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Considerations Of The Physics Of Enteral Feeding

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We all recognize that the developing preterm infant faces many challenges to get their gut working. Despite an early start that lays down organ structure, called organogenesis, the functional aspects of the bowel take considerably longer to get established.

Some of these functions include digestion, absorption, motility, immune function, barrier function and suck/swallow. Fortunately some of these milestones can be accelerated such as with digestion with increased activity and expression of digestive enzymes such as lactase with exposure to lactose. This is not the case for a milestone like suck/swallow that seems hardwired to develop efficiently well past 30 weeks gestation regardless of what precedes this time. No amount of coercion seems to help here. Therefore, a significant number of infants before 34 weeks gestation rely heavily on the nasogastric tube. Having an appreciation of the ins and outs of this delivery device, including some of the physical constraints, is important to the neonatal provider as some of these factors may impact our ability to optimize nutrient delivery in a safe manner.

So what kind of factors come into play. Here is a short list of some of the areas that I think are important to ponder.

Tube material type

There are different materials being used, varying lengths of tubing and extension tubing. There are three main types that are on the market: polyvinyl, polyurethane and silicone. For the most part each of these materials are interchangeable in that no distinct differences have clearly been determined. There is a tendency for polyvinyl to stiffen more over time, while the other two are good for longterm indwelling purposes. Do we know which material type is better for the preterm? Not really. Some other considerations however include elasticity/bendability or adherence of milk components and propensity for colonization by microorganisms, which I will talk later about. Adherence of nutrients was something our group looked into and really did not found a clear difference between the different materials and specifically human milk fat adherence (unpublished observations).

Tubing length

A column of liquid will traverse a length of tubing at a rate proportional to the length of tubing and to the 4th power with the diameter of the lumen. This means that if you decrease the diameter by half the resistance to flow goes up 16 fold! Doubling the length will decrease the flow by half. The viscosity of the milk going through the tube also has a role to play. Do we have clarity on what length of tubing is ideal? Not clearly, other than the practical size issues and getting enough distance to reach the pump delivery system. Like IV tubing there is an interest to keep the lumen narrow for fear of loss of nutrients in the tubing itself. I think we could benefit from more clinical evaluation of optimal tubing length and diameter with consideration of altering the delivery systems to accommodate these factors.

Continuous vs bolus delivery

The rate of infusion is dependent of the method of delivery to infants. There is no question that some, particularly small, infants do not do well with bolus feeding. They have more events with A's, B's, and D's. A study is not really need since slowing down the feeds dramatically improves these signs. I think we all have seen this way too many times to need convincing. So at some point the rate of stomach filling does play a role in feeding tolerance. What about the age old argument of bolus versus continuous feeding? Most espouse the notion that bolus feeding is more physiologic but I remember being asked at a lecture about the kind of intake that fetuses do when they are in utero, where they are constantly swallowing amniotic fluid at high rates. For all intensive purposes this may mimic a more continuous physiologic exposure. The flipside too is that the stomach does not passively release liquid into the small bowel at a regular continuous rate even with continuous feeding. Rather it takes peristaltic movements that propel contents forward and many preterm infants have a degree of gastric dysmotility when they are starting feeds (reflected in frequent gastric residuals). There are supportive data for the VLBW infants that continuous feeding can be better for overall growth.(Dsilna 2005) In fact many places in Europe feed continuously all the time for VLBW infants and then switch over to bolus. The most significant downside is the significant potential loss of nutrients that occurs with continuous feeding as milk fat, in particular, adhere more over a period of time. (Rogers 2010) Extra effort is required to ensure syringe and tubing are fully purged at the end of feeding in these cases. Precautions aside, continuous feeding can be a viable feeding option for the smallest infants.

Temperature of the feeding

As for what is the optimal temperature of feeding, little data exists. What data there is suggests that something closer to body temperature may be better at improving feeding intolerance.(Gonzales 1995) Unfortunately there is no accepted standard of milk warming and so great variability exists in perceived ideal temperature and what actually gets accomplished on a daily basis.(Dumm 2013, Lawlor-Klea 2013) Also, many of us believe that after heating up a container or syringe of milk to body temperature this is the temperature the baby receives the milk. This is quite far from the truth. One can only think about how quickly your hot cup of coffee in the morning cools when sitting at room temperature for 15 min. Many feeding schedules are done with slow bolus over 30 min to continuous feeding over 3 hour stretches. More often than not then, infants are generally getting milk at closer to room temperature by current means if that at all. Fortunately we have seen several efforts by industry to start to provide equipment specific to milk warming. What we need now is more clinical data on the best practice of thawing and warming milk for preterm infant feeding so the science can advance. After that we can begin standardizing milk cooling…

Contamination of tube

Another concern that has not been fully addressed is the importance of the formation of biofilm from microorganisms growing on the inside and outside of the feeding tube. Given the warm internal environment and availability of nutrients with milk feeding it is no surprise that biofilm forms very quickly and colonizes with multiple organisms.(Hurrell 2009) The importance of these organisms and their biofilm and the best practice in changing out the enteral feeding tube in the development of sepsis or bacteremia is still unknown. Currently units change their enteral feeding tubes out from every 3-4 days to up to 30 days! Perhaps in the future we will have more data on how best to optimize tube changes and tube materials to keep any potential infectious risks at bay.

Delivery systems

Our enteral feeding system has been developed as stepchildren of intravenous pump systems. Milk is most often loaded in various size syringes and hung with gravity feeding or attached to syringe pumps. It is not clear to me that this would ever have been created de novo if we started from scratch. There are inherent costs with all this equipment and as mentioned compromises with length of tubing that come into play. I would greatly appreciate more development here with slicker more efficient systems to be available to do the same thing as our kludgy systems.

Side ports

Pushing liquid down to and through the side ports is generally easy. So why is it that the side ports are so ineffective at times at venting air? I see routine evidence that the naso/oro-gastric tube is not venting the stomach even if the stomach bubble is quite large and seen on the morning X-ray. The answer to this is simple: the available side ports are often by nature of gravity (with infant supine) finding their way into the liquid portion of the stomach where gastric secretions and/or milk are found. The tube then has no easy capacity to permit ready venting. To make matters worse, it takes very little too with a 5Fr to resist releasing air (remember flow physics) even if the side ports were exposed to the gastric air bubble because of the increased resistance of the tubing (small diameter). Future development of enteral feeding will hopefully address optimizing both in and out traffic in the tubing.

Overall, it has been great to see that enteral feeding has moved to safer grounds with color coded systems and incompatibility with IV wares but our efforts to delivery milk nutrition still has a long way to go to make the entire process simple and foolproof. Since human milk is a complex liquid we need a system that can work with this complexity to delivery it in the most optimal form. For our babies, every last drop counts!

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Jae Kim is an academic neonatologist and pediatric gastroenterologist and nutritionist at UC San Diego Medical Center and Rady Children's Hospital of San Diego. He has been practicing medicine for over 23 years both in Canada and the USA. He has published numerous journal articles, book chapters, and speaks nationally on a variety of neonatal topics. He is the Director for the Neonatal-Perinatal Medicine Fellowship Program at UC San Diego and the Nutrition Director of an innovative multidisciplinary program to advance premature infant nutrition called SPIN (Supporting Premature Infant Nutrition, spinprogram.ucsd.edu). He is the co-author of the book, Best Medicine: Human Milk in the NICU. Dr. Kim is a clinical consultant with Medela, Inc.