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

	Mild	Moderate	Severe
Venous pH	>7.2 <7.3	>7.1 <7.2	<7.1
Bicarbonate (mmol/L)	<15	<10	<5

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

$$\text{Osmolality} = 2(\text{Na} + \text{K}) + \frac{\text{glucose (mg/dL)}}{18}$$

Minimal ketonemia, ketonuria

Mild to moderate acidosis

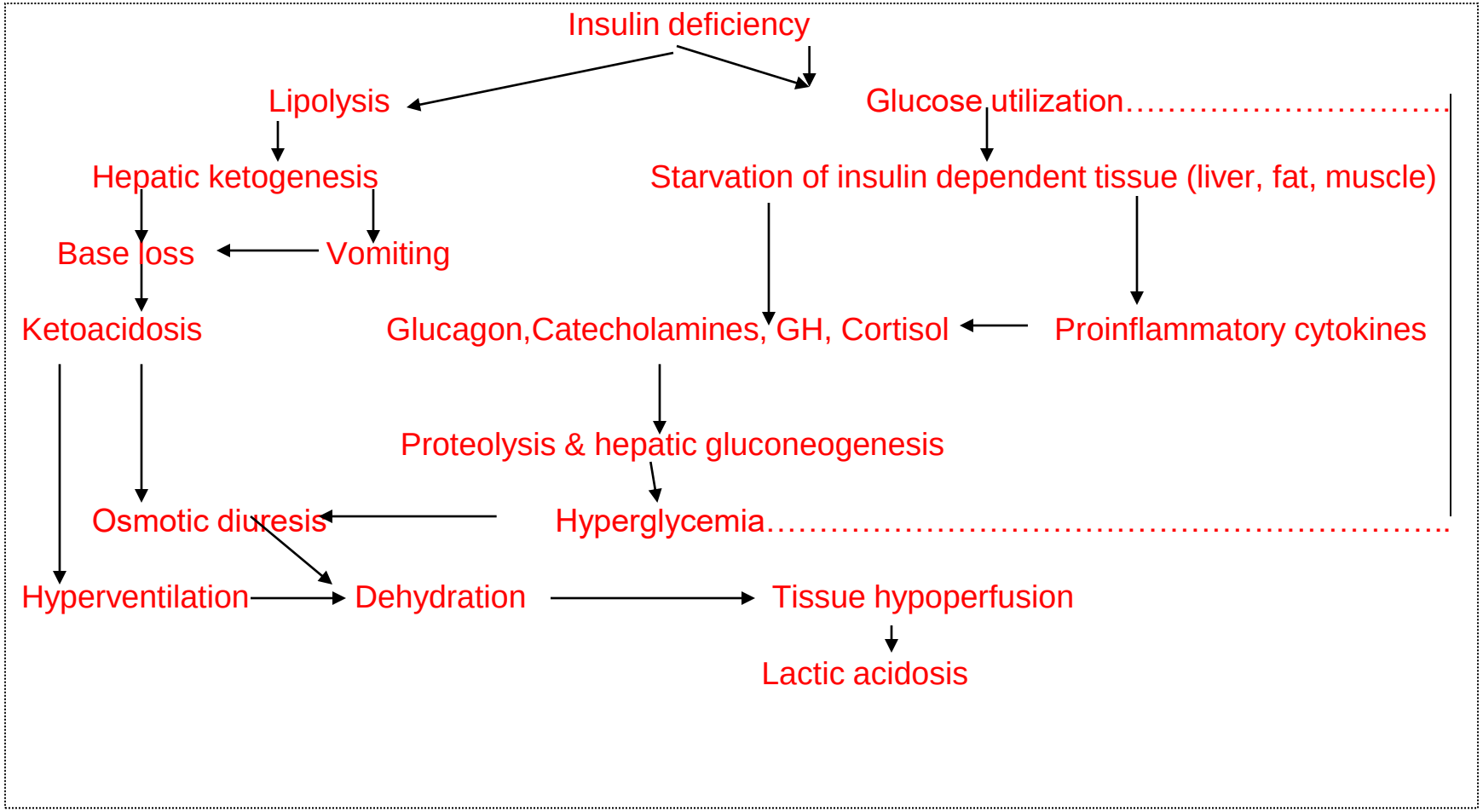
Serum HCO_3 > 15 mmol/L

Stupor or coma

Very severe dehydration but mild or moderate acidosis

T2DM > T1DM (satisfy polydipsia with high concentration fluid)

Pathophysiology of DKA



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 =

$$\textit{measured Na} + \frac{\textit{[plasma glucose (mg/dL) – 100] x 1.6}}{\textit{100}}$$

