HYPERGLYCEMIC CRISSES IN DIABETES

Kudoos Amod
INDEX CASE

72 year female with background history of:-
- Hypertension
- Diabetes Type 2
- Multi-infarct Dementia – CT Scan showed multiple infarcts in BG and R. cerebellum and brain atrophy.
HISTORY

• Poor collateral history
• “Sleeping” for 2 days
• Presented at resus on 28/02/2008, 11.30AM
• PDHx: Hct / Enal 5bd / ASA / Daonil 2.5bd
EXAMINATION

- BP 54/44  P120  SATS 100%  GM 27.1
- GCS 7/15  E1V1M5  Dipstix no ketones
- Clinically dehydrated -> 20% supine hypotension
- No meningism
- PEARRL
- L sided CN 7 Palsy
- Decreased tone globally
- Decreased power globally
- Pus discharging from the right eye
- Rest of examination normal
DIFFERENTIAL DIAGNOSIS

- HHS
- DKA
- ALCOHOLIC KETOACIDOSIS
- STARVATION KETOSIS
- OTHER CAUSES HIGH AG METABOLIC ACIDOSIS –
Other Hyperglycemic States:
- Diabetes Mellitus
- Non-Ketotic Hyperosmolar Coma
- Impaired Glucose Tolerance
- Stress Hypoglycemia

Other Ketotic States:
- Ketotic Hypoglycemia
- Alcoholic Ketosis
- Starvation Ketosis

Other Metabolic Acidotic States:
- Lactic Acidosis
- Hyperchloremic Acidosis
- Salicylamide
- Uremic Acidosis
- Drug-Induced Acidosis
MANAGEMENT PLAN

- Responded well to intravenous fluid bolus N/S and 10u Actrapid s/c.
- GM 5.5  BP  92/65  poor urinary output
- Baseline bloods taken at resus / central line CVP 3CM
- ABG - PH 7.34  PCO2  3.5  PO2  8.9  11.30AM
  
  Na 156  K 5.2  GLUC  7.3
  HCO3-  16.9  BE  - 10.2
  SATS  92%  Hb  11.8

- U&E =  Na 158 / K 5.6 / Cl 127 / co2  16 / U 76.9 / CR 610/ AG 20.6,  CPM normal. LFT 54/21/12/92/32349/321  LDH 1454
- Rocephin  2g stat imi, Clexane prophylaxis  80u daily s/c.
- IVI fluids  0.45%  N/S with  5% dextrose
- BSU  CXR /ECG
- Actrapid infusion commenced as per protocol  5ml/hr
- No beds in ICU / High Care.
AGE IS NOT ENTERED, ASSUMED TO BE 50 YEARS OLD FOR PURPOSE OF ECG INTERPRETATION

97. SINUS RHYTHM. ................................................................. normal P axis, V-rate 50-99
164. NONSPECIFIC IVCQ WITH LAD. ................................. QRSd >120ms & LAD
124. EXTENSIVE ANTERIOR INFARCT, RECENT ...................... Q >35ms, ST >0.07mV, T neg, V1-V6
380
483

- ABNORMAL ECG -

Unconfirmed Diagnosis
• Deteriorating  GM 7.0
• ABG = PH 7.27  PCO2 4.0  PO2 11.3  
  Na 149  K 4.7  lact 1.0  HCO3- 15.6  
  BE - 11.9  SATS 95%  Hb 11.8
• IVI fluids continued 0.45% N/S with 5% dextrose
• Actrapid infusion continued.
• Hourly GM’s and serial ABG’s.
• Transferred to High-Care.
HIGH- CARE 17.30PM

- U&E: Na 151, K 4.7, CL 125, CO2 14 U 71 CR 519
- AG: 16.7
- FBC: WBC 18.76 Hb 12.4 PLET 194 MCV 81.2
HI-CARE  29/2/08    8.35AM

