreases by more than 100 mg/dL in an hour, increase dextrose in IVF to higher concentration. If already on 10%, increase to 12.5%
- If BG is < 100 mg/dL, increase total IVF to 2 X maintenance or discontinue two-bag system and give dextrose 12.5% with same electrolyte content
- Recheck BG in 30 minutes after a change in IVF dextrose or adjustment of IV insulin

Suggested potassium components for continuous IV fluids:

Serum K^+	KPhos (mEg/L)	KCL^- (mEg/L)
<4.5	30	30
4.5-6	20	20
>6	None	None

Blood glucose (mg/dl)	10 % Dextrose NS % of total IV fluids	Final dextrose concentration	Normal Saline % of total IV fluids
> 300	0	**0**	100
200- 300	50	**5 %**	50
101- 199	100	**10 %**	0

Algorithm

Treatments Not Recommended

Bicarbonate therapy should not be used in children with DKA

- Lack of clinical benefit
- Paradoxical central nervous system acidosis
- Associated with development of cerebral injury
- May slow the resolution of ketosis

Insulin bolus is not indicated

- No clinical benefit
- May increase risk of cerebral edema
- May lead to hypoglycemia

Algorithm

Rosenbloom AL. The management of diabetic ketoacidosis in children. *Diabetes Ther*. 2010;1(2):103-120.
Cashen K, Petersen T. Diabetic ketoacidosis. *Peds in Review*. 2019. 412-420.

PICU Admission Criteria

PICU admission for any of the following:

- New onset neurologic deficit
- Concern for cerebral edema

Strongly consider PICU admission

- pH < 7.1 for age < 3 years old
- pH < 7.0 for age ≥ 3 years old
- Initial blood glucose > 1000 mg/dL
- Corrected serum sodium > 155 mEq/L

Algorithm

Key References

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Algorithm

Pathway Team & Process

Pathway Development Team

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Advisory Committee Date: *July, 2022*

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Next Revision Date: *October, 2028*

Clinical Pathway Development

This clinical pathway was developed using the process described in the NCH Clinical Pathway Development Manual Version 6, 2022. Clinical Pathways at Nationwide Children's Hospital (NCH) are standards which provide general guidance to clinicians. Patient choice, clinician judgment, and other relevant factors in diagnosing and treating patients remain central to the selection of diagnostic tests and therapy. The ordering provider assumes all risks associates with care decisions. NCH assumes no responsibility for any adverse consequences, errors, or omissions that may arise from the use or reliance on these guidelines. NCH's clinical pathways are reviewed periodically for consistency with new evidence; however, new developments may not be represented, and NCH makes no guarantees, representations, or warranties with respect to the information provided in this clinical pathway.

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Algorithm