

Review

Transitional nutrition for very low birth weight infants in neonatal intensive care units: Where do we stand now?

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Abstract: The role of nutrition in managing preterm infants, particularly those classified as very low birth weight (VLBW), is pivotal. Optimal nutrition is vital, as early growth deficits and inadequate neonatal nourishment have been linked to significant long-term developmental issues. In the neonatal intensive care units (NICU), tailored nutritional interventions are necessary to meet the unique dietary needs of these infants. Despite advances in neonatal nutrition, gaps remain in understanding the ideal composition and duration of parenteral nutrition, the process of transitioning to enteral feeding, and the need for breast milk augmentation. This review explores current insights and methodologies in the nutritional management of VLBW infants during the critical transition phase. It addresses existing challenges, recent progress, and future directions in enhancing nutritional care for these at-risk infants, aiming to improve outcomes.

Keywords: very low birth weight, transitional phase, parenteral nutrition, enteral nutrition, neonatal intensive care units.

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Introduction

An estimated 15% to 20% of all infants worldwide, or more than 20 million births annually, are born with low birth weight (LBW) [1]. The LBW rates in Asian sites were notably high, with 20.2% reported, comprising 18.6% for LBW, 1.1% for very low birth weight (VLBW), and 0.5% for extremely low birth weight (ELBW). Similarly, the Central American site reported a substantial LBW rate of 15.6%, with 14.7% for LBW, 0.5% for VLBW, and 0.4% for ELBW, as indicated by Marete et al. [2].

Newborns weighing less than 1500 grams at birth are classified as VLBW newborns, who account for 60% of infant fatalities and represent a category with significant morbidity and mortality that has not received sufficient attention in the literature [3]. Extreme prematurity and VLBW are strongly associated. According to the INTERGROWTH-21st research, the 50th percentile of birth weight for a fetus at 32 weeks is 1,500 g [4]. As a result, historical patterns of VLBW may suggest progression toward severe prematurity in the lack of precise gestational age data [5]. Large cohorts of live births identified risk factors associated with preterm birth and LBW, including nulliparity, severe antenatal hemorrhage, hypertensive disorders, inadequate antenatal care [6], and exposure to secondhand smoking during pregnancy [7].

Preterm newborns with VLBW face numerous physiological and metabolic challenges, necessitating tailored nutritional support. Most VLBW newborns have nutritional deficiencies during their hospital stay, especially in ICU settings because their gastrointestinal immaturity supplies inadequate energy and

nutrients to fulfill their increasing requirements, and their meager nutrient reserves seldom allow them to achieve optimum postnatal development [8]. Parenteral nutrition (PN), which offers a reasonably safe way to satisfy nutritional requirements, is essential for the management of VLBW newborns [9]. Enteral feeding has the potential to improve nutrient absorption and growth velocities, expedite the postnatal adaptation of gastrointestinal physiology, metabolism, and microbiome, and reduce complications linked to the use of intravascular devices for administering fluids. Nonetheless, the commencement of enteral nutrition in VLBW infants is often delayed due to concerns over tolerance and the heightened risk of necrotizing enterocolitis (NEC) [10].

Several reviews have been dedicated to aspects of transitional nutrition for very low birth weight (VLBW) infants in neonatal intensive care units (NICUs) in the last decade, typically concentrating on early nutritional strategies such as parenteral nutrition [11-16] and the gradual transition to enteral feeding [17-24]. These publications often highlight the challenges associated with achieving optimal growth [8, 25-29] and the risk of complications like necrotizing enterocolitis (NEC) [30-34] during the early stages of life. However, comprehensive evaluations of the *entire continuum* of transitional nutrition – from parenteral to enteral nutrition – are less commonly discussed. Many previous studies have either focused on a single aspect, such as human milk fortification [26,35-38] or protein intake [20], without a thorough integration of the entire nutritional transition phase.

By focusing on evidence-based practices and emerging nutritional interventions, this review presents a **novel viewpoint** that can fill that gap by focusing specifically on the transition from PN to EN, synthesizing recent evidence on best practices for safely weaning VLBW infants off parenteral nutrition. This review highlights novel strategies for managing the delicate balance between avoiding nutrient deficits while minimizing the risk of feeding intolerance or NEC, providing a timely, integrated perspective on optimizing this critical phase of neonatal care.

Transitional nutrition phase: challenges and significance

Definition and importance of the transitional phase

Definition

The transitional phase (TP), also known as the transition from parenteral nutrition (PN) to enteral nutrition (EN), is a critical period in the care of very low birth weight infants in order to achieve adequate growth [23]. It refers to the time when these infants shift from receiving nutrition through intravenous means to oral or tube feeding. This phase holds immense importance as it sets the foundation for the baby's long-term nutritional well-being and growth [21, 22].

