Diabetic ketoacidosis (DKA) in children and adolescents

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Outline

• Definition
• Risk factors
• Pathophysiology
• Diagnostic considerations
• Management
• Complication of management – cerebral edema
Diabetes Mellitus (DM)

Fasting plasma glucose > 126 mg/dL

Type 1      Insulin deficiency
Type 2      Insulin resistance

hyperglycemia
ketoacidosis
dyslipidemia
DM: symptoms & signs

Polyuria, polydipsia, polyphagia
Weight loss, lethargy
Vaginal moniliasis

T2DM: mild symptoms

obesity
Dx with complications
Diabetic ketoacidosis (DKA)

**DKA:** relative, absolute insulin deficiency
  
  increased level of counter-regulatory hormones
  
  catecholamines
  
  glucagon
  
  cortisol
  
  growth hormone
  
  stress from sepsis, trauma, G-I illness

New case

Known case do not take insulin
DKA – severe depletion of water and electrolytes from intra- and extracellular fluid compartments

Clinical manifestations of DKA

Dehydration
Rapid, deep, sighing (Kussmaul breathing)
Nausea, vomiting, abdominal pain
Progressive obtundation, loss of consciousness
Tachycardia, hypotension, shock
coma, dead
(Fever from infection)
Definition: biochemical criteria

- Plasma glucose > 200 mg/dL
- Metabolic acidosis, venous pH < 7.3
  - bicarbonate < 15 mmol/L
- Serum ketone, urine ketone and glucose positive
- [Rare euglycemic ketoacidosis (low CHO intake)]
  - 5% of T2DM with new diagnosis
- Leukocytosis with left shift
- Nonspecific elevation of serum amylase
## Severity of DKA

<table>
<thead>
<tr>
<th></th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Venous pH</strong></td>
<td>&gt;7.2</td>
<td>&gt;7.1</td>
<td>&lt;7.1</td>
</tr>
<tr>
<td></td>
<td>&lt;7.3</td>
<td>&lt;7.2</td>
<td></td>
</tr>
<tr>
<td><strong>Bicarbonate (mmol/L)</strong></td>
<td>&lt;15</td>
<td>&lt;10</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>
Frequency and risk factors

New cases
- incidence T1DM 0.6:100,000 northeast Thailand

Known cases: recurrent DKA
- poor control
- omit insulin
- peripuberty, puberty
- psychiatric, eating disorders
- unstable family
- poor medical services
- insulin pump therapy, short-acting
Hyperglycemic hyperosmolar state (HHS)

- Serum glucose > 600 mg/dL (33 mmol/L)
- Serum osmolality > 320 mOsm/L
  
  Osmolality = \(2(Na + K) + \frac{\text{glucose (mg/dL)}}{18}\)

- Minimal ketonemia, ketonuria
- Mild to moderate acidosis
- Serum HCO3 > 15 mmol/L
- Stupor or coma
- Very severe dehydration but mild or moderate acidosis

T2DM > T1DM (satisfy polydipsia with high concentration fluid)
Pathophysiology of DKA

- Insulin deficiency
  - Lipolysis
    - Hepatic ketogenesis
      - Base loss
        - Vomiting
          - Ketoacidosis
          - Glucagon, Catecholamines, GH, Cortisol
            - Proteolysis & hepatic gluconeogenesis
              - Osmotic diuresis
                - Hyperventilation
                  - Dehydration
                    - Tissue hypoperfusion
                      - Lactic acidosis
        - Glucose utilization
          - Starvation of insulin dependent tissue (liver, fat, muscle)
            - Proinflammatory cytokines
              - Hyperglycemia
                - Hyperventilation
                  - Dehydration
                    - Tissue hypoperfusion
                      - Lactic acidosis
Management of DKA

• Emergency assessment
  Confirm the diagnosis
  Look for infection, insulin omission
  Body weight
  Severity of dehydration 5-10%
  Level of consciousness (Glasgow coma scale)
  Blood sample
  Urine ketone
  Specimen for cultures: blood, urine, throat
  EKG base line evaluation of K+
Severity of dehydration 5-10%

Prolonged capillary refill time (N<1.5-2 sec)

Abnormal skin turgor

Hyperpnea
Blood sample

Glucose, ketones (beta-hydroxybutyrate)
Electrolyte, BUN, Cr
Venous, arterial pH
Osmolality
CBC (DKA is associated with leukocytosis)
Ca, Po4, Mg, HbA1c
Supportive measures

