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BCCH DKA GLUCOSE, INSULIN AND FLUID MANAGEMENT

2024 Revisions to the BCCH DKA Protocol

The 2024 revisions to the *BCCH DKA Medical Protocol* are based on the results of recent research findings on rehydration protocols. These revisions bring the *BCCH DKA Medical Protocol* into alignment with the *Clinical Practice Consensus Guidelines 2022* from the International Society for Pediatric and Adolescent Diabetes (ISPAD) and with the 2023 DKA resources from TREKK Canada (references below).

Initial Fluid Replacement

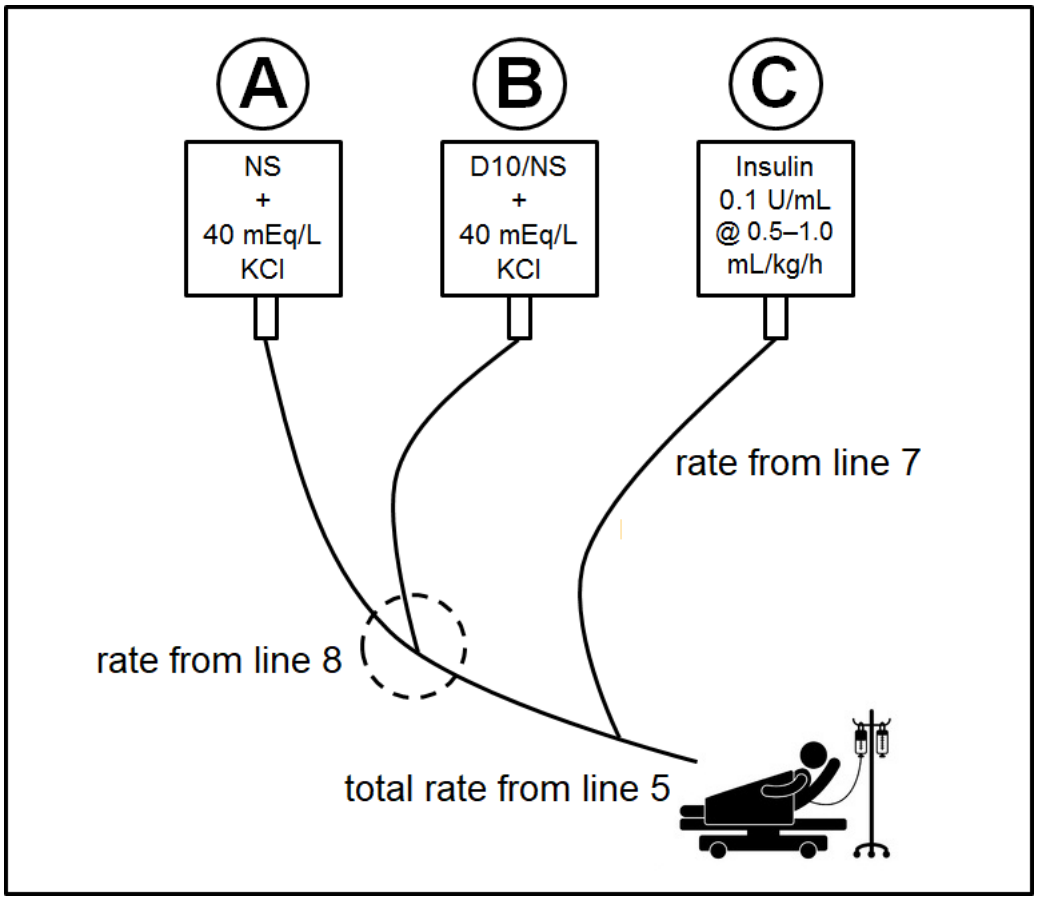
Results from the PECARN DKA FLUID Study (reference below) have demonstrated that fluid replacement can safely be achieved using more-aggressive regimens than have been in place over the past two decades. It is now recommended that most patients in moderate-to-severe DKA receive a 20–mL/kg bolus of 0.9% sodium chloride (normal saline, NS), maximum 1000 mL, over 30 minutes. Those patients with persistent tachycardia, prolonged capillary refill (>2 sec), and cool extremities should receive rapid repeated 20-mL/kg fluid pushes to restore peripheral circulation. Once the fluid push(es) have been delivered, and having ensured that the patient has adequate urine output and a plasma potassium ≤5.5 mmol/L, fluid replacement is continued using NS + 40 mEq/L KCl (Bag A, see next section), until the patient has been receiving fluids for 1–2 hours; at that point, intravenous insulin is started. Fluid replacement rates are now calculated for a 36-hour period of rehydration, compared to the 48-h period used in the past. The fluid replacement rate calculated includes both the fluid deficit and maintenance fluids; ongoing urinary losses are generally not replaced.