• GCS E3V1M5  9/15
• BP 116/49  SATS 99%  UO 1760ml
• CVP 8cmH2O
• Assessed as HHS with pre-renal impairment and decreased GCS
• Augmentin and Clexane prophylaxis
• Strict input and output monitoring
• ECG - RBBB and LAD - Bifascicular block
• Seen by consultatnt - not candidate for ICU
• Transferred to 5B1 on sliding scale.
WARD 5B1 4/3/2008

- GCS 11/15 E4V2M5
- U&E: Na 142 K 3.3 Cl 118 UREA 6.7 CR 107 CO2 18 AG 9.0
- TRANSFER TO DISTRICT WARD
HYPERGLYCEMIC CRISIS

"Oh, hey! I just love these things! ... Crunchy on the outside and a chewy center!"
CONTENTS

• OTHER HYPERGLYCEMIC STATES
• PATHOGENESIS
• CLINICAL PRESENTATION
• NEUROLOGIC MANIFESTATIONS
• PRECIPITATING FACTORS
• COMPLICATIONS
• CEREBRAL ODEMA
INTRODUCTION

• DKA & HHS represent 2 extremes in spectrum of marked decompensated DM
• Annual incidence hospital admissions for DKA > HHS
• Mortality rates for HHS > DKA -- severe dehydration, older age and the presence of co-morbid conditions.
• Cause of death related to underlying medical illness and not from metabolic complications.
• Factors affecting outcome :-
  - effective standardised treatment protocols
  - prompt identification & Tx of precip. cause.
INTRODUCTION

- Important differences in pathogenesis
- Common basic underlying mechanism = ↓ circulating insulin and concomitant ↑ counterregulatory hormones
- DKA - mostly T1DM
  - catabolic stress of acute illness in T2DM
  - more common in adults > children
  - > 40% blacks with DKA were >40 years
  - > 20% blacks with DKA were > 55 yrs
  - 30% classified as T2DM – obese/measurable insulin secretion, low prevalence AI markers of beta cell destruction.
# Metabolic Causes of Acidosis and Coma

## Lab Evaluation

<table>
<thead>
<tr>
<th></th>
<th>Starvation or high fat intake</th>
<th>DKA</th>
<th>Lactic acidosis</th>
<th>Uremic acidosis</th>
<th>Alcoholic Ketosis</th>
<th>Salicylate intoxication</th>
<th>Methanol or ethylene glycol intoxication</th>
<th>Hyperosmolar coma</th>
<th>Hypoglycemic coma</th>
<th>Rhabdomyolysis</th>
<th>Lactic acidosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pH</strong></td>
<td>Normal</td>
<td>↓</td>
<td>↓</td>
<td>Mild↓</td>
<td>↓↑↑</td>
<td>↓</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td><strong>Plasma glucose</strong></td>
<td>Normal</td>
<td>↑</td>
<td>Normal</td>
<td>Normal</td>
<td>↓ Or Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td><strong>Total plasma Ketones</strong></td>
<td>Slight↑</td>
<td>↑↑</td>
<td>Normal</td>
<td>Normal</td>
<td>Slight to Moderate↑</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td><strong>Anion gap</strong></td>
<td>Slight↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>Normal</td>
<td>↑</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td><strong>Osmolality</strong></td>
<td>Normal</td>
<td>↑</td>
<td>↑</td>
<td>Normal</td>
<td>↑</td>
<td>↑↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td><strong>Uric Acid</strong></td>
<td>Mild↑</td>
<td>↑↑</td>
<td>Normal</td>
<td>Normal</td>
<td>↑</td>
<td>↑↑</td>
<td>↑↑ (≥330 mOsm/kg)</td>
<td>Normal</td>
<td>↑</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td><strong>Glycosuria</strong></td>
<td>Negative</td>
<td>++</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative↑</td>
<td>Negative</td>
<td>Negative</td>
<td>++</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td>Tube +</td>
<td>↑</td>
<td>lactate &gt;7 mmol/L</td>
<td>Serum BUN &gt;200 mg/dl</td>
<td>Salicylate serum levels +</td>
<td>+ serum levels</td>
<td>Magnesium-Uria</td>
<td>Magnesium-Uria</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*+, positive; *Acetate and Ketostix measure acetoacetic acid only; thus, misleading low values may be obtained because the majority of ketone bodies are β-hydroxybutyrate.

