

Development of bowel habit in preterm infants

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Abstract

The bowel habits in 844 preterm infants were observed during the first 56 days after birth. Delay in the passage of meconium beyond the second day occurred in 32%, and there was an inverse relation between gestational age and the day of first bowel action. Thereafter the increase in frequency of stools passed each day was related directly to the volume of milk ingested. Unfed infants had a modal defecation rate of one stool each day. For each 50 ml/kg increase in the volume of milk ingested the infants showed a further increase of one stool passed each day. Infants fed with human milk passed a greater number and softer stools than those who received cows' milk formula. In the absence of milk feeds an intrinsic pattern of large bowel motor activity, present as early as 25 weeks' gestation, ensures a defecation rate of one stool each day. The effect of enteral nutrition on this inherent motility is governed by the volume and composition of milk feeds, independently of gestational age.

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Successful adaptation of the newborn infant to enteral nutrition requires integration of the digestive, absorptive, barrier, and motor functions of the gastrointestinal tract. Of these least is known about the motility of the gut. The ingestion of milk involves sucking and swallowing followed by oesophageal peristalsis, gastric retention and emptying, small intestinal transit, passage of material across the ileocaecal valve to the large bowel, and thence to the rectum in preparation for defecation. The large bowel is the site of salt and water conservation, bacterial fermentation of luminal nutrients that have escaped digestion in the small intestine, and compaction to stools of what remains. This paper describes the development of large bowel habit in relation to gestational and postnatal age, and volume and composition of milk feeds during early postnatal life.

Patients and methods

A total of 844 preterm infants of birth weight less than 1850 g were studied during the first 56 days after birth. They ranged in gestational age from 25 to 36 weeks, and in birth weight from 540 to 1849 g (table 1). All were born in, or transferred to, one of five neonatal units in the south east and centre of England, where they were the subjects of a multicentre trial of the feeding of low birthweight infants.¹

All infants who survived more than 48 hours, whatever their clinical condition, were studied. Data collected by the nurses caring for the infants included a daily record of the number of stools passed, their consistency (using a scoring system of loose, formed, or hard), and the volume and composition of milk ingested.

Infants were fed on expressed or banked human milk, preterm or full term formula, or a combination of these.¹ For most analyses all infants were grouped together. To explore the relation between feed type and bowel habit, however, those infants whose enteral feeds were exclusively breast milk (mother's own, donated, or a combination; 237 infants) were compared with those whose enteral feeds were exclusively formula milk (term or preterm; 217 infants). Infants in whom enteral nutrition was delayed received intravenous fluids before the start of milk feeding. χ^2 analysis was used to test the significance of the relation between gestational and postnatal age, and the time of passage of first stool. Regression analysis was used to explore the relation between the volume of milk ingested, milk composition, and stool frequency and consistency.

Results

PASSAGE OF FIRST STOOL

Of the 611 infants in whom complete records in the first 48 hours were obtained, only 37% passed their first stool within the first calendar day after birth (12 midnight to 12 midnight). Thereafter there was a steady daily increase in the cumulative percentage of infants who defecated, such that by the ninth day 99% had passed a stool (fig 1).

There was a direct relation between postconceptional age at birth and the time of passage of the first stool: 57% of infants born before 29 weeks' gestation, 66% of infants of 29-32 weeks, and 80% of preterm infants of greater than 32 weeks' gestation passed their first stool by the end of the second calendar day (fig 2). There was a significant difference in the proportion of infants who passed their first stool within 48 hours of birth between those who were born before 29 weeks' and those who were born at more than 32 weeks' gestation ($p < 0.02$).

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Table 1 Type of milk fed to infants studied. Values are numbers of infants

Gestational age (weeks)	Type of milk fed to infants			Total No of infants
	Exclusively human milk	Exclusively formula milk	Human milk plus formula milk	
≤28	52	60	79	191
29-32	146	93	195	434
≥33	39	64	116	219
Total No of infants	237	217	390	844

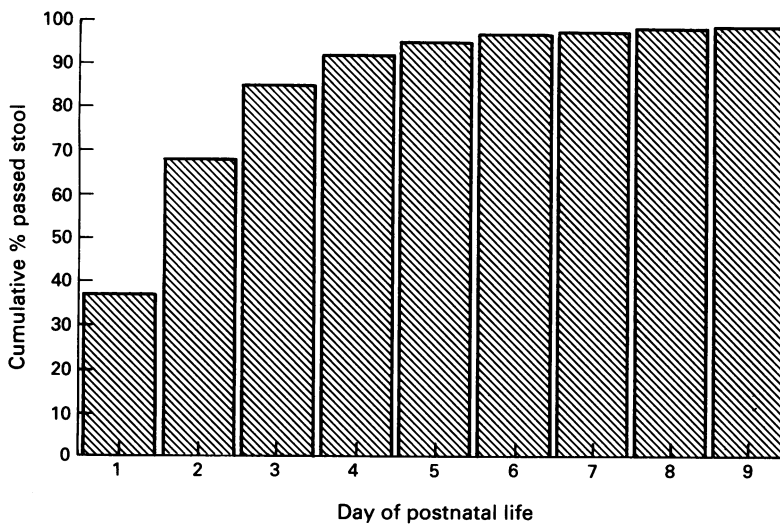


Figure 1 Cumulative percentage of preterm infants who passed their first stool each day after birth.

