Neonatal feeding: care and outcomes following gastrointestinal surgery

Optimising nutrition is an essential component of infant care. This can be more complex for those infants who have undergone gastrointestinal surgery. While many of the principles guiding the feeding of all newborns are applicable to these patients, there are significant challenges and potential pitfalls that may result in faltering growth and have long-term health implications. Based on a clinical case, this article will discuss the feeding of surgical newborns from the immediate post-operative period, working through to full enteral nutrition, and the longer term care of patients who may remain dependent on parenteral nutrition.

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Key points

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1. Following GI surgery the primary aim is to establish enteral feeds and wean off parenteral nutrition (PN) while optimising growth and long-term outcomes.
2. Newborns who have had bowel resection are at risk of under-nutrition and some may need long-term PN.
3. Long-term outlook has improved with the establishment of expert multidisciplinary teams.

Neonatal surgery is delivered primarily in specialist centres, co-located with maternity units or in specialist children's hospitals. However, management principles are important for all those caring for newborns both at tertiary and local level.

There are a many reasons for gastrointestinal (GI) tract surgery (**TABLE 1**) and following surgery the aim is to efficiently establish infants on enteral feeds and wean them off of parenteral nutrition (PN). Decisions about introducing and advancing feeds should be individualised, based on the known underlying pathology in each case. Operating surgeons can appreciate overall bowel condition, degree of bowel handling and resection, and the evidence of ischaemia and inflammation. The attending physicians will understand and manage the infant's comorbidities, eg prematurity and cardiorespiratory stability. Multiple factors affect the bowel's overall condition, its motility and subsequent ability to tolerate enteral feeds.

- Gastroschisis
- Hirschsprung's disease
- Atresias and webs
- Spontaneous intestinal perforation
- Malrotation
- Necrotising enterocolitis
- Volvulus
- Meconium ileus/plug
- Exomphalos
- Anorectal anomalies

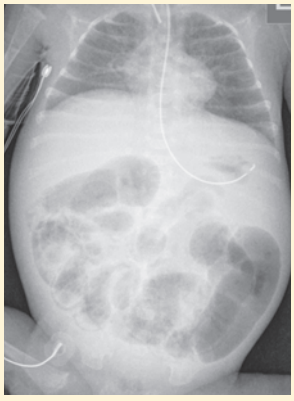
TABLE 1 Possible reasons for GI tract surgery in newborn infants.

The immediate post-operative period and initiating feeds

Early trophic feeds may improve recovery time by increasing gut blood flow, improving motility and limiting the impact of starvation on the structure of the gut and its ability to absorb nutrients. Starting

Case study: Baby D

Baby D was a twin from a dichorionic diamniotic twin pregnancy delivered at 26 weeks' gestation with a birth weight of 650g. She had an uneventful initial course being successfully extubated to continuous positive airway pressure on day 2 of life, and established on maternal expressed breast milk over a period of seven days. However, the maternal milk supply dwindled and she was gradually transitioned to a standard preterm formula. On day 41 she unexpectedly deteriorated with abdominal distension and blood in her stool. She was intubated and an abdominal X-ray confirmed a diagnosis of necrotising enterocolitis (NEC). After a week of conservative management a laparotomy was undertaken where 3cm of necrotic small bowel was resected, and an ileal stoma with a mucous fistula formed.



An abdominal x-ray confirming NEC.

small volume feeds of 10mL/kg/day within 12-18 hours of surgery may reduce the time to achieving full enteral nutrition.[1]

In more complex patients, for example necrotising enterocolitis (NEC), where there may be concern about motility and inflammation, a period of bowel rest is often standard practice. When initiating feeds, assessment of the colour and volume of gastric aspirates can reflect bowel motility and guide feed advancement. Large volume, dark green aspirates indicate that bile released into the duodenum has yet to start moving through the bowel. It may be more appropriate to wait to start feeds once the aspirates have begun to clear and/or reduce in volume (**FIGURE 1**).

Some conditions follow recognisable patterns. In duodenal atresia large, bilious, gastric aspirates may persist and should not limit feeding via a transanastomotic feeding tube. A dysmotile bowel in gastroschisis can take several weeks to tolerate enteral feeds and green aspirates should not preclude initiation of feeds in this condition.