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

	Mild	Moderate	Severe
	Infant ≤ 5%, children ≤3%	Infant 6-10%, children 4-6%	Infant>10-15%, children>6-10%
Clinical state	Alert	Drowsy,irritable	Lethargic, obtunded
Blood pressure	Normal	Normal	Low
Heart rate	Normal	Increase, weak pulse	Rapid, feeble pulse
Capillary refill	Normal	= 2 sec	> 3 sec
Skin turgor	Normal	Tenting	Absent
Eyes	Normal	Slightly sunken, reduced eyeball turgor	Sunken, soft eyeballs
Oral mucosa, lips	Moist	Dry	Very dry, parched
Urine output	Normal	Reduced	Anuria

* 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 ÷ 24)
+ (3,000 ÷ 48)
: 70 mL/hr + 63 mL/hr
= 133 mL/hr NSS,0.45%NSS

Electrolyte : K^+, HCO_3^-

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 K_2PO_4

Bicarbonate

severe acidosis pH < 6.9, HCO_3 < 5 mmol/L

7.5% NaHCO3 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, PO_4 in severe DKA

Flow sheet

Retained NG tube, urinary cath in shock, unconscious

Persistent acidosis

HCO_3 < 10 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

1 st 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, intraventicular 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

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 analoque

self monitoring of BG

Keep BG premeal 80-130 mg/dL

Diet : CHO : fat : protein

50-55 : 25-30 : 15-20

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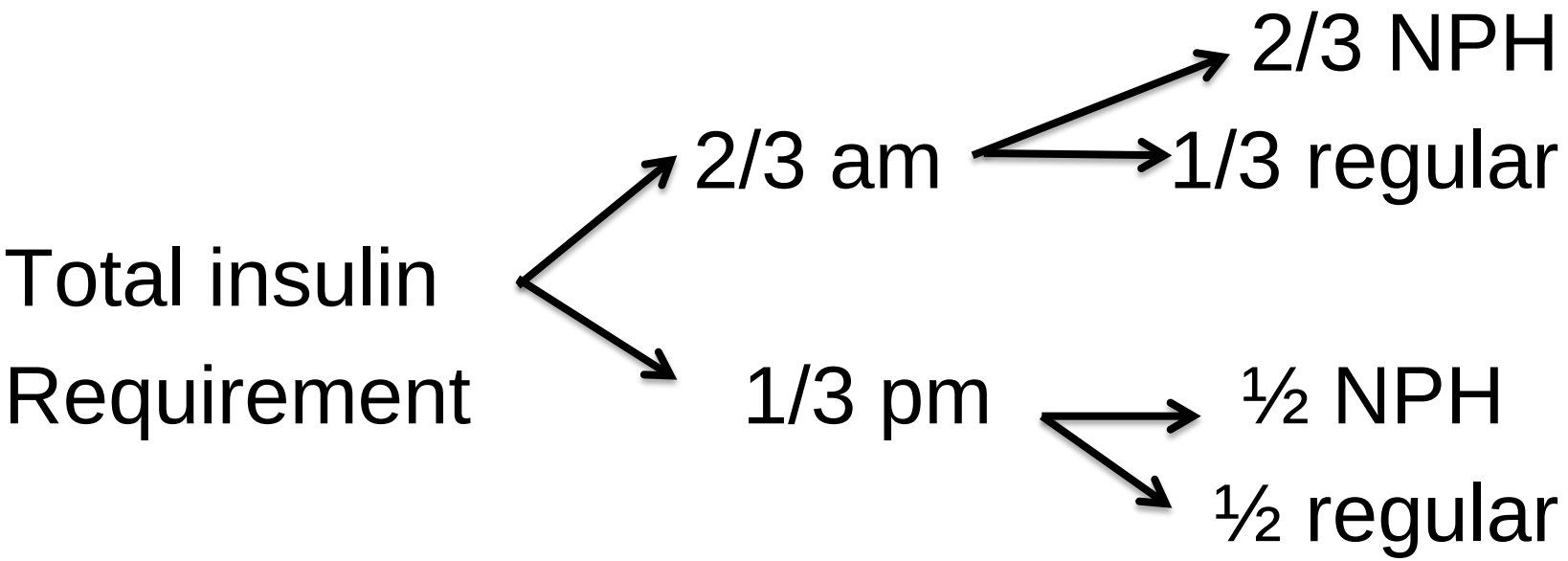
Total insulin
Requirement
2/3 am
2/3 NPH
1/3 regular
1/3 pm
½ NPH
½ regular

Self monitoring of blood glucose (SMBG)

ac breakfast, lunch, dinner, hs

urine ketone if glucose

> 200 mg/dL

keep BS 80-130 mg/dL

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1. ພະຍາດເບົາຫວານ
2. Insulin ແລະວິທີການສັກ
3. ອາຫານ ການອອກກຳລັງກາຍ
4. SMBG
5. ການເບິ່ງແຍງຕົນເອງແລະການແກ້ໄຂ hypo- ແລະ hyperglycemia
6. Complications