The PN phase, TP, and EN phase were used to categorize the nutritional stages in all of the research, with the TP being defined as the phase of progressive PN decrease. Liottot et al. referred to the transition phase (TP) from parenteral to enteral nutrition was characterized as the time interval that began on the day when parenteral intakes began to drop and ended on the day when PN was totally stopped [20]. TP was quantitatively characterized in some studies as the enteral feeding volume ranging from 30 to 160

ml/kg/day [23] or 30-120 ml/kg/day [19] or 20-120 ml/kg/day [18] while a different study determined the enteral feeding volume of 60 to 150-180 ml/kg/day as the quantitative definition of the TP [20]. The transition phase is often segmented further into two distinct periods: the early phase, characterized predominantly by parenteral nutritional support (PN; enteral feeding volume <80 ml/kg/day) and the latter phase, where enteral nutritional support (EN; EN accounts for ≥50% of total energy intake; enteral feeding volume ≥80 ml/kg/day) takes precedence [20, 25]. Wang et al. describe the transition phase (TP) as beginning when the infusion of amino acids (AA) in PN is escalated to the target range of 3.5-4.0 g/kg/day and concludes upon achieving full enteral nutrition [25].

Importance of the transitional phase

During the transitional phase, the infant's digestive system undergoes significant development and adaptation to handle enteral feeds. Enteral feeds, whether administered orally or through a feeding tube, are essential for supplying the vital nutrients required for growth, development, and overall health (Figure 1). Miller et al. highlighted that the limited growth observed in preterm infants during TP from PN to EN could predict restricted growth at discharge. This was determined through a multivariate analysis considering nutritional and clinical predictors of postnatal growth failure (PGF). They proved that poor growth (<10 g/kg/day) in TP was an independent factor associated with an increased likelihood of PGF (OR=5.4, 95% CI: 1.66-17.52) [23]. The suboptimal growth observed during both the PN-only and EN phases does not significantly correlate with the growth failure in preterm infants at the time of discharge [21-24]. Since then, there has been a lot of interest in the potential of TP.

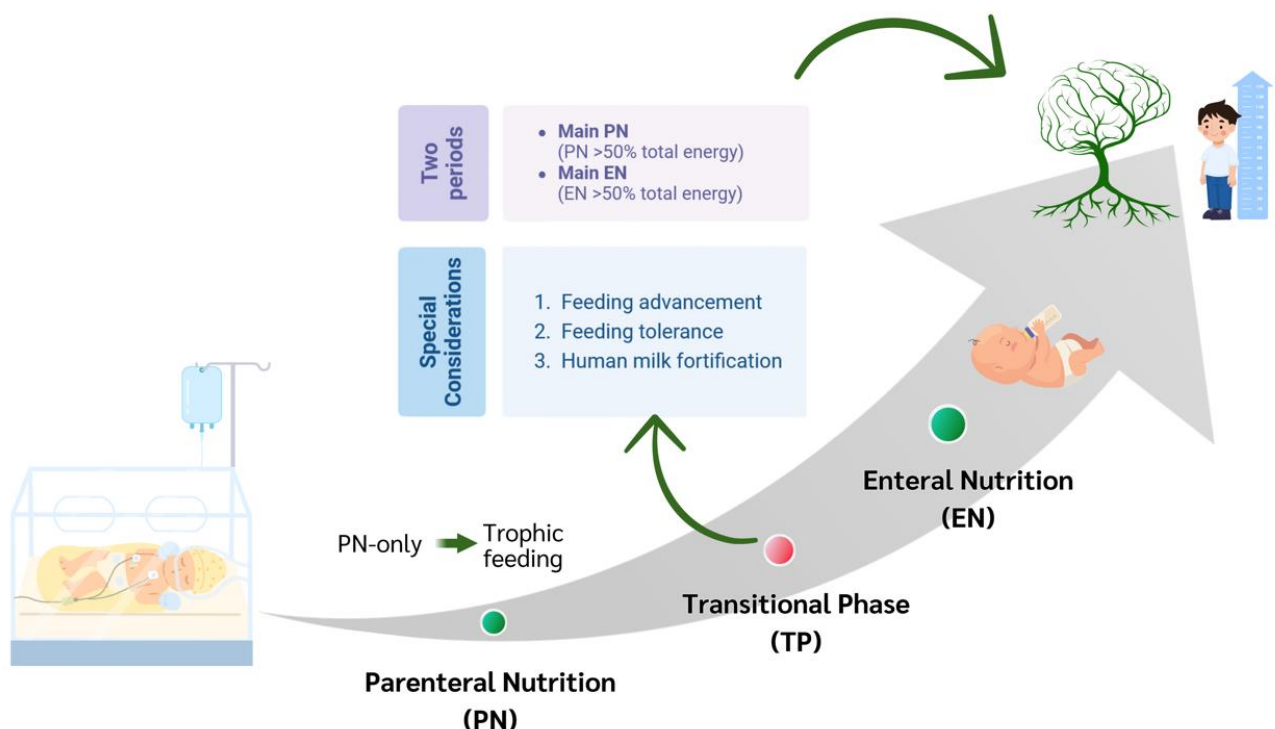


Figure 1. The role of the transitional phase in the nutritional care steps for VLBW infants.