Defunctioning stomas are often formed during neonatal GI surgery. This may be because of congenital abnormalities (eg atresias) or as part of treatment for more complex cases (eg NEC). In these patients, feeding progress will be influenced and sometimes limited by the underlying pathology, the amount of bowel resected and the site of stoma formation. When enteral feeds are increased, the bowel may not be able to absorb sufficient fluid and nutrients for growth; these babies require additional strategies to improve enteral tolerance.

Strategies to improve enteral tolerance – intestinal rehabilitation

Choice of feed

There is a paucity of evidence for feeding strategies following GI surgery even in complex conditions like NEC where gut injury and inflammation will have occurred. However, for the majority of post-surgical patients, including those whose bowel has been compromised or resected, the use of specialised formulas may not be necessary (other than those appropriate for gestation). Freshly expressed maternal breast milk is usually the feed of choice for almost all infants as it is readily absorbable and contains many 'non-nutritional' factors that aid bowel adaptation, digestion and absorption, for example, growth factors, hormones, oligosaccharides, glutamine and enzymes. Donor milk can be used, and anecdotally may be better tolerated than formula in premature infants, but there is no evidence of additional benefit in surgical newborns.

FIGURE 1 Comparison of dark and light bilious nasogastric aspirates following surgery.

Baby D: Post-surgery feeding strategies

Baby D was started on PN shortly after surgery and then enteral feeds of preterm formula ten days after surgery. Her enteral feed volumes were increased gradually to 100mL/kg/day and she gained weight but her central line had to be removed because of infection. Her feeds were increased to 150mL/kg/day but her stoma output increased to greater than 20mL/kg/day and her weight gain faltered. To improve nutrition she was given a hydrolysed formula, put on continuous feeds and started on loperamide therapy to slow down the movement of the bowel. Her growth, however, was poor.

Formula	Calories (kcal/ 100mL)	Protein (g/100mL)	MCT (%)	Osmolality (mOsm/ kg H_2O)	Clinically lactose free?	Designed to meet needs of preterm infants?
Mature human milk	69	1.3 (whole/ peptides	1-3	284	No	No
Nutriprem 1 (Cow & Gate)	80	2.6 (whole)	18	375	No	Yes
Hydrolysed Nutriprem (Cow & Gate)	80	2.6 (peptides)	15	405	No	Yes
SMA Pro Gold Prem 1 (SMA)	80	2.9 (peptides)	40	293	No	Yes
Pepti-Junior (Cow & Gate)	66	1.8 (peptides)	50	210	Yes	No
Pregestimil (Mead Johnson)	68	1.89 (peptides)	55	280	Yes	No
Neocate LCP (Nutricia)	67	1.8 (amino acids)	5	340	Yes	No
Nutramigen Puramino (Mead Johnson)	68	1.9 (amino acids)	33	350	Yes	No

TABLE 2 A comparison of some of the available specialised formula feeds. Key: MCT= medium chain triglycerides.

Complex patients (eg, those with high stomas or extensive resection) may require either a hydrolysed, lactose-free or a feed containing fats as medium chain triglycerides (MCT) (**TABLE 2**). Hydrolysed formulas, with whole proteins broken down into peptides and amino acids, may be more readily absorbed. MCTs do not affect the osmolality of feed and their absorption is not bile-dependent, which may be of benefit for patients with cholestasis. Lactose absorption can be impaired and using lactose-free formulas may be beneficial, as can lower osmolality feeds. In practice, feed choice often involves trial and error, clinical judgment and regular assessment of growth as bowel adaptation and recovery occur.

Continuous or bolus feeds?

The use of continuous feeds, rather than bolus, may have advantages. Some patients may tolerate them better in the early post-operative period and beyond if motility is affected by prematurity or gastroschisis. It is mandated for those patients being fed jejunally. In patients with short bowel

syndrome (SBS) it can improve absorption of feed by exposing the bowel to a steady flow of milk rather than delivering surges, which overwhelm the bowel's absorptive capacity. It may also help bowel adaptation in the longer-term by keeping the gut maximally exposed to nutrients and improve energy efficiency, nutrient absorption and adaptation.

Bolus feeding, on the other hand, is more 'physiological' promoting the cyclical release of GI hormones such as gastrin, gastric inhibitory peptide and enteroglucagon.[2] Surges of these hormones help the gut develop and pulsatile release of amino acids and insulin improve metabolism of protein.[3] Another advantage of bolus feeding is that it can be delivered orally, which for the majority of patients is the ultimate goal.