For obese children, adult fluid rates are used: 1000 mL for a resuscitation bolus and a rate of 500 mL/h for ongoing fluid infusions.

The "Two-Bag System"

The "two-bag system" (reference below) consists of two IV bags (**A** and **B**) with equal electrolyte concentration, one containing no dextrose, the other 10–12.5% dextrose. They are administered simultaneously. The total rate is determined by the child's degree of dehydration, according to the BCCH DKA Medical Protocol (line 5). The insulin infusion (**Bag C**) will eventually be **Y**'d into these bags (see below).

In the "two-bag system", Bag A is generally NS + 40 mEq/L KCl, and Bag B is usually D10/NS + 40 mEq/L KCl (or D12.5/NS + 40 mEq/L KCl, if your institution can make this). The BCCH Pharmacy has prepared a "recipe book" for preparing these solutions from commercially available IV solutions, which is available from the Parenteral Drug Manual on the BCCH ePOPS website and on BCCH Endocrinology's website (references below).



MANAGING THE BLOOD GLUCOSE (BG) LEVEL

The goal is to keep the BG levels in the 8–12 mmol/L range, both to minimize glycosuria and to allow for a buffer against hypoglycemia. This is most easily achieved by alternately adjusting the rates of the non-dextrose-containing Bag A and the dextrose-containing Bag B, while keeping the insulin infusion rate constant (see example below).

At the onset, it is recommended having both bags prepared and hung, starting Bag A at nearly the full rate (from line 8 of the BCCH DKA Medical Protocol), and starting Bag B at a "to-keep-open" rate (2–5 mL/h). The insulin infusion rate of 0.05–0.1 U/kg/h (0.5–1.0 mL/kg/h) should not be adjusted until the pH is close to normal (see below).

Example: IV rate from protocol line 8 = 100 mL/h
(this does not include insulin infusion rate)
rate Bag A + rate Bag B = 100 mL/h

rate Bag A no dextrose (mL/h)	rate Bag B D10 (mL/h)	final dextrose concentration (%)
100	0	D0
80	20	D2
60	40	D4
40	60	D6
20	80	D8
0	100	D10

The BG level will fall quite rapidly in the first hour or two with the initial fluid management, even before insulin is started, secondary to improved renal clearance and hemodilution. Thereafter, one should aim for a fall in BG of ~2–5 mmol/L/h.

Assuming that the BG is being monitored every 30–60 minutes, once it starts to approach ~14–17 mmol/L—sooner if the initial BG drop is >5 mmol/L/h—the rate of Bag A is decreased, and the rate of Bag B is increased by an equivalent amount. A general rule is to make changes of approximately 10–20% of the total every hour. This will depend on the rate of fall of the BG level and the patient's response to these changes.

If the patient's BG level is lower than desired, despite maximal dextrose infusion from Bag B, you may (in order of safety):

1. cut the insulin infusion rate by ~25%, provided the acidosis is correcting
2. give the patient a small amount (1–2 mL/kg) of juice or 2–4 dextrose tablets (being mindful of the overall fluid balance)
3. change the insulin bag to D10/NS
4. in institutions with intensive-care capabilities, consider placing a central line and using a higher concentration of dextrose (e.g. D20) in Bag B.

The Insulin Infusion

The optimal initial insulin infusion rate is not known, but an increasing number of experts are suggesting a starting rate of 0.05 U/kg/h, i.e. 50% of the rate of previous protocols. ISPAD 2022 (reference below) supports the use of either starting rate (0.05 or 0.1 U/kg/h), until more conclusive information is available. ISPAD does suggest 0.05 U/kg/h when pH >7.15. We would suggest that this lower rate be considered especially when (1) patients have already had a significant drop in their BG prior to starting insulin; (2) when the patient's acidosis is less severe; (3) or when it is expected that the patient will be quite insulin-sensitive (some young children with DKA, patients with hyperglycemic hyperosmolar state, and some older children with established diabetes and insulin pump-site failure or acute insulin omission).