Table 1. Electrolytes and minerals requirement for preterm, including VLBW infants

Electrolytes	Preterm neonates (mEq/kg)	Element	Weight <1500 g (mcg/kg/day)
Sodium	2-5	Zinc	400
Potassium	2-4	Copper	20
Calcium	2-4	Chromium	0.05-0.3
Phosphorus	1-2	Manganese	1
Magnesium	0.3-0.5	Iodide	1
Acetate and chloride	As needed to maintain acid-base balance	Iron	100-200

Extremely preterm newborns frequently experience postnatal growth failure (PGF), and there is a significant chance that they will experience detrimental metabolic and neurological consequences in the future. Indeed, assessing neurological development in these infants has never been easy due to the requirement of not only qualified but also well-trained clinicians [39]. Thus, it has increasingly become apparent how crucial early nutritional therapy is to preventing early growth failure in preterm infants [27,40]. For neonatologists, nutrition during the TN phase presents a novel problem since it includes the conversion of enteral protein from parenteral amino acid (AA) [22]. According to Liotto et al. preterm infants' postnatal development was enhanced by more rigorous dietary management during the TN [20]. Furthermore, a high proportion of subpar growth during the TN phase was predictive with discharge-related growth failure.

Challenges in transitioning from parenteral to enteral

It has been recently determined that the transitional nutrition (TN) phase, during which PN is being tapered with progressive enteral feeding, is a vital window of time during which growth may be affected [23]. Present guidelines [41,42], however, do not treat this stage as a separate entity and are centered on providing EN or PN. Research on nutritional intakes [43,44] are mostly based on "chronological age," with variances being calculated from a single set of guidelines. But this method makes it harder to effectively identify nutrient imbalances, especially deficiencies, given the growing variation in the preterm population regarding the length of exclusive PN, the start of EN, and the proportion of development from PN to full EN. These controversies lead to many challenges in clinical practices on how to manage and handle VLBW nutritional problems. For instance, in NICUs, suspected feeding intolerance and the possibility of NEC are frequent issues. Enteral feeding is commonly started later than planned due to these worries, which also cause feeds to develop slowly and result in inadequate intake of nutrients [45]. The requirement for PN and related problems such as sepsis, liver failure, thrombosis, and inflammatory disorders rises when the gastrointestinal (GI) tract is not used well [46,47]. Moreover, it causes GI mucosal atrophy, which results in less protective mucus, greater permeability, a reduction in regenerative capacity, and, ultimately, GI dysfunction with a higher risk of NEC and feeding intolerance [48].

Impact on growth and development outcome

Premature newborns, especially VLBW infants must receive parenteral nutrition intravenously until enough EN is established in an effort to spare growth. On the other hand, poor growth, central line infections [16], cholestasis, and metabolic bone disease can result from both weaning off PN and slowly advancing feeds [16,49].

Consequently, a large number of newborns experience extrauterine growth restriction (EUGR) or "faltering growth" [42], a condition in which the anthropometric measurements of the neonates at the time of discharge fall below the 10th percentile of the predicted intrauterine growth for the postmenstrual age [50]. This might be because PN has trouble maximizing energy because of lipid and glucose intolerance, inadequate caloric and protein supply during the transition to advanced feeds and weaning, and higher metabolic needs [16, 49].

Nutritional strategies: parenteral to enteral transition

Overview of parenteral nutrition protocols and practices

Early parenteral nutrition improved short-term results without showing signs of increased morbidity and death, according to a meta-analysis by Moyses et al. [15]. In premature babies, parenteral nourishment should be administered via a central or peripheral line as soon as possible after birth [13]. Preterm infants require well-balanced parenteral nutrition, adopting an early and proactive strategy to minimize postnatal weight reduction, facilitate a quicker restoration to birth weight, and diminish the risk of extrauterine growth retardation [13, 51]. Infants with VLBW exhibit significantly elevated energy demands, stemming from their developmental immaturity, growth needs, and heightened susceptibility to both hypothermia and hyperthermia [13].

Carbohydrates

In total parenteral nutrition (TPN), dextrose acts as the main source of energy and is the carbohydrate most frequently used. Providing 3.4 kcal/g, dextrose is recommended to fulfill 30–35% of the daily energy needs. In full-term, healthy newborns, intrinsic glucose production rates vary from 5.5 mg/kg/min to 8 mg/kg/min in VLBW infants [52]. Early after birth, an initial glucose infusion of 6-8 mg/kg/min is recommended to align with the body's endogenous glucose production. This rate should then be incrementally raised to achieve blood glucose concentrations between 45-120 mg/dL [53]. Given their limited carbohydrate reserves, VLBW infants may need greater glucose infusion rates (GIRs) (~8 mg/kg/min), surpassing their intrinsic production rate. Premature birth of VLBW babies increases the risk of hyperglycemia. Gradual increases in GIR reduce hyperglycemia and are more tolerable. Increasing the dextrose content and/or the overall fluid intake will result in a higher GIR. For dextrose concentrations greater than 12.5%, a central line should be used. Numerous negative consequences of high glucose infusion include elevated oxygen consumption, elevated energy expenditure, raised serum osmolality, osmotic diuresis, fat accumulation in the liver, and surplus fat storage [54]. Present data does not endorse the regular administration of insulin in preterm infants; it should be reserved for cases where reducing GIR to 4 mg/kg/min fails to correct hyperglycemia [13].

