Complications of Overfeeding the Critically Ill Patient

In this chapter:

- Patients who are very small, very large, or very old are particularly vulnerable to overfeeding.
- Excessive protein leads to to azotaemia, hypertonic dehydration, hyperammonaemia and metabolic acidosis.
- Excessive carbohydrate leads to in hyperglycemia, hypercapnea and fatty liver
- Excessive fat have caused hyperlipidaemia and fat-overload syndrome.
- Enteral feeding is more frequently associated with *under*nutrition; a patient is more likely to be overfed with TPN, whcih has a greater risk than enteral overfeeding

Though perhaps not as dangerous as refeeding syndrome, "overfeeding syndrome" has its own disadvantages. If the overfed patient is able to tolerate such large gastric volume (which frequently they cannot), they will develop diarrhoea as the result of high osmotic load. Malabsorption of the nutrients may result. If they absorb everything, they may develop metabolic complications of dietary protein and carbohydrate excess. In the past papers, the examiners approach this topic only once - in Question 28 from the second paper of 2007. It has not been seen since, and may never appear again.

An excellent article (Klein et al, 1998) is available which summarises the metabolic derangements which befall the grossly overnourished ICU patient. It is the primary reference for this chapter. Those with insititutional access should be able to get hold of it, and share it with those without such access. I will make an attempt to summarise its most important points, to benefit the ICU trainees who don't have powerful friends with paid journal access. One should keep in mind that this article was written in 1998, and when it comes to macronutrient proportions and particualrly protein supplementation, the authors say all sorts of wacky things (like "nobody benefits from more than 1.2g/kg/day of protein" for example).

Other good resources include:

- Montejo et al, 1999 (more metabolic complications)
- Smith et al, 1990 (diarrhoea)
- Griffiths et al, 2007 (excess of enteral nutrition)

In short, the problem of overfeeding arises from the fact that no mammalian organism has ever evolved in the context of continuous nutrient delivery and immobility. We simply haven't the metabolic capacity to cope with such a situation; all of our nutrient storage and fuel use mechanisms developed in the presence of the constant threat of famine. The ability to rapidly absorb, store and then gradually release nutrients has been much more useful in the environment of our ancestors.

Mechanical complications of hyperalimentation

Intolerance of nasogastric volume

This is a brutally mechanical complication of excess nasogastric feed volume. The precise maximum volume is not easy to estimate because every stomach is different and might behave difrently under different circumstances.

On top of the hourly nasogastric feed volume the stomach itself also secretes a substantial amount of mucus and juices (around 100-150ml/hr) which contributes to the volume. Liquid empties faster than solid (Collins et al, 1983) and emptying in general follows an exponential pattern. If any given volume is given, approximately half of it will be emptied in the first hour. In addition to volume calorie content of the meal also plays a role, with low-calorie meals emptying faster than high-calorie meals. In the context of drinking only pure water, and on an empty stomach, the theoretical maximal rate of stomach emptying is approximately 2.5L/hr - but this is in the context of exercising atheletes.

Generally speaking, in the critically ill the gastric emptying rate is reduced. Heyland et al (1996) performed an experiment where stomach emptying was measured by the rate of paracetamol absorption (for a number of reasons paracetamol is a favourite marker substance in measuring stomach emptying). These experiments demonstrated that in critically ill patients the gastric emptying rate is halved in

comparison to controls. Ergo, feeding these patients an excessive dose of nasogastric nutrients will result in gastric distension, vomiting, and potentially aspiration. Montejo et al (1999) found that high gastric residuals were reported in the course of 39% of NG-fed patient encounters.

Osmotic diarrhoea

Most nutrient mixtures are isoosmolar. Some, intentionally, are hypertonic. For example, formulae for renal patients tend to be more concentrated so as to reduce the total fluid input. The consequence of this is an osmotic diarrhoea. Smith et al (1990) found three major contributors to diarrhoea associated with NG feeding:

- Higher rates of infusion
- Greater tube-feeding osmolality
- Change of formula

Interestingly, antibiotic use and serum albumin levels were not predictors. Though everybody knows about the associated of NG feeds and diarrhoea, Montejo et al (1999) found the incidence of constipation and diarrhoea were approximately similar (15%) in their prospective cohort of NG-fed patients.

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Consequences of dietary protein excess

Azotaemia

The key issue here is protein. Already in your critical-illness-induced hypercatbolic state the hormones and the cytokines have mobilised metabolic fuel susbtrates, and amino acids are awarm in the circulation. The liver and kidneys are struggling to maintain some sanity by rapidly excreting these molecules by the conventional mechanism, which turns them into urea. Urea tends to rise in critical illness as a result of this activity.

Now, into this equation, imagine adding a supraphysiological volume of supplemental protein. The amino acid content of portal blood will rise, and the urea cycle will struggle valiantly against this tide. Usually, with a normal liver, the cycle will win, and a massive increase in urea will be the result. Obviously having a ridiculously high urea is not good for anybody, and this is a strong argument against protein overfeeding even in the context of normal renal and hepatic function.

Hyperammonaemia

If one has a defective urea cycle, or if one's liver has been damaged by many years of overindulgeance, one may find oneself rather more confused by the administration of a large protein load. Ammonia will be generated by the deamination of the excess amino acids, and it will accumulate, giving rise to hepatic encephalopathy.

Hypertonic dehydration

Even in the presence of a normal liver and a working urea cycle, an abnormally high protein load is a disadvantage. The uremia which results may of a low level, and thus may not have any adverse clinical effects (i.e. the patient is neither encephalopathic nor experiencing any bleeding from their platele dysfunction).