It is important to ensure a plasma potassium ≥3.5 mmol/L before starting insulin.

The half-life of IV insulin is quite short (minutes), so the insulin infusion should never be discontinued, until the patient has been established on subcutaneous insulin. If the patient's BG level is difficult to maintain >8–10 mmol/L despite the measures suggested above, one can cut the insulin infusion rate by ~25%, provided that the metabolic acidosis is resolving. It is unusual for a child in DKA to need <0.025 U/kg/h.

Potassium

Nearly all children in DKA will require large amounts of potassium for repletion, and 40 mEq/L KCl in the IV will generally suffice. Some children will require extra oral or nasogastric potassium chloride (0.5–1.0 mEq/kg) to keep their plasma potassium level ≥3.5 mmol/L. Rarely, children will require less potassium, in which case one could use 20 mEq/L. Potassium should be deferred if a patient is not urinating or if plasma K^+ >5.5.

Switching to Half-Normal Saline

The goal of treating DKA is to slowly allow the BG and hyperosmolality to normalize, which initially requires the use of isotonic fluids, i.e. normal (0.9%) saline. After about 4–6 hours, once the corrected Na^+ is ≥140 mmol/L and is stable or rising, the patient should receive some free water in the form of hypotonic fluids to continue to have a drop in plasma osmolality. At this point, Bags A and/or B can be switched to their half-normal (0.45%) saline equivalents.

Treating the Acidosis

At presentation, DKA-associated acidosis can be combination of lactic and ketoacidosis. Lactic acidosis will resolve with restoration of peripheral circulation. The ketoacidosis

will resolve with fluids and insulin; the β-hydroxybutyrate should drop ~0.5 mmol/L/h. There is a general contraindication to the use of bicarbonate in DKA. Later in the course of DKA, a patient can develop a hyperchloremic acidosis from the large amounts of NaCl and KCl they are receiving. This can be distinguished from ketoacidosis by measuring β-hydroxybutyrate. Hyperchloremia can be treated or prevented using 0.45% normal saline or a combination of KCl and KPhos (see next section).

Monitoring Phosphate Levels

Phosphate levels frequently drop during DKA treatment. There is little evidence supporting the routine use of phosphate-containing fluids in DKA. However, severe phosphate deficiency (<0.32 mmol/L ± symptoms) should be treated. This can be done by replacing 50% of the KCl in the infusion as KPhos (20 mEq/L each KCl and KPhos). If this is done, one needs to pay attention to the possibility that this can cause hypocalcemia and hypomagnesemia.

Calculations

Anion gap: $Na^+ + K^+ - Cl^- - HCO_3^-$: normal 16 ± 2 mmol/L
Corrected Na^+ = measured Na^+ + [0.36 × (plasma glucose – 5.6)]
Effective osmolality = plasma glucose + [2 × ($Na^+ + K^+$)]: normal 275–295 mOsm/kg

Treatment of Suspected Cerebral Injury

1. airway / breathing / circulation
2. elevate head of bed
3. reduce fluid rate by ⅓, but avoid hypotension
4. administer hyperosmolar agent:
   - mannitol 20% 0.5–1 g/kg (2.5–5 mL/kg) IV over 15 min
   - NaCl 3% 2.5–5 mL/kg IV over 15 min
5. intubate if pending respiratory failure
6. mild hyperventilation, avoid hypocapnia

Help in Real Time

If you have questions or problems related to the management of DKA or diabetes (for patients in BC and the Yukon), please feel free to contact the BC Children's Hospital Pediatric Endocrinologist on call at 604-875-2161.

Online Links

The following resources are all available on our BCCH DKA Protocol webpage:

- *BCCH DKA Protocol Toolkit*
- *BCCH DKA Medical Protocol* (PLAIN PDF FORMAT)
- *BCCH DKA Medical Protocol* (FILLABLE PDF FORMAT)
- *BCCH DKA Nursing Protocol*
- *BCCH DKA Flowsheet*
- *BCCH DKA Glucose, Insulin and Fluid Management*
- *BCCH DKA Recipes for Making Solutions*

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