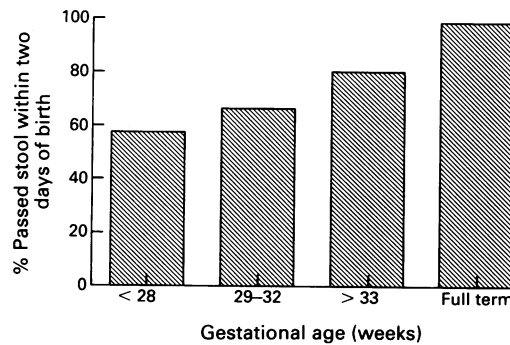


Figure 2 Percentage of infants who passed meconium within the first two days after birth. Data for full term infants are taken from Tejavej *et al*³ and Kramer and Sherry.⁴ There was a significant difference ($p < 0.02$) between the results from those infants less than 28 and those more than 33 weeks' gestation.

STOOL FREQUENCY AND VOLUME OF FEEDS

There was a direct and significant relation between the volume of milk ingested and the number of stools passed each day. Using regression analysis to relate the volume of milk ingested and gestational age to stool frequency at each week after birth, with stool frequency as the dependent variable and milk volume and gestational age as independent variables, it was shown that only the volume of milk ingested was significantly related to stool frequency. This suggests that an apparent relation between gestational age and stool frequency was due to the association between gestational age and volume of milk ingested. As gestational age was not independently related to stool frequency (as opposed to age when the first stool was passed), all the analyses presented are those relating volume of milk ingested to stool frequency.

The relation between the number of stools passed and the volume of milk ingested was highly significant during the first week, and significant until the sixth week (table 2). This relation is shown in detail in fig 3. The greater the volume of milk ingested, the greater the defecation rate. By the fifth day infants ingesting more than 150 ml/kg/day passed four times

Table 2 Results of regression analysis of volume of milk ingested on number of stools passed by age in weeks after birth

Age (weeks)	Regression coefficient (95% confidence interval) of milk intake on number of stools passed (ml/kg/day)	p Value
1	45 (43 to 47)	<0.0001
2	56 (53 to 59)	<0.001
3	59 (55 to 62)	<0.001
4	72 (66 to 80)	<0.01
5	62 (58 to 69)	<0.01
6	65 (57 to 75)	<0.02
7	57 (50 to 66)	<0.02

the number of stools as those receiving no feeds by mouth ($p < 0.0001$). Thereafter this relation between volume of milk ingested and stool frequency persisted for all infants who received enteral feeds. Those infants who received no milk feeds had a modal frequency of one stool each day during the first four weeks ($p < 0.001$). Using regression analysis we found that during the second to fourth weeks infants passed one more stool each day for each 50 ml/kg increase in volume of milk ingested ($p < 0.001$, after adjusting for gestational age). These results apply to a group of infants fed with human milk, formula milk, and a combination of these. The type of feed itself influenced stool frequency, however.

STOOL FREQUENCY AND COMPOSITION OF MILK FEEDS

Figure 4 shows the number of stools passed each day in relation to the composition of milk feeds. Those infants who received human milk had a greater defecation rate than those receiving cows' milk formula throughout the first eight weeks after birth. Log transformation of the data showed this relation to be linear for days 2-7 ($r = 0.98$; $p < 0.001$) and for days 8-56 ($r \geq 0.90$, $p < 0.001$) for the two groups, and the difference between the slopes to be significant ($p < 0.001$). The infants predominantly fed breast milk reached a mean peak rate of four stools each day during the second week compared with 2.75 each day in the infants fed formula milk.

STOOL CONSISTENCY AND COMPOSITION OF MILK FEEDS

Table 3 shows the consistency of stools passed each day in relation to the composition of feeds ingested. An increasing proportion of infants fed human milk passed softer stools and the infants fed formula milk passed harder stools during the first week after birth ($p < 0.001$). These differences persisted throughout the study period.