Secure airway, empty stomach
Peripheral IV catheter or arterial cath (critical ill)
Cardiac monitor (T wave for hypo-, hyper K)
Oxygen in shock
Antibiotics after culture, bladder cath
Monitoring

Flow chart hr by hr:
  clinical, IV medications, fluid, lab results
Hourly: VS, neuro signs (GCS)
  fluid I/O
  amount of insulin
  capillary blood glucose
2-4 hr: electrolyte, glucose, BUN, Ca, Mg, PO4, Hct, blood gas, urine ketones until cleared
Corrected Na

Osmotic effect of hyperglycemia → induced dilutional hyponatremia

Corrected Na =

\[
\text{measured Na } + \frac{[\text{plasma glucose (mg/dL)} - 100] \times 1.6}{100}
\]
Goal of therapy

- Correct dehydration
- Correct acidosis and reverse ketosis
- Restore BS to near normal
- Avoid complications of therapy
- Identify and treat any precipitating event
Treatment of DKA

1. Fluid and electrolyte therapy
2. Insulin
3. Treat precipitating factors
Fluid and electrolyte therapy

Moderate DKA  5-7 %
Severe     DKA 7-10 %

Objectives

Restoration of circulatory volume
Replacement of Na and ECF, ICF water deficit
Improved GFR
Reduction risk of cerebral edema
Estimating the level of dehydration

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<th>Moderate</th>
<th>Severe</th>
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<tr>
<td>Infant ≤ 5%, children ≤3%</td>
<td>Infant 6-10%, children 4-6%</td>
<td>Infant &gt;10-15%, children &gt;6-10%</td>
</tr>
<tr>
<td>Clinical state</td>
<td>Alert</td>
<td>Lethargic, obtunded</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>Normal</td>
<td>Low</td>
</tr>
<tr>
<td>Heart rate</td>
<td>Normal</td>
<td>Rapid, feeble pulse</td>
</tr>
<tr>
<td>Capillary refill</td>
<td>Normal</td>
<td>&gt; 3 sec</td>
</tr>
<tr>
<td>Skin turgor</td>
<td>Normal</td>
<td>Absent</td>
</tr>
<tr>
<td>Eyes</td>
<td>Normal</td>
<td>Sunken, soft eyeballs</td>
</tr>
<tr>
<td>Oral mucosa, lips</td>
<td>Moist</td>
<td>Very dry, parched</td>
</tr>
<tr>
<td>Urine output</td>
<td>Normal</td>
<td>Anuria</td>
</tr>
<tr>
<td>Capillary refill</td>
<td>Normal</td>
<td></td>
</tr>
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* With severe hyperosmolarity, skin and subcutaneous tissues are doughy rather than hypoelastic.
Fluid and electrolyte therapy

Fluid:

shock: NSS 10-20 mL/kg within 15-30 min

unshock: 10-20 mL/kg/hr 0.9% NSS in 1st 2 hr

5-10% dehydration

3rd-24th h Total fluid = 24 hr maintenance

+ 5-10% deficit in 48 hr

0.9% or 0.45% NSS (hyperchloremic metabolic acidosis)

(controversy between replacement over 24 and 48 hr)

not more than 4 L/day
Example: fluid in 30 kg child with DKA and without shock

First 2 hr: NSS 10-20 mL/kg/hr

= 300-600 mL/hr

Next 24 hr: maintenance \((1,700 \div 24)\) + \((3,000 \div 48)\)

= 70 mL/hr + 63 mL/hr

= 133 mL/hr NSS, 0.45\% NSS
Electrolyte: K⁺, HCO₃⁻

K⁺: second hour, after voiding, insulin infusion
Serum K < 6 mmol/L
If serum K < 2.5 mmol/L initial hydration
replace K 40 - 80 mmol in fluid 1L,
not more than 0.5 mmol/kg/hr
½ KCl, ½ K₂PO₄
Bicarbonate

severe acidosis pH < 6.9, HCO$_3^-$ < 5 mmol/L
7.5% NaHCO$_3$ 1-2 mmoL/kg, once intravenous drip within 1 hr

NaHCO$_3$

Paradoxical CNS acidosis
Na add to hyperosmolality
Alkali increase hepatic ketone production
Insulin replacement after initial fluid expansion