Protein

Preterm infants possess limited energy stores at birth, and without prompt initiation of enteral or parenteral nutrition post-delivery, they are forced to break down protein for energy requirements. Ten to fifteen percent of total calorie intake should come from protein, which is 3.4 kcal/g. A fetus around 28 weeks of gestation is expected to accrete roughly 2 g/kg of protein per day;

therefore, in order to encourage protein accretion, account for required losses [55], and avoid a negative nitrogen balance, a minimum of 3-3.5 g/kg of protein or amino acid are required. Research has indicated that starting at about 2 g/kg/day of amino acids is safe to consume immediately after delivery [56, 57]. The starting dose of amino acids ranged from 0 to 3 g/kg/day, aiming for a target of 2.4-4 g/kg/day; comparative studies have shown no significant difference in pH or base deficit among groups receiving varying doses of amino acids [58, 59]. The current guidelines propose consuming 2 to 3.5 grams of amino acids per kilogram on the initial day of life, rising to 4.0 g/kg/day over the first week.

Seven randomized controlled trials comparing early amino acids (in the first 24 hours) to late amino acids varied among these studies

(2.5-4.0 g/kg/day) in preterm newborns were included in the Cochrane review [60]. Four studies showed a positive nitrogen balance and a notable difference in blood urea nitrogen (BUN) levels within the first 48 hours, while another study observed no change in head circumference or crown length by the tenth day. Metabolic acidosis was not observed in the first 24 hours following early amino acid intake [61]. They concluded that available evidence does not support the advantages of early amino acid supplementation on mortality, early and late growth, and neurodevelopment [60]. Neonatologists and nutritionists generally concur that early, sufficient protein and calorie intake is essential in preventing extrauterine growth limitation in VLBW newborns in some research [62].

Table 2. Nutrition protocols of preterm infants

	Dsilna et al. (2005) [75]	Senterre et al. (2014) [45]	Miller et al. (2017) [24]	Barr et al. (2019) [14]	Wang et al. (2022) [19]
Colostrum care	N/A	Yes	N/A	Yes	N/A
Trophic feeds	Started before 30 hours postnatal age	Initiated as soon as possible after delivery	Initiated 24-72h postbirth, maintained <20ml/kg/day for 3-10 days	≤1250 g (4 days total): 10 ml/kg × 3 days and 20 ml/kg × 1 day; 1251-1500 g (2 days total): 10 ml/kg × 1 day and 20 ml/kg × 1 day	Initiated as early as possible after delivery without contraindication. Using HM or formula 10-20 ml/kg/day for 3-5 days
Advance feeds	< 1000 g: 10-15 ml/kg/day, 1000-1199 g: 15-20 ml/kg/day during first 2 days; From third day: all infants were advance 15-20 ml/kg/day if no feeding intolerance found	10-35 ml/kg/day	10-20 ml/kg/day to goal feeds of 160 ml/kg/day	<20 ml/kg/day	N/A
Feeding delivery method (non-trophic feeds)	<1000 g: Intermittent bolus over 15-40 min every 3 h	Intermittent bolus over 10-30 min every 2 or 3 h (try continuous feeding <1000 g)	N/A	≤1250 g: long bolus over 2 hours; ≥ 1251 g: bolus 30 minutes –1 hour	N/A
Maximum feeds	N/A	180-200 ml/kg/day	160 ml/kg/day	160 ml/kg/day	N/A
PN written for volume while feeds advancing	Partial PN started at 60-80 ml/kg/day, increased by 10 ml/kg/day to goal of 140-160 ml/kg/day	Increase the volume of PN to approximately 150 ml/kg/day by day 3, combined with lipid reached energy intake approximately 100 kcal/kg/day	At EN volumes of 50 ml/kg, full kcal and protein orders concentrated in 100 ml/kg; run at adjusted rate to maintain 140 mL/kg/day.	PN and lipids written for < total fluid volume, 100 ml/kg/day, when feeds advancing	N/A
Lipid dosing (20% IVLEs)	N/A	≥ 2 g/kg/day, advancing to goal 3-4 g/kg/day	0.5-1 g/kg/day, advancing to goal 3 g/kg/day	1 g/kg/day after 24 hours, advancing 1 g/kg/day to goal 3 g/kg/day. If direct bilirubin >2 mg/dL, restrict to 0.5–1 g/kg/day.	1 g/kg/day, advancing 0.5-1 g/kg/day to goal 3 g/kg/day
PN discontinued	EN volume reached 75% of goal volume	EN volumes of 125-150 ml/kg/day	EN volume of >80-120 ml/kg/day	Lipids at 80 ml/kg/day; PN at 100 ml/kg/day	EN volume of >120 ml/kg/day
Feeding type initiation	Only human milk	Colostrum, unfortified EBM	Unfortified EBM, or preterm formula 24 kcal/oz	Preterm formula 24 kcal/oz; breast milk 20 kcal/oz	Human milk, or formula
Breast milk fortified	When PN discontinued, fortification of HM was started	At EN volumes of 100 ml/kg/day, add human milk fortifiers	At EN volumes of 100-120 ml/kg/day: first 24hrs: at half-strength HMF (22 kcal/oz), then full-strength (24 kcal/oz)	At 100 ml/kg/day, when PN was discontinued, fortified EBM to 24 kcal/oz. Continued fortification and 24 kcal/oz formula until 1800 g or longer as needed for growth (unless excess weight gain or high intake >180 ml/kg/day)	At human milk volumes at 50-100 ml/kg/day, HMFs was added
Remove central lines		N/A	N/A	At 100–120 mL/kg/d	N/A
Goal energy intake (PN+EN)	120-150 kcal/kg/day	110-135 kcal/kg/day to gain at least 15 g/kg/day	100-120 kcal/kg/day	N/A	Target caloric of full PN: 80-100 kcal/kg/day, full EN: 110-135 kcal/kg/day
Goal protein intake (PN+EN)	3.0-4.0 g/kg/day	3.5-4.5 g/k/day	>3 g/kg/day	N/A	3.5-4.0 g/kg/day

