

Review: Glucose Management in Pediatric Cardiac Surgery

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Learning Objectives:

- Review of the physiology of glucose metabolism in children undergoing cardiac surgery;
- Variables impacting glucose homeostasis in the setting of cardiac surgery.

Carbohydrates are the best source of short-term fuel in animals because they are much simpler to metabolise than fats or amino acids; of these glucose is the most important and is the primary source of energy for most cells. Glucose undergoes 3 metabolic steps to release its energy; glycolysis, in which glucose is converted to pyruvate, decarboxylation of pyruvate to produce Acetyl CoA, and the entry of this into the Krebs cycle where most of the energy is released in the form of NADH and ATP. Other substrates, such as amino acids and fatty acids, also feed into the Krebs cycle in the form of Acetyl CoA; indeed, the primary energy source for myocardial cells are fatty acids.

Excess glucose is converted to glycogen, although this is not an efficient storage medium as it has a high affinity for water. Longer term energy storage is by conversion via Acetyl CoA to fatty acids, triglycerides and lipids, although humans are unable to re-synthesise glucose from lipid.

The level of glucose in the blood is very tightly regulated so that normal fasting blood sugar is 3.5 – 5.6 mmol/l, (or 60-100 mg/dl, the conversion factor being x18). There is normally only enough circulating glucose to serve the body's needs for about 30 minutes. Brain cells are almost entirely dependent upon glucose, as only astrocytes are able to store glycogen, and neurological dysfunction is an early sign of hypoglycaemia. Seizures are likely when blood glucose falls below about 2mmol/l (40mg/dl), and neuronal silence occurs at around 0.5mmol/l (10mg/dl).

Regulation of blood glucose is hormonal; the catabolic hormones glucagon, growth hormone and cortisol, and the catecholamines increase blood glucose, while insulin decreases blood sugar. Insulin induces the liver to convert glucose into glycogen, and muscle cells and fat to take up glucose. By binding to receptors on cell surfaces insulin stimulates the release from storage vesicles and movement to the cell surface of glucose transport proteins, such as GLUT 4, which facilitate the diffusion of glucose into the cell.

When blood sugar is low, the catabolic hormones stimulate glycogenolysis, in which glycogen stored in the liver and muscle is converted to glucose. The liver can release this glucose into the blood stream for transport and use elsewhere, but that from muscle is not released and is only available locally. Gluconeogenesis is also stimulated, in which liver lactate is converted back to glucose via pyruvate; most amino acids and glycerol are also used as energy substrates, but not fatty acids.

It has long been recognised that stress, whether it be trauma, burns or critical illness is associated with hyperglycaemia; this is also the case with surgery, particularly cardiac surgery involving cardiopulmonary bypass. This has multifactorial causes, mainly attributed to the stress response and the release of catabolic hormones and catecholamines, but also to insulin resistance at cellular level. Blood glucose rises pre-bypass, and during and after bypass; blunting the stress response, for example with fentanyl, can attenuate but does not abolish this rise. The hyperglycaemia that occurs with cardiac surgery may last for many hours into the postoperative period, and may exceed 20mmol/l (~400mg/dl).

Many anaesthetic and surgical factors are implicated in this peri-operative hyperglycaemia, such as:

- Anaesthetic technique; for example volatile agents may impair insulin secretion;
- Use of stored blood, which has a very high glucose content; many centres now wash their pump primes when blood is used;
- Choice of fluid for the pump prime;
- The use of pulsatile or non-pulsatile bypass;
- Fluctuation in body temperature;
- The administration of perioperative steroids;
- The administration of catecholamines

There is wide variation between institutions and between individuals within institutions as to what constitutes hyperglycaemia, and what level warrants treatment with insulin. Transient hyperglycaemia has long been thought by many to be relatively harmless, although there is evidence that prolonged hyperglycaemia is associated with adverse outcomes. The literature is full of conflicting evidence about the influence of hyperglycaemia on neurological outcome in a variety of situations such as head injury, burns and cardiac arrest. The current controversy as to the benefits or otherwise of tight glycemic control in critical illness in general and in pediatric cardiac surgery in particular is one of the more interesting topics at this time and I look forward to hearing the arguments for and against this.