Continuous low – dose intravenous insulin infusion
Short acting insulin 0.1 unit/kg/hr via insulin pump
Insulin 1 mL = 100 unit
50 unit in NSS 50 mL, 1 mL = 1 unit
Lowering blood glucose 75-100 (50-150) mg/dL/hr
Maintain BG at 180-200 mg/dL
If BG < 150 mg/dL – 10% dextrose solution
  – reduced insulin 0.05U/kg/hr
Blood glucose 250-300 mg/dL

Rehydration fluid 5% dextrose in NSS/2
Insulin infusion 0.05 unit/kg/hr
Start subcu short acting insulin
0.25-0.5 unit/kg/6 hr
Keep BS 180-200 mg/dL
Monitor
VS and neuro sign q 1 hr
Blood glucose q 1 hr
Serum electrolyte, blood gas q 2-4 hr
Intake/output q 2-4 hr
Urine ketone q 6 hr until plasma glucose <250 mg/dL
Serum BUN, Cr, Ca, PO₄ in severe DKA
Flow sheet
Retained NG tube, urinary cath in shock, unconscious
Persistent acidosis

\[ \text{HCO}_3^- < 10 \text{ mmol/L after 8-10 hr of Px} \]
- inadequate insulin effect
- infection

Check insulin dilution and rate
Treat infection
Transition

Stopped IV fluid after oral fluid without vomiting RI or rapid acting insulin 0.25 U sc every 6 hrs
Stopped IV insulin 60-120 min after sc RI
Complications

Cerebral edema
Hypoglycemia
Persistent metabolic acidosis after Px 8-10 hr
Hypokalemia
Hypophosphatemia
Peripheral venous thrombosis
Cerebral edema

Risk factor

- Young children < 5 yr
- Severity of acidosis, dehydration
- NaHCO$_3$ therapy
- Failure of serum Na to increase appropriately during Px for DKA
- Very rare in adults
Mechanism of cerebral edema

Complex: vasogenic, Cytotoxic, osmotic

1stp symptoms and signs: 2/3 within 6-7 hr
1/3 within 10-24 hr after Px

CT brain
39% negative
26% diffuse edema
17% subarachnoid, intraventricular hemorrhage

Clinical diagnosis
Monitoring

Diagnostic criteria

- Abnormal motor, verbal response to pain
- Decorticate, decerebrate posture
- Cranial nerve palsy: III, IV, VI
- Abnormal neurologic respiratory pattern: grunting, tachypnea, Cheyne-Stokes, apneustic

Major criteria

- Altered consciousness, deceleration of heart rate

Minor criteria

- Vomiting, headache, lethargy, diastolic BP > 90 mmHg, age < 5 yr

1 Dx + 2 major, 1 major + 2 minor
Treatment of CE

IV mannitol 1.0 g/kg over 20 minutes
Repeat as necessary in 1-2 hr
Rate of fluid reduction to 2/3
Head elevation
If no response to mannitol,
  5-10 mL/kg 3% saline rapidly (for acute intracranial hypertension)
Respiratory compromised, intubation
Conclusion

Treatment of DKA, \(0.9\)% NSS 5-10% dehydration follow by 0.45% saline, K replacement

Low dose 0.1 U/kg/hr insulin IV infusion after fluid resuscitation

\(\text{HCO}_3\) is contraindicated

CE is the most serious complication
Maintenance therapy

Twice daily injection (TDI)
Insulin: intermediate + short 0.7-1 unit/kg/day
  2/3 in the morning, 1/3 in the evening
  (2:1)                                           (1:1)

Multiple daily injection (MDI)
  : rapid, long acting insulin analogue
  self monitoring of BG

Keep BG premeal 80-130 mg/dL

Diet  : CHO : fat : protein
  50-55 : 25-30 : 15-20
Total insulin Requirement

2/3 am

2/3 NPH

1/3 pm

1/3 regular

½ NPH

½ regular
Self monitoring of blood glucose (SMBG)

ac breakfast, lunch, dinner, hs

urine ketone if glucose > 200 mg/dL

keep BS 80-130 mg/dL
ການໃຫ້ໂຄງກິດກັບພະຍາດເບົາຫວານ

1. ປະຢາດເປັນທາວ
2. Insulin ແລະວິທີການສາທາ
3. ເຈກນາ ການຂອບກາລັກ
4. SMBG
5. ການເບີ່ຄແຍຄຕົນຂອງແລະການແກ້ໄກ່ hypo- 
   ໃລະ hyperglycemia
6. Complications