Table 3. A practical approach to improve enteral feeding procedures for ELBW (<1,000 g) and VLBW (1,000-1499 g) [45]

	ELBW	VLBW
Feeding type initiation	HM	HM
Trophic feeding	6-48 h postnatal	6-48 h postnatal
Initial MEN	0.5 ml/kg/h or 1 ml/kg q2h	1 ml/kg/h or 2 ml/kg q2h
Length of MEN	1-4 days	1-4 days
Feeding advancement	15-25 ml/kg/day	20-30 ml/kg/day
If continuous feeding	+0.5 ml/kg/h q12h	+1 ml/kg q8h
If q2h intermittent feeding	+1 ml/kg q12h	+1 ml/kg q8h
HM fortification	before 100 ml/kg/day	Before 100 ml/kg/day
Target energy intakes	110-130 kcal/kg/day	110-130 kcal/kg/day
Target protein intakes	4-4.5 g/kg/day	3.5-4.0 g/kg/day

Table 4. Transitional nutrition protocols for VLBW

<i>Characteristics</i>
- Critical period for poor development and accumulated nutritional inadequacies due to weaning off PN and starting EN [18,21-23].
- Standardized feeding regimens help infants achieve complete enteral feedings more quickly [116,117], reduce the length of hospital stay and PN [118], lower the incidence of NEC [75,91], and enhance growth and neurodevelopment [23,27,40].
<i>Recommendations</i>
- Feeding type initiation: Breastmilk or preterm formula milk 24 kcal/oz [19,24,41,45].
- Trophic feeding or minimal enteral feedings (MEN): start as soon as possible after birth without contraindicated [19,41,45].
- MEN volume: 10-24 ml/kg/day [14,19,24,41].
- Duration of MEN: 1-7 days [41,45].
- Daily advancement of enteral feeds: varied at 10 to 35 ml/kg/day in stable infants [14,24,41,45].
- Enteral fluid intakes: 150-180 ml/kg/day (can be up to 200 ml/kg/day if appropriate) [14,41,45].
- Breastmilk fortification: starting when enteral intakes reach 40-100 ml/kg/day, fortified breastmilk to 24 kcal/oz [19,24,41,45].
- Target energy intakes: 110-140 kcal/kg/day [41,45].
- Target protein intakes: 3.5-4.0 g/kg/day (can be increased up to 4.5 g/kg/day) [41,45,79].
<i>Growth outcomes goal</i>
- Average weight gain: 17-21 g/kg/day [42].
- Head circumference: >0.9 cm/week [111].

Lipids

Lipids are a fundamental component of the nutritional regimen for VLBW infants. They serve as a significant source of energy, contribute to the growth and development of the brain and nervous system, and are essential for the absorption of fat-soluble vitamins. Soybean oil, or combinations of fish and olive or soybean oils, is the fundamental component of commercial lipid emulsions. Due to their reduced phospholipid-to-triglyceride ratio, lipid tolerance is best with a 20% preparation and should be the first choice treatment; this is also preferable in neonates [63]. Given that the osmolality of the emulsion matches that of plasma, its administration through either a peripheral or central vein is considered safe. The first dosage of lipid emulsion in VLBW infants may be as little as 2 g/kg/day [63] and subsequent dose increases should be made gradually by 0.5-1 g/kg/day until reaching a maximum of 3 g/kg/day. However, it's also common practice to start with a lesser dose and go up to a maximum of 3 g/kg/day but should not exceed 4 g/kg/day [63]. For neonates, encompassing preterm infants, the standard application of intravenous lipid emulsions (ILEs) ought to be maintained continuously throughout a 24-hour period. Also, lipid emulsions alleviate the biochemically apparent shortage of essential fatty acids that occurs in preterm newborns within 72 hours [64]. For longer than two weeks of parenteral nutrition, soybean-based lipid emulsions are not recommended because they may accelerate the onset of cholestasis and liver damage [65, 66]. The latest development in lipid emulsions features a formulation that includes fish oil [65]. In VLBW newborns, early lipid administration within the initial week is deemed well-tolerated and safe, correlated to weight increase, and may enhance these newborns' early nutritional support [67, 68].

According to various studies and guidelines, the optimal period to begin lipid administration is within the first two days of life [63, 68].

Electrolytes and minerals

With any parenteral nutrition practices and protocols, vitamins and minerals must be included. [Table 1](#) listed daily electrolytes [69] for preterm infants and mineral requirement [70] for VLBW infants. Noted that copper and manganese are omitted in patients with obstructive jaundice due to its excretion primarily in bile and chromium is avoided in patients with renal dysfunction.