*Respiratory alkalosis/metabolic acidosis; *may get false-positive or false-negative urinary glucose caused by the presence of salicylate or its metabolites.

Adapted from reference 5
• Glucose and lipid metabolism regulated by insulin & GCCG
• Insulin - anabolic – glucose used for energy substrate or glycogenesis/protein formation/fats stored as TG’s.
• GCCG – catabolic – glycogenolysis/proteolysis-gluconeogenesis and lipolysis – to FFA & ketone bodies
• FAST → BG falls → insulin decreases & GCCG ↑. This mobilises stored energy substrates
  - glycogen → glucose
  - protein → amino acids → glucose
  - fats → FFA → glucose or ketoacids
• Hyperglycemia- ↑ hepatic prodn & ↓ peripheral utilzn
• ↑ gluconeogenesis – high availability of non-cho substrates (ala/lact/glycerol/glu) & ↑ gluconeogenic enzymes (PEPCK – phosphoenolpyruvate carboxykinase// fructose 1.6 biphosphatase and pyruvate carboxylase)
• Hyperglycaemia & increased ketone bodies -- increased osmotic diuresis and hypovolemia – decre GFR -- aggravates hyperglycaemia.
KETOGENESIS MECHANISMS

- Insulinopenia & ↑ CGGC -- activates lipase in adipose– b/d TG’s into FFA + Glycerol
- Glycerol – substrate for gluconeogenesis in liver
- FFA - massive release – hepatic precursors of ketoacids.
- Liver – glucagon – FFA → oxidised to ketone bodies.
- ↑ Glucagon == ↑ CPT-1 – for trans-esterification of fatty acyl CoA to fatty acyl carnitine -- allows oxidation of fatty acids to ketones -- inhibited by malonyl CoA -- but glucagon decreases this inhibition – increased movement of FFA into mitochondria for oxidation.
- In mitoc – reverse esterifn – fatty acyl coA → acetyl co A forms BHBA and acetoacetic acid – acidosis in DKA. - Filtered via kidney – in presence of hypovolemia , decr GFR - INCR levels ketones.
Pathogenesis of DKA and HHS
Stress, Infection and/or Insufficient Insulin Intake

- Absolute insulin deficiency
  - Lipolysis
  - FFA to liver
  - Ketogenesis
  - Alkali reserve
  - Ketoacidosis
  - Triacylglycerol
  - Hyperlipidemia

- Glucagon
  - Catecholamines
  - Cortisol
  - Growth hormone

- Relative insulin deficiency
  - Absent or minimal ketogenesis

- Glucose utilization
  - Gluconeogenesis
  - Glycogenolysis

- Proteolysis
  - Protein synthesis
  - Gluconeogenic substrates

- Hyperglycemia
  - Glucosuria (osmotic diuresis)
  - Loss of water and electrolytes
  - Dehydration
  - Decreased fluid intake
  - Hyperosmolarity
  - Impaired renal function