Surgical infants can develop an aversion to oral feeding if oral feeding is delayed or if painful symptoms are associated with feeding. Regular use of dummies dipped in milk, short breastfeeds or small bottle feeds may help to reduce the impact of oral aversion. Most term-born surgical newborns with an unaffected upper GI tract should be able to feed orally within 24 hours of recovering from their anaesthetic. Medical comorbidities, eg prematurity, are more likely to delay initiation of oral feeds.

Stoma re-feeding and reversal

Once a stoma is reversed there is often sufficient bowel to enable enteral autonomy, ie the infant should be able to derive full nutritional requirements from enteral feeds. However, surgeons may prefer to wait a number of weeks before undertaking a stoma closure. This facilitates bowel recovery, patient growth and stabilisation, which is particularly important in the most vulnerable premature infants. An interim measure is to pass effluent collected from the proximal stoma into the distal bowel via a mucous fistula (if one has been formed and patency established). This is called 're-feeding' or recycling (**FIGURE 2**). This increases the amount of enteral feed absorbed, potentially enabling reductions in PN. The other theoretical aim of re-feeding is to overcome the atrophy of the otherwise unused distal bowel, which may shorten recovery time when the stoma is ultimately reversed. The process can be messy, but it is possible to form specialised stomas with catheters that make re-feeding easier and manageable by parents.

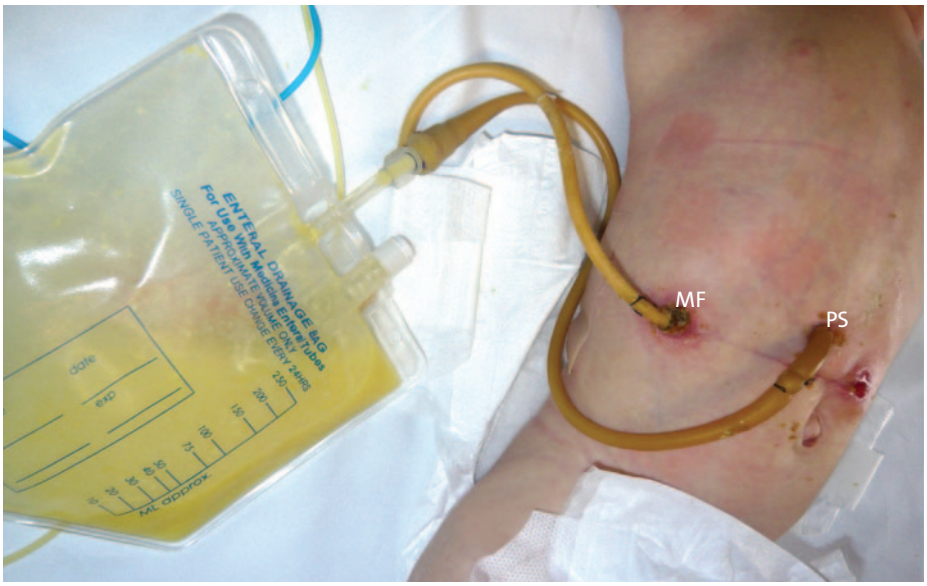


FIGURE 2 Specialised stomas enable collection and re-feeding of effluent to increase enteral absorption. Key: MF = mucous fistula, PS = proximal stoma.

Baby D (right) at two months corrected age with her twin sibling.

Growth improvement and stoma reversal

Given Baby D's poor growth a new central line was inserted at 39 weeks and PN was restarted. Her enteral nutrition was optimised at 115mL/kg/day of Pepti-Junior delivered continuously and she gained weight. Re-feeding of the mucous fistula was not possible due to identification of distal strictures. Her liver function was affected by the PN but plateaued and did not progress to IFALD. At a corrected gestational age of three months her stoma was reversed. She had initial problems with loose stools but by five months of age she achieved enteral autonomy and was discharged from hospital fully bottle fed and gaining weight.

In some patients, even when utilising their entire available bowel, enteral feeds cannot deliver adequate nutrition and long-term PN is required.

SBS and intestinal failure

SBS occurs when there is insufficient bowel to absorb adequate fluid and nutrients from enteral feeds to sustain growth. Estimates of incidence are difficult but it affects around 3.5/100,000 term infants and 354/100,000 preterm infants.[4] SBS most commonly occurs when the small bowel is lost (or not developed) due to:

- NEC (35% of cases)
- intestinal atresia (25%)
- complex gastroschisis (18%)
- malrotation with volvulus (14%).