Since impaired bone mineralization is linked to insufficient supplementing throughout postnatal life, calcium and phosphorus are crucial minerals. The third trimester is when most calcium and phosphorus are accumulated in pregnancy. Thus, the preterm newborn is highly susceptible to these mineral shortages, which in turn increases their risk of developing osteopenia of infancy (also referred to as metabolic bone disease). This disorder can have enduring consequences, such as osteopenia and reduced stature in adult life [13]. For parenteral feeding, the optimal ratio of calcium to phosphorus (mg:mg) is between 1.3 and 1.7 to 1 [71], as this proportion appears to facilitate the maximum absorption of these nutrients. The current guideline is to fortify human milk and offer early and appropriate calcium/phosphorus supplements as well as vitamin D to prevent metabolic bone disease [72-74].

Strategies and protocols for transitioning to enteral nutrition

Initiating enteral feeding promptly to stimulate the stomach's trophic functions and reduce the duration of central venous access is advisable to decrease infection risks. It's important to recognize that during this transition phase, various dietary elements cannot

be delivered at consistent levels, leading to a critical phase of nutritional vulnerability as parenteral nutrition is gradually reduced and enteral feedings are increased.

There are various recommendations and guidelines, as well as strategies and protocols for the nutritional management of preterm infants, particularly those with VLBW. Some of these protocols are listed in [Table 2](#).

Improved growth velocity in VLBW newborns is linked to an earlier start of complete enteral feeding, which may indicate a shorter transition phase. Making judgments about variable nutrition delivery strategies, such as overall fluid volume, PN, feed fortification, vascular access, and intravenous lipids, is necessary when switching from complete parenteral fluids to enteral nutrition [23, 76-78]. In particular, attempts to lower central line-associated bloodstream infections have an impact on decisions regarding the discontinuation of central-line vascular access, and the cardiovascular state of newborns with VLBW might influence recommendations concerning total fluid volume [77]. Premature infants that grow quickly have higher protein and calorie needs. A guideline from Europe in 2010 suggested for newborns weighing under 1000 g, an enteral protein intake of 4.0-4.5 g/kg/day, and for those between 1000 and 1800 g, a recommended intake of 3.5-4.0 g/kg/day [79]. ESPGHAN (2022) recommended protein intake at least 3.5-4.0 g/kg/day for very preterm infant and could be increased up to 4.5 g/kg/day in particular circumstances [41]. The protein content of expressed breast milk is around 1.1-1.3 g/100 ml after the first 3-4 weeks. Commercial HMF raises the protein level by 0.8-1.0 g per 100 ml [80]; therefore, in order to achieve a daily protein intake of 4.0 g/kg, an enteral volume of 180 (160-200) ml/kg is needed [81]. Although fortification can be tailored to each individual to enhance protein consumption and growth at 100-160 ml/kg/day [14, 24, 45], raising the daily enteral volume to 180-200 ml/kg/day [81, 82] might be a practical approach to obtain the target.

Falciglia et al. carried out a study on the energy and protein consumption during the transitional phase, leading to several recommendations for enhancing energy and protein intake in VLBW infants: provide PN and intravenous lipids up to the point where EN volume constitutes $\leq 66.7\%$ of the total intake to optimize energy consumption; consider continuing PN until full enteral feeding is established to ensure adequate protein intake; preferentially use a central line for administering PN; aim to remove the central line before full enteral feeding is reached whenever possible; initiate fortification once EN volume exceeds $>33.3\%$ of the total intake to improve protein consumption; and avoid fluid restriction and the intake of excessive non-nutritive fluids [21]. The Irish Society for Clinical Nutrition and Metabolism recommended when moving from parenteral to enteral nutrition, optimal nutrition intake and normal glucose levels should be maintained [12]. When determining PN requirements for preterm infants, enteral nutrition volumes should be taken into account once they have been increased beyond trophic and are clinically deemed to be tolerated [22]. The Irish guideline suggested that: (1) PN should be decreased in proportion to the rise in enteral nutrition quantities without jeopardizing nutritional consumption; (2) to guarantee that maximum lipid tolerance is not exceeded during the transition to enteral nutrition in preterm infants, the lipid infusion should be decreased as enteral nutrition advances (with EN volume at ≤ 50 ml/kg/day and ≥ 60 ml/kg/day, the lipid provision should not be exceed 3 g/kg/day and 2 g/kg/day, respectively); (3) Lipid infusion and aqueous PN infusion should be maintained until the newborn

can tolerate an enteral feeding volume of at least 120 ml/kg/day; and (4) Should it be essential to fulfill fluid and nutritional needs, the combined volume of parenteral and enteral fluids may exceed 150 ml/kg/day, provided there are no existing contraindications [12].

Administering ibuprofen or indomethacin in the early stages of life to encourage patent ductus arteriosus closure can be a barrier to the early accomplishment of complete enteral feedings. Trophic feedings are still possible, although enteral feedings are frequently restricted or stopped during therapy due to intestinal perforation concerns. It was shown by Clyman et al. that neonates <1250 grams receiving either medication responded faster to full enteral feedings when given 15 ml/kg of ongoing trophic feedings than when their feedings were paused during treatment without any rise in gastrointestinal perforations or NEC [83]. In Clyman's study, the infants had not been given human milk fortifiers, achieved enteral feedings of more than 60 ml/kg/day, or consumed preterm formula exceeding 20 calories per ounce [83]. Nevertheless, a recent study by Louis et al. also showed that newborns weighing less than 1,500 grams could be given enteral feedings exceeding 60 ml/kg/day while receiving indomethacin therapy without having their risk of NEC enhanced [84, 85].