- HHS
- DKA
CLINICAL PRESENTATION

• DKA - Younger, lean patients with T1DM  
  - Evolves rapidly within few hours of precipitating events  
  - Kussmauls respiration, acetone breath
• HHS - older, obese pts T2DM  
  - take days or weeks to develop fully  
  - elderly pts - ↓ renal fxn with no h20 access  
  - polydipsia /kussmaul’s and acetone breath absent
• Both conditions - Nausea, vomiting and abdominal pain due to acidosis or ↓ mesenteric perfusion ? Acute abd
• Abd. Pain ∝ severity of acidosis
• More pronounced dehydration in HHS
• Often hypothermic - ? Infection with normal or elevated temps
• Often alert – to profound lethargy/coma
<table>
<thead>
<tr>
<th></th>
<th>Mild DKA</th>
<th>Moderate DKA</th>
<th>Severe DKA</th>
<th>HHS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plasma glucose</strong></td>
<td>&gt; 13.9</td>
<td>&gt; 13.9</td>
<td>&gt; 13.9</td>
<td>&gt; 33.3</td>
</tr>
<tr>
<td><strong>Arterial pH</strong></td>
<td>7.25 to 7.30</td>
<td>7.00 to 7.24</td>
<td>&lt; 7.00</td>
<td>&gt; 7.30</td>
</tr>
<tr>
<td><strong>HCO3</strong></td>
<td>15 - 18</td>
<td>10 to &lt; 15</td>
<td>&lt; 10</td>
<td>&gt; 15</td>
</tr>
<tr>
<td><strong>Urine ketones</strong></td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Sma ll</td>
</tr>
<tr>
<td><strong>Serum ketones</strong></td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Sma ll</td>
</tr>
<tr>
<td><strong>Beta-hydroxybutyrate</strong></td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Normal or elevated</td>
</tr>
<tr>
<td><strong>Serum Osm</strong></td>
<td>Variable</td>
<td>Variable</td>
<td>Variable</td>
<td>&gt; 320</td>
</tr>
<tr>
<td><strong>Anion Gap</strong></td>
<td>&gt; 10</td>
<td>&gt; 12</td>
<td>&gt; 12</td>
<td>Variable</td>
</tr>
<tr>
<td><strong>LOC</strong></td>
<td>Alert</td>
<td>Alert drowsy</td>
<td>Stupor coma</td>
<td>Stupor coma</td>
</tr>
</tbody>
</table>
Typical total body water deficits

<table>
<thead>
<tr>
<th>Diagnostic criteria and classification</th>
<th>DKA</th>
<th>HHS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plasma glucose (mg/dl)</strong></td>
<td>&gt;250</td>
<td>&gt;600</td>
</tr>
<tr>
<td><strong>Arterial pH</strong></td>
<td>7.25-7.30</td>
<td>7.30</td>
</tr>
<tr>
<td><strong>Serum bicarbonate (mEq/L)</strong></td>
<td>15-18</td>
<td>&gt;15</td>
</tr>
<tr>
<td><strong>Urine ketone</strong></td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Serum ketone</strong></td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Effective Serum Osmolality</strong></td>
<td>Variable</td>
<td>Variable</td>
</tr>
<tr>
<td><strong>Anion Gap</strong>*</td>
<td>&gt;10</td>
<td>&lt;12</td>
</tr>
<tr>
<td><strong>Mental Status</strong></td>
<td>Alert/Drowsy</td>
<td>Stupor/Coma</td>
</tr>
</tbody>
</table>

**Typical deficits**

<table>
<thead>
<tr>
<th>Water loss (ml/kg)</th>
<th>% of body weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>100-200</td>
<td>5-13</td>
</tr>
</tbody>
</table>

**Calculation:**

* Nitroprusside reaction method

** Calculation: Effective serum osmolality: 2[m measured Na⁺ (mEq/L) + glucose (mg/dl)/18 [mOsm/Kg]

*** Calculation: Anion Gap: (Na⁺)-(Cl⁻ + HCO₃⁻) (mEq/L) [normal = 12 ± 2].

δ Per Kg of body weight

Data adapted from (1,5).
Mental status and Osmolality

Ranges in Osmolality

( ) = number of patients

Mean Osmolality (mOsm/Kg)

Alert (51)  Drowsy (48)  Stupor (17)  Coma (6)

MENTAL STATUS

Alert  Drowsy  Stupor  Coma
## Comatose versus Noncomatose BIOCHEMISTRY

<table>
<thead>
<tr>
<th></th>
<th>Noncomatose</th>
<th>Comatose</th>
<th>P values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>36.1 ± 3.9</td>
<td>50.2 ± 6.8</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>Glucose (mg/dl)</td>
<td>577.5 ± 42.5</td>
<td>988 ± 175.15</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>HCO₃(meq/l)</td>
<td>8.6 ± 0.72</td>
<td>6.1 ± 0.9</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>pH</td>
<td>7.19 ± 0.25</td>
<td>7.10 ± 0.45</td>
<td>NS</td>
</tr>
<tr>
<td>BUN (mg/dl)</td>
<td>24.1 ± 1.2</td>
<td>54.5 ± 5.2</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Osmolality(mosmol/kg)</td>
<td>313.6 ± 2.2</td>
<td>365 ± 15.2</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Ketones (mM)</td>
<td>13.7 ± 0.76</td>
<td>14.3 ± 1.4</td>
<td>NS</td>
</tr>
</tbody>
</table>
DKA - MENTAL STATUS