Discussion

Delay of passage of the first stool beyond the second day occurred in 32% of preterm infants and there was an inverse relation between gestational age and the time of first bowel action. Thereafter there was a direct relation between the volume of milk ingested and stool frequency throughout the first eight weeks after birth. Infants who received no milk had a modal frequency of one stool each day whereas

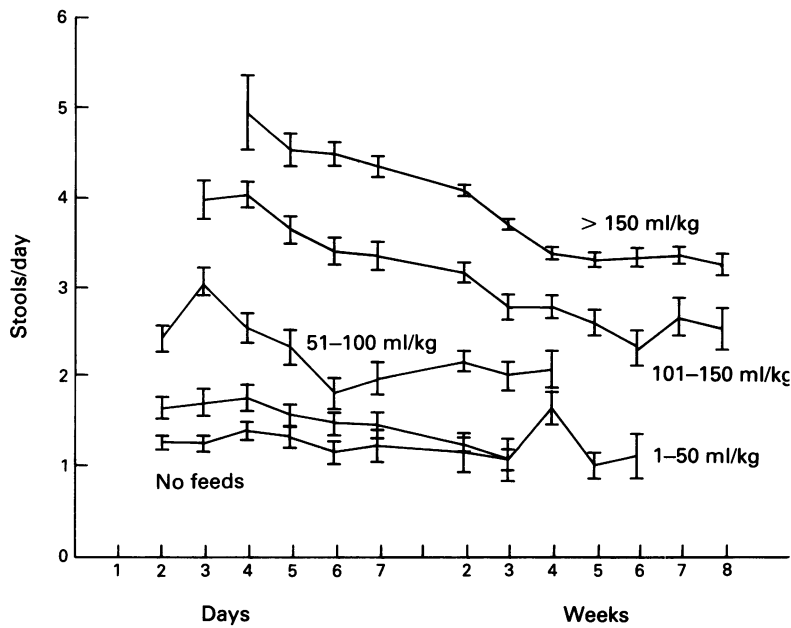


Figure 3 Frequency of passage of stools of preterm infants in relation to volume of milk ingested daily during the first eight weeks after birth. Each point represents at least 25 infants. Means with standard error bars are shown; see results section for significance of findings.

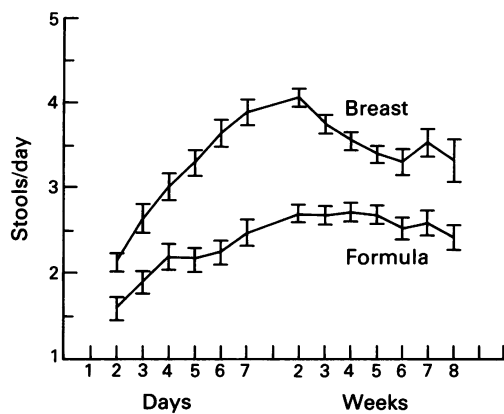


Figure 4 Frequency of passage of stools of preterm infants in relation to composition of milk feeds. Means with standard error bars are shown; the differences between the groups were significant ($p < 0.001$).

those receiving greater than 150 ml/kg/day passed between three and four stools each day. Infants receiving human milk had consistently higher defecation rates, and passed softer stools, than those receiving formula milk, irrespective of gestational age and feed volume.

The results of this study were derived from the observation of 91 716 stools passed by 844 preterm infants during 28 636 infants days. This large data set allows relatively robust conclusions to be made about the large bowel function of preterm infants during early life.

Table 3 Consistency of stools passed by infants breast fed (Br) and infants fed with cows' milk formula (F), expressed as percentage of loose, formed, and hard stools passed by each feeding group during the first week after birth

	Day after birth													
	1		2		3		4		5		6		7	
Type of milk	Br	F	Br	F	Br	F	Br	F	Br	F	Br	F	Br	F
Stool consistency:														
Loose (%)	1	1	0	2	4	2	5	3	11	3	10	1	15	4
Formed (%)	99	99	100	98	96	98	95	89	87	84	88	83	85	79
Hard (%)	0	0	0	0	0	0	0	8	2	13	2	16	0	17

It has been well shown by earlier studies that over 95% of healthy full term infants pass their first stool within 24 hours of birth.^{2,3} It has also been recognised that neonates of low birth weight may have a delayed passage of meconium; only 80% of 500 infants of less than 2500 g,⁴ and 76% of 80 infants of less than 37 weeks' gestation,^{5,6} passed meconium by 24 hours after birth. Our data confirm these findings and show a direct relation between gestational age and time of first stool.

The finding of a modal frequency of one stool each day in the unfed neonate suggests that there is an intrinsic pattern of large bowel motor activity present as early as 25 weeks' gestation. This daily passage of stool may perform the 'housekeeping' function of clearing the colon of intestinal secretions and other unwanted material, though what prevents prenatal evacuation is unknown.