"Increased" stomach residues are seen during regular examination, especially following the switch from intravenous to enteral feeding. Enteral feeding advances are sometimes withheld or delayed due to the idea that elevated gastric residuals could be indicative of NEC [86]. However, physiologically, immediately before any planned meal, 2-4 ml/kg of stomach residual fluid is routinely withdrawn [87]. Furthermore, the position and size of the feeding tube, as well as the patient's posture, affect gastric residual volume, which further reduces the practice's clinical utility [88]. This approach was found to have no advantage in a later randomized controlled study with 143 preterm babies weighing less than 1250 grams at delivery [89]. While it is evident that this tiny trial lacked the power to evaluate the impact of this procedure on NEC rates, by week five the group without gastric residues was exhibiting an advanced enteral feeding habit and larger feeding volumes [89, 90].

While most NICUs practice breastmilk fortification [35], the evidence supporting its long-term benefits remains notably limited [36]. A systematic review revealed that compared to non-fortified human milk, fortifying human milk enhances in-hospital growth rates in weight, head circumference, and length, without a higher NEC risk [36]. However, scant follow-up data on growth after discharge and neurodevelopmental outcomes in later childhood reveal no significant advantages of fortification [36]. Furthermore, a recent meta-analysis indicated that initiating fortification early (at 20-40 ml/kg/day of enteral feeds) versus late (starting at 100 ml/kg/day) had minimal impact on short-term growth outcomes [26, 90].

Special considerations and individualized approaches for VLBW infants

In VLBW newborns, the incidence of NEC may be decreased and feeding tolerance may be greatly improved by using only human milk (HM) and standardizing feeding procedures [75, 91]. Optimal ingesting schedules can also enhance neurodevelopment and postnatal growth into adolescence [92, 93]. Our review exceptionally went through some individualized strategies and special concerns for VLBW newborns.

Minimal enteral nutrition and initiation of enteral nutrition

This concept involves feeding infants small quantities of food, which may lead to adaptation or adjustment of the intestinal mucosa. Research indicates that infants fed early with few meals experienced fewer episodes of feeding discomfort and gained weight more quickly than those fed later as well as reduced PN needs and PN-associated complications [31]. These feeds have been used for minimum enteral nutrition (MEN), with quantities ranging from 0.1 to 24 ml/kg/day [45, 48, 94]. They are hypocaloric, meaning that insufficient calories are supplied [94]. A meta-analysis of research evaluating the clinical effects of MEN has been carried out by Tyson et al. [95]. The results of their study demonstrated a reduction in the average number of days to resume feeding, a decrease in the days when feeding was halted, and a shorter overall hospital stay. Additionally, the study observed no significant rise in the occurrence of necrotizing enterocolitis (relative risk=1.10; 95% CI 0.63-1.90) [95]. McClure et al. demonstrated that infants who receive minimal enteral feeding experience fewer bouts of culture-confirmed sepsis and to gain weight more quickly [96].

Enteral Nutrition Advancement in VLBW

Feeds are usually advanced by 10-35 ml/kg/day varied in guidelines and recommendations [14, 24, 45, 75], depending on clinical circumstances and body weight. Time to acquire complete enteral feeding, postnatal morbidities such as NEC, and postnatal growth are the main documented parameters to assess the suitability of feeding regimens. According to certain research, slow feed advancement may help prevent NEC in children born with VLBW [33, 34]. This hasn't been verified, though, and a delayed progression of feeds suggests a higher requirement for PN and raises the risk of PN-related problems such as bloodstream infections and prolonged hospital stays [47]. In comparison to quicker rates between 30-40 ml/kg/day, some recent systematic analyses have indicated that slower feed advancement (<24 ml/kg/day) did not lower the risk of NEC in infants with VLBW [30, 97]. These studies also demonstrated that achieving complete enteral feeding and regaining birth weight may be accomplished more quickly when feeds are increased faster [30, 97].

Feeding administration and delivery method

Premature infants typically delay oral feeding due to neurological immaturity, and following delivery, VLBW infants need to be tube fed for an extended length of time [45]. Small feeding tubes are typically inserted into VLBW infants through the mouth (orogastric tube) or the nostril (nasogastric tube). There was insufficient data to recommend a specific practice based on a systematic review comparing the oral and nasal routes in terms of feeding tube placement in premature infants [98, 99]. The "traditional" tube feeding technique involves giving a bolus gavage intermittently every two or three hours by gravity over a period of 10 to 30 minutes [100]. Due to their miniature stomach capacity, newborns may find heavy feeding volumes uncomfortable and more prone to develop gastroesophageal reflux [101]. In VLBW newborns, continuous feeding is also utilized to promote postnatal GI maturation, lower energy expenditure, lessen reflux, and increase eating tolerance. In particular for VLBW and ELBW infants, continuous feeding may promote linear growth and hasten the attainment of full enteral feeding [75]. A recent systematic analysis comparing intermittent vs continuous bolus feeding in infants with VLBW revealed no disparities in the incidence of NEC, postnatal

growth, hospitalization length, or time to acquire complete oral feeds [102]. Even yet, the authors proposed that continuous feeding could help newborns weighing less than 1,250 grams gain weight more quickly and be discharged earlier, even in the face of overwhelming evidence [102].