• Controversy - PH versus osmolality.
• 3 Studies - 123 cases of DKA - depressed consciousness related to osmolality, not PH.
• Children < 16 -- related to PH
• Table shows 48 pts - evaluated biochemistry of pts with stupor/coma vs non-comatose pts -- showed that only glucose, bicarb, urea and osmolality were signif different - not PH.
• SHOWS osmolality related to glucose levels, not PH.
NEUROLOGIC MANIFESTATIONS HHS

• CNS dysfxn – common – at every level of brain
• Varied neurologic syndromes - from focal findings to frank coma.
• Mechanisms - cerebral dehydration, changes in n/t levels and microvascular ischemia
• Common - lethargy and disordered sensorium
• Less common - coma - marked hypertonicity > 350. Associated with higher sodium > glucose.
  (DKA - glucose > sodium)
FOCAL NEUROLOGIC FINDINGS IN HHS

- Eye deviation
- Nystagmus
- Homonymous hemianopia
- Vestibulobasal dysfxn
- Aphasia
- Autonomic dysfxn - HPT, hyperpnea
- Myoclonic jerks/ seizures
- Focal ↑ or ↓ muscle tone
- Hemiparesis
- Unilateral hyperreflexia
- Babinski sign
- Hemisensory defects
• Rare in DKA
• Occurs in areas of cerebrovasc insufficiency or in distr of old cerebral scars
• Often admitted ? CVA
• Focal findings often remit completely after correction of hypertonicity
• If persists – evaluate for structural lesion or infection
SEIZURES AND HHS

• 25% pts
• Focal/generalised/unusual characteristics
• Gaze-induced visual seizures, posture-induced focal seizures, opsoclonus, occipital seizures
• Often asoc with mean osmol 311 – only 20% > 320
• HHS assoc seizures often resistant to anticonvulants. Often exacerbated by phenytoin
• Treatment by decreasing the hypertonicity
SIGNIFICANT OVERLAP BETWEEN DKA & HHS HAS BEEN REPORTED IN MORE THAN 33% PATIENTS !!
CLINICAL ASSESSMENT

- Detailed history - LOC/UNDERLYING ILLNESS
- Vital signs - tachy = early indicator of dehydration
  - ↓ BP = later sign of profound dehydration
  - Tachypnea = resp. compensation for met.aci
  - sepsis = abn. Low or high temp.
- Thorough skin examn - skin turgor / warm moist – early sepsis / cool, dry – late sepsis
- ENT /LAD/ MENINGISM/ CCF/ARDS/PN/PYELO/PR/PV
- Thorough neurological assessment
**PRECIPITATING FACTORS**

- Most common = inadequate insulin treatment and infections
- Pancreatitis, MI, CVA, Drugs
- DKA - new-onset T1DM or discontinuation of insulin in established T1DM
- HHS - underlying medical illnesses – CVA, MI → provokes release of counterregulatory hormones/ compromises the access to water → severe dehydration.
- Bedridden or restraints – exacerbated by altered thirst response of elderly.
- Delayed recognition of hyperglycemic symptoms in pts with no history of diabetes
- Residents of chronic care facilities – elderly new onset diabetes
- Elderly with known DM who become hyperglycemic but unaware of it or unable to take fluids when necessary.
**PRECIPITATING FACTORS**

- Drugs affect CHO metabolism - steroids, thiazides, sympathomimetics (dobutrex), antipsychotics pp ts DKA/HHS
- T1DM young pts - 20% recurrent DKA’s – psychological problems complicated by eating disorders – fear wt gain – omit insulin // fear hypoglycemia.// stress of chronic disease.
DM TYPE 1.5