Using regression modelling we have shown that once the passage of stools is initiated, there is a direct and significant relation between stool frequency and the volume of milk ingested, which is independent of gestational age (table 2); increasing volumes of feeds ingested were associated with increasing stool frequency, and at all gestational ages human milk was associated with a higher defecation rate than cows' milk formula.

Such a pattern of large bowel habit after birth has also been described in the full term infant in whom increasing volumes of feed ingested during the first week are associated with an increasing rate of defecation.⁷ Initially full term breast fed infants pass fewer stools than the formula fed infants, probably due to the smaller feed volumes consumed by the former during the establishment of lactation. By the age of two weeks breast fed infants, like the preterm infants reported here, have been reported to pass nearly twice the number of stools each day as those receiving cows' milk formula.⁸

In the small intestine, motor activity is detectable as early as 26 weeks' gestation, as brief, disorganised, random contractions. These are succeeded by repetitive, regular bursts of motor activity (fetal complexes) by 30 weeks' gestation, and by more prolonged cyclical migrating motor complexes by 33 weeks' gestation.⁹ This interdigestive pattern is disrupted by the presence of milk in the stomach, and replaced by a pattern of segmentary propulsive contractions which probably help to mix the luminal contents, ensuring maximum mucosal contact and nutrient absorption.¹⁰ During enteral feeding there is a direct relation between increasing gestational age and increasing gastroduodenal pressures and propulsive activity. Moreover, the length of time spent taking feeds and the volume of milk ingested appear to be the principal determinants of the postprandial motor response.^{10,11}

The neuromuscular development of the human gut occurs largely during the first trimester of pregnancy. Circular and longitudinal muscles are detected in the small intestine by eight weeks and in the large intestine by 10 weeks. Auerbach's and Meissner's plexi are identifiable in the small and large intestines by

13 weeks, and there is completion of the cranio-caudal migration of neuroblasts by 20 weeks. Neuroendocrine cells are identified first in the gastrointestinal mucosa at 10 weeks.¹² Thus the smooth musculature and the enteric neuroendocrine system necessary for propulsive motor activity appear to be morphologically mature long before the initiation of enteral feeding.

Coordinated sucking and swallowing, also required for the independent utilisation of milk feeds, is not achieved until 34–35 weeks' gestation,¹³ after which time most preterm infants are capable of taking feeds by mouth.¹⁴ This gestational age coincides with a significant increase in defecation rate, and a surge in circulating concentrations of intestinal regulatory polypeptides (gastrin, motilin, and neurotensin) in response to milk feeds,¹⁵ suggesting that not until five to six weeks before term is gastrointestinal motor function sufficiently mature to fully support independent enteral nutrition.

Defecation follows the contraction of the rectum and relaxation of the involuntary musculature of the internal anal sphincter. In newborn infants, who possess no voluntary control, evacuation probably occurs in response to an increasing volume of stool in the rectum. Our findings suggest that milk feeds override the intrinsic, fasting, motor activity of the colon, and induce regular defecation at a frequency determined directly by the volume of the products of digestion that reach the rectum; the more feeds, the more stools. Although the number and size of stools may vary, however, their water content remains within a narrow range (around 70%), indicating that the water conserving capacity of the colon is finely regulated at birth.^{16 17} In full term⁷ and preterm infants, the peak stool frequency occurs during the first week after birth, after which there is a decrease, in spite of increasing milk intake, indicating a maturation of the water conserving ability of the gut. It is not known, however, whether this is due to the increasing efficiency of small intestinal absorption or colonic water retention. Nor is it clear why breast fed infants pass softer stools, more often, and have a greater stool water loss than formula fed infants.¹⁷ It is possible that the two characteristics are regulated by circulating peptides which display different levels of response in relation to the composition of milk feeds.¹⁸ Maturation of motilin secretion and the response of the large bowel to this gut hormone may explain why premature passage of meconium in the distressed fetus is rarely seen before 36 weeks' gestation.^{19 20}

In describing the normal pattern of large bowel function of preterm infants the findings

reported here not only add to our understanding of the physiology of the large bowel from birth to old age,²¹ but also help to define what is normal and abnormal. Delay in the passage of meconium after 24 hours is often a sign of intestinal disorders; 94% of infants with Hirschsprung's disease²² and up to a quarter of infants with cystic fibrosis may not pass their first stool until more than 24 hours after birth. Our data show that for preterm infants delay in passage of meconium beyond this time may occur in more than 30%, and thereafter bowel habit at all gestational ages is regulated by the volume and composition of milk feeds.

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