SBS will normally be anticipated following extensive surgical resection and symptoms usually become apparent as feeds are increased (eg stoma output increases). PN is needed to maintain growth. Predicting those patients that will develop SBS is difficult. In most patients, approximately 40cm of small bowel is associated with a good outcome but enteral autonomy has been reported in patients with only 25cm of small bowel and an

intact ileo-caecal valve. Success has been reported in patients with only 10cm after long periods of adaptation. However, absolute length alone is probably insufficient to make accurate predictions, in part because normal bowel length increases with gestation and age.[5] The quality of the remaining bowel is also critical.

Intestinal failure and long-term complications

Intestinal failure (IF) is defined as a critical reduction of the gut mass or its function below the minimum needed to absorb nutrients and fluids required for adequate growth.[6] SBS is the primary cause of IF in neonates, but IF has a broader aetiology that includes conditions where the gut is unable to absorb (eg microvillous inclusion disorder) or is dysmotile (eg Hirschsprung's).

The long-term outcome for patients with IF/SBS has improved but significant challenges remain. Among infants born prematurely who develop NEC and SBS, 52% are below the tenth percentile for weight, with a greater impact on head circumference and length compared to those with medically managed NEC.[7] IF/SBS patients commonly have developmental delay and abnormal neurology, suggesting longer-term neurological deficits.[8] IF/SBS patients on PN spend more time in hospital with catheter-related sepsis and intestinal failure-associated liver disease (IFALD),[9] which contributes to IF patients having an estimated 52-73% five-year-survival.[10] Recent reports suggest continuing improvements in survival in expert centres.

Managing the complex health needs of patients with IF/SBS requires input from a dedicated multidisciplinary team of neonatologists, paediatric surgeons, paediatric gastroenterologists, nurses, dietitians and pharmacists with a goal of limiting the morbidity associated with PN and achieving enteral autonomy.

PN in intestinal failure

The use of PN for a newborn infant with IF was first described in 1968.[11] Improved formulations and intravenous access have made it possible to deliver long-term nutrition to patients with IF but there are associated difficulties of sepsis, long-term vascular access problems and IFALD.

A rise in levels of conjugated bilirubin indicates the development of IFALD, although significant liver damage can occur with little evidence of cholestasis. Close attention to the components of PN, avoidance of enteral fasting and prevention of line sepsis are key to limiting IFALD. Four per cent of patients who develop IFALD progress to end stage liver disease,[12] and should be managed by a specialist multidisciplinary team with expertise in the management of liver disease. Early referral to an appropriate centre is recommended as this has been consistently demonstrated to improve outcomes. Evidence for the benefit of newer lipid sources remains limited but many centres now opt for mixed lipids containing both omega 3 and omega 6.

Achieving enteral autonomy

The primary determinant for achieving enteral autonomy is the integrity and amount of remaining small bowel. At two years of age, 96% of newborns who lost 50% of their small bowel will have weaned off PN, compared with 50% of those with only 10% of their small bowel remaining.[5] Yet, patients can continue to make the transition from parenteral to enteral nutrition up to five years of age[13] as the bowel not only continues to grow but also adapts, undergoing villous hyperplasia and bowel dilatation, which increases the surface area available for absorption.

In a small number of cases, bowel-lengthening procedures can be considered. The Bianchi procedure (or long intestinal lengthening) involves cutting the bowel in half along its length, producing two sections of bowel, which can then be placed end-to-end in continuity with the remainder of the GI tract. A newer method is the serial transverse enteroplasty procedure (STEP). A series of incisions are made along the dilated bowel that can then be extended (like a concertina) and re-sewn. Both procedures increase the surface area of the gut available for absorption, however outcomes are variable.

Another option is a small bowel transplant but, even with a matched donor, the intervention is not without significant mortality and morbidity. It is reserved for patients unable to achieve enteral autonomy who have developed end-stage liver disease or very limited central vascular access. A combined small bowel and liver transplant may be necessary.

Conclusion

The post-operative management of neonates following GI surgery can range from rapid post-operative transition to normal feeding, to complex nutritional care that may be protracted over many months and sometimes years. While their long-term outcome has improved, these infants pose unique challenges. Therefore, expert nutritional teams should be the gold standard for managing and supporting the needs of this patient group and their families.

Parental consent

The authors received consent to publish this report from the patient's parents.

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