• DKA’s without precipitating cause – children/adoles/adults with T2DM
• 50% of newly diagnosed african-americans and hispanic subjects with unprovoked DKA have T2DM.
  - Obese/FHx DM/
  - Measurable pancreatic insulin reserve
  - low prevalence AI markers β cell destruction
  - able to discontinue insulin during follow-up
• Variant of T2DM = atypical DM/ Idiopathic T1DM/Ketosis prone T2DM/ T1.5DM
COMPLICATIONS OF DKA/HHS

- Overzealous treatment with insulin – hypoglycemia and hypokalemia
- Hypokalemia – if tx of acidosis with bicarb
- Hyperglycaemia – if discontinue actrapid infusion without subsequent coverage with s/c actrapid
- Hypoxemia in DKA - ↓ COP – increases lung water content and decreases lung compliance.
- Non-cardiogenic pulmonary oedema in DKA - ESP. patients who have widened alveolo-arteriolar oxygen gradient on initial ABG or with pulmon creps on initial physical examination are at higher risk.
GOALS OF TREATMENT

• FLUIDS, FLUIDS, FLUIDS!
GOALS OF TREATMENT

- Restore perfusion - increases glucose use in periphery, restores GFR, reverses progressive acidosis
- Correct electrolyte losses
- Avoid complications of treatment - intracerebral
Complete initial evaluation. Check capillary glucose and serum/urine ketones to confirm hyperglycemia and ketonemia/ketonuria. Start IV fluids: 1.0 L of 0.9% NaCl per hour.

**IV Fluids**
- Determine hydration status
  - Severe Hypovolemia
  - Administer 0.9% NaCl (1.0 L/hr)
  - Mild dehydration
  - Cardiogenic shock
  - Hemodynamic monitoring/pressors
- Evaluate corrected serum Na⁺
  - Serum Na⁺ high
    - 0.45% NaCl (250-500 ml/hr) depending on hydration state
  - Serum Na⁺ normal
    - 0.9% NaCl (250-500 ml/hr) depending on hydration state
  - Serum Na⁺ low
- When serum glucose reaches 200 mg/dL, change to 5% dextrose with 0.45% NaCl at 150-250 ml/hr

**Insulin**
- IV Route
  - Uncomplicated DKA: SC route
    - Insulin: Regular 0.1 U/kg B. Wt. as IV bolus
    - Rapid-acting insulin: 0.3 U/kg B. Wt., then 0.2 U/kg 1 hr later
  - 0.1 U/kg/hr IV continuous insulin infusion
  - Rapid-acting insulin: 0.2 U/kg SC every 2 hrs
- When serum glucose does not fall by 50-70 mg/dL in first hour, double IV or SC insulin bolus
- If serum glucose reaches 200 mg/dL, reduce regular insulin infusion to 0.05 - 0.1 U/kg/hr IV, or give rapid-acting insulin at 0.1 U/kg SC every 2 hrs. Keep serum glucose between 150 and 200 mg/dL until resolution of DKA.

**Potassium**
- Establish adequate renal function (urine output ~ 50 ml/hr)
- If serum K⁺ is < 3.3 mEq/L, hold insulin and give 20 - 30 mEq K⁺/hr until K > 3.3 mEq/L
- If K⁺ is ≥ 5.3 mEq/L, do not give K⁺ but check serum K⁺ every 2 hrs
- If serum K⁺ is > 3.3 but < 5.3 mEq/L, give 20-30 mEq K⁺ in each liter of IV fluid to keep serum K⁺ between 4 - 5 mEq/L

**Assess need for Bicarbonate**
- pH < 6.9
  - Dilute NaHCO₃ (100 mmol) in 400 ml H₂O with 20 mEq KCl. Infuse for 2 hrs
- pH 6.9-7.0
  - Dilute NaHCO₃ (50 mmol) in 200 ml H₂O with 10 mEq KCl. Infuse over 1 hr
- pH > 7.0
  - No HCO₃