However, the urea still manages to be somehow harmful. The additional urea load demands that a certain volume of water is passed, so as to remove a sufficient volume of nitrogenous wastes.

This volume of water which undergoes this "obligate" excretion depends largely on one's ability to concentrate water. Thus, patients who are poor water cencentrators (eg. hypothermic patients, patients on lithium, patients on diuretics, and the elderly) will end up excreting much more water with their urea, and will become dehydrated and hypertonic. In addition to this process, there is a dehydrating contribution from the osmotic diuresis due to hyperglycaemia.

This process of gradually drying out due to uremia was well known in the 1950s and 1960s, under the name "Tube Feeding Syndrome". The modern experience of this disturbance remains largely unchanged. The key appears to be the correct estimation of total daily water needs, and the replacement of an adequate amount of water, as well as (obviously) not feeding the patient to excess.

Metabolic acidosis

Historically, this has been associated with hydrochloric acid being a silent preservative in TPN, with lysine hydrochloride contained in early versions of TPN, or with excess casein hydrolysate.

The cause of the metabolic acidosis in these cases has been the complete metabolism of the amino acids concerned, and the complete lack of metabolism of the chloride. The consequence is a decrease of the strong ion difference, and thus a normal anion gap metabolic acidois (this is discussed in greater detail elsewhere).

These days it is difficult to cause a metabolic acidosis due to overfeeding in the critically ill patient, because TPN no longer contains quite so much chloride. However, there has been at least one report of metabolic acidosis due to high protein enteral nutrition; a reference to it can be found in my primary source. This report is unpublished - I have no way to look at the abstract. It was presented in 1997 during a conference. It is very difficult to generate a good valid mechanism for metabolic acidosis due to enteral nutrition, and I would love to see what they came up with.

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Consequences of dietary fat excess

Fat Overload Syndrome

Rather than a complication of excess enteric feeding, this tends to happen when one administers an excessively large amount of lipid-containing TPN emulsion to their patient.

- Acute respiratory failure, manifesting as pulmonary oedema
- Coagulopathy, manifesting as abnormal platelet function, as well as proper DIC
- Headache, fever and jaundice
- Hepatosplenomegaly

These are all good reasons why you should never bolus TPN. The critical fat dose per day seems to be somewhere above 2.5g/kg/day, and somewhere below 4.0g/kg/day (though much of our data regarding this complication comes from TPN-dependent children with short gut syndromes, which are hardly a representative sample).

Hyperlipidemia, particularly high triglycerides

The overadministration of oral or NG carbohydrates has been shown to result in high serum triglyceride levels. Thia is thought to be the consequence of hepatic de novo synthesis of fatty acids, which are then packaged into triglycerides and VLDLs. The abovementioned saturable mechanisms of lipoprotein synthesis are responsible for keeping the liver from becoming massively swollen with stored fats. On top of this, the actual lipids in the feeds (and especially in TPN) are contributing to serum lipid level elevation.

And what, might one ask, are the acute consequences of extreme hypertriglyceridaemia?

Well.

- Hypercoagulability and thrombosis
- Pancreatitis
- Chylomicronaemia syndrome:
  - Abdominal pain
  - Hepatosplenomegaly (probably responsible for abdominal pain)
  - Nausea
  - Eruption of skin and tendon xanthomae
  - Milky appearance of blood plasma
  - Again, pancreatitis

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Consequences of dietary carbohydrate excess

Fatty Liver

It has been thought that the administration of excess carbohydrate is the main factor responsible for this process. Certainly, at autopsy the livers of children who had premortem glucose infusions (at rates of 9-17mg/kg/min) were enlarged with fatty infiltrates, weighing from 150% more than normal to a whopping 440% more. However, this was the 1970s, so who knows what the hell they were doing - perhaps something else was going on. According to what we know about hepatic lipogenesis in humans, this steatosis cannot be a complication of excessive carbohydrates being turned to fat, but due to the brutally mechanical exogenous fat excess. The liver has some good normal mechanisms of packaging fatty acids into lipoproteins and distributing them to the tissue; however these mechanisms are saturable. With saturated fat distribution mechanisms, the liver resorts to depositing the additional lipid load inside its own parenchyma, with hepatic steatosis the unfortunate result. This tends to manifest as a non-specific rise in LFTs and bilirubin.

Hypercapnea

It is known that carbohydrate metabolism causes more CO_2 production per molecule of metabolised O_2 than does fatty acid oxidation. Carbohydrate-rich nutrients have long been implicated in hypercapnea, and efforts by nutrient manufacturers have catered to the belief that fat-rich feeds would decrease the chronically elevated $PaCO_2$ of COPD patients.

Certainly, there is a measurable rise in CO_2 production from glucose boluses, and if their respiratory reserve is already compromised then carbohydrate overfeeding can make weaning from mechanical ventilation difficult or impossible.

Hyperglycaemia

This is a complication which is not unique to diabetic patients. A patient with a normal endocrine pancreatic function will be able to tolerate the administration of even large amounts of IV glucose.

However, subject the same patient to the hypercatabolic stress response, and hypeglycaemia will result even in absence of glucose administration. Now, mix TPN into this equation, with its 50% dextrose (or highly sugary enteric feeds for that matter). Hyperglycaemia will ensue.

In the ICU this is sually not an issue because we are very strict about out glucose control; however, in the TPN-dependent outpatient population and in the general wards, this hyperglycaema can gradually evolve in a hyperosmolar hyperglycaemic coma

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