Check electrolytes, BUN, venous pH, creatinine and glucose every 2 - 4 hrs until stable. After resolution of DKA and when patient is able to eat, initiate SC multidose insulin regimen. Continue IV insulin infusion for 1 - 2 hr after SC insulin begun to ensure adequate plasma insulin levels. In insulin naive patients, start at 0.5 U/kg to 0.8 U/kg body weight per day and adjust insulin as needed. Look for precipitating cause(s).
Complete initial evaluation. Check capillary glucose to confirm hyperglycemia. Start IV fluids: 1.0 L of 0.9% NaCl per hour.†

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    - 0.45% NaCl (250-500 ml/hr) depending on hydration state
  - Serum Na⁺ normal
  - 0.9% NaCl (250-500 ml/hr) depending on hydration state
  - Serum Na⁺ low
    - 0.45% NaCl (250-500 ml/hr) depending on hydration state
- When serum glucose reaches 200-250 mg/dl, change to 5% dextrose with 0.45% NaCl at 150-250 ml/hr

**Insulin**
- IV regular insulin
  - Insulin: 0.1 U/kg body weight as IV bolus
  - 0.1 U/kg/hr IV continuous insulin infusion
  - If serum glucose does not fall by 50-70 mg/dl in first hour, double insulin dose
  - When serum glucose reaches 300 mg/dl, reduce regular insulin infusion to 0.05-0.1 U/kg/hr IV.
  - Keep serum glucose between 250 and 300 mg/dl until plasma osmolality is ≤315 mOsm/kg and patient is mentally alert

**Potassium**
- Establish adequate renal function (urine output ~ 50 ml/hr)
  - K⁺ < 3.3 mEq/L
    - Hold insulin and give 20 - 30 mEq/K⁺/hr Until K⁺ > 3.3 mEq/L
  - K⁺ > 5.3 mEq/L
    - Do not give K⁺, but check serum K⁺ every 2 hrs.
  - K⁺ = 3.3-5.3 mEq/L
    - Give 20 - 30 mEq K⁺ in each liter of IV fluid to keep serum K⁺ between 4-5 mEq/L

Check electrolytes, BUN, creatinine and glucose every 2 - 4 hrs until stable. After resolution of HHS and when patient is able to eat, initiate SC multidose insulin regimen. Continue IV insulin infusion for 1 - 2 hr after SC insulin begun to ensure adequate plasma insulin levels. In insulin naive patients, start at 0.5-0.8U/kg per day and adjust insulin as needed. Look for precipitating cause(s).
CEREBRAL OEDEMA

- Rare fatal complication DKA
- 0.7-1.0% children with DKA
- Newly diagnosed DM children and known DM children
- Young adults in 20’s
- Fatal cases with HHS
- Clinically ↓ level of consciousness, lethargy, decreased arousal and headache, rapid ↓ GCS, with seizures, incontinence, bradycardia and respiratory arrest with brain stem herniation.
- Rapid progression – no papilloedema
- High mortality rate > 70%. Only 7-14% recover.
- Mechanism – if give fluids too rapidly – plasma osmolality declines too rapidly – water moves by osmosis into CNS. Also due to increased cerebral perfusion
PREVENTATIVE MEASURES FOR CEREBRAL ODEMA

• Gradual replacements of sodium and water deficits in patients who are hyperosmolar.
• Addition of dextrose once GM < 12/16
• HHS – maintain glucose between 14-16 until the hypersosmolarity, mental state, improves.
FINAL DIAGNOSIS HHS

- PPT. FACTORS - PREV CVA, ? MI, THIAZIDES
- HHS EVOLVED OVER DAYS
- DID NOT PRESENT WITH VOMIT, ABD PAIN, KUSSMAULS
- COMATOSE STATE /ALTERED SENSORIUM
- NO SIGNS OF ACIDOSIS – KUSSMAULS AND ACETONE BREATH
- PRESENCE OF FOCAL NEUROLOGIC SIGNS
- NO KETONURIA
- MINIMAL ACIDOSIS ON BLOOD GAS
- EFFECTIVE SERUM OSMOLALITY = 355