Feeding tolerance

In VLBW newborns, feeding intolerance is poorly characterized. During non-invasive ventilation, abdominal distension is frequently seen, and within the initial week of life among VLBW babies, antegrade peristalsis with bilious aspirates is also regularly reported [87]. It is standard procedure to aspirate gastric residuals in order to assess GI tolerance while using a feeding tube. If stomach residuals are exceed 3-4 ml/kg, constitute more than 30-50% of the preceding meal, or have a bilious appearance, many doctors view them as questionable [45, 87]. Hence, if gastric residuals are less than 4 ml/kg or below 50% of the feed from 3 hours earlier, without any significant clinical signs or symptoms, it is not a valid reason to limit or stop enteral feeding [103]. In actuality, GI maturation and feeding tolerance can be enhanced by maintaining enough enteral feeding [48, 104]. It is necessary to modify feeds based on each infant's developmental stage when there is a suspicion or confirmation of feeding intolerance. Even after a few hours, enteral feeding ought to be promptly reinstated as soon as feasible if clinical assessment excludes NEC or any other condition notwithstanding the interruption of feeding. There are also some worries regarding a correlation between NEC and cyclooxygenase inhibitor medication, patent ductus arteriosus, and blood transfusions in infants with VLBW. Nevertheless, there is no proof that delaying feeding in these circumstances lowers NEC or produces better results [45, 103].

Human Milk Fortification

The substantial nutritional requirements of VLBW children can be fulfilled despite the greater protein and calorie content of the HM nutrients of moms who delivered early, particularly for protein, phosphorus, and calcium. This results in osteopenia, an inadequate development rate, and other nutritional deficiencies [38]. Multicomponent HMF dramatically enhances postnatal weight gain, linear growth, and head development, according to a systematic study [38]. According to recent investigations, numerous newborns who were given HM with standardized fortification continued to have postnatal growth restriction (PNGR) [37, 105]. It appears that inadequate protein and energy intakes are the primary causes of this condition [37, 43]. Furthermore, there is a correlation between the procedures of HM administration, retention, and extraction and a reduction in fat content, which in turn lowers energy content [106]. De Halleux et al. concluded that there are notable differences in the composition of macronutrients of donor HM pools and expressed preterm OMM, particularly with regard to protein, fat, and energy. The high nutritional needs of immature newborns are not met by standard fortification, as advised by the manufacturer, which puts them at risk for under- or overnutrition [106]. Preterm infants' protein and calorie intakes can be improved and regulated with individualized fortification based on daily HM analysis, however it does require staff training and certain equipment [106]. The inclusion of HMF raises the osmolality of milk, and there have long been concerns regarding the possible association between the hyperosmolality of milk and the risk of NEC [107]. Nevertheless, no appreciable side effects associated with HMF use could be shown

by systematic reviews [32, 38]. Furthermore, a recent analysis has shown no proof of a connection between hyperosmolar feeding and the occurrence of intestinal damage or NEC in VLBW infants [108]. As a result, HMF should no longer be started early as is customarily reported because the advantages of HMF for VLBW infants clearly exceed any possible hazards [109].

By taking these special considerations and individualized approaches into account, healthcare professionals can help optimize the nutrition and long-term outcomes of VLBW infants during the transitional nutrition phase. [Table 3](#) provides some clinical recommendations for optimizing enteral feeding strategies in VLBW and ELBW infants.

Relationships between transitional phase nutrient intake and growth outcomes

For preterm newborns, ensuring sufficient development is an essential kind of treatment. Whereas it could take two weeks for term infants to acquire their birth weight again, for the tiniest preterm infants this could take much longer due to a large decline in percentiles during this time [85]. Growth standards are size-dependent, but generally speaking, following an initial loss, an average gain of 17-21 g/kg/day is recommended for VLBW [110] considering the evidence of frequent extrauterine growth restriction [8]. A guideline of more than 18 g/kg/day in weight gain and over 0.9 cm/week in head circumference growth for the tiniest newborns might be preferable, since this has been linked to better long-term health and neurodevelopmental outcomes [111]. The two included studies defined postnatal growth failure as EUGR (weight <10th percentile) [20] whereas the other research utilized growth velocity under 15 g/kg/day [23, 25]. Nonetheless, the concept of postnatal growth failure in preterm newborns remained unclear since the decrease in growth velocity was not the same as reaching a particular percentile.

For premature infants, EUGR continues to be a major problem. As mentioned earlier, over 50% of babies born in the US with VLBW are nevertheless released from the hospital when their weights drop to below the 10th percentile for their age group [8]. The greatest strategy to reduce extrauterine growth restriction after early PN initiation and early attainment of suitably fortified enteral feedings is to identify weight increase below target levels as soon as possible [85]. The first step towards optimizing overall nutrition and calories is to increase eating volume. Given that a recent Cochrane study found no advantage to fluid restriction for infants with early bronchopulmonary dysplasia, this is also conceivable for chronic infants [85, 112]. It can be necessary to raise the feeding calorie density if poor development continues on an appropriate volume. Preterm baby produce is accessible at up to 30 calories per ounce when given formula. Fortification of human milk above 24 calories per ounce, however, becomes more challenging. This is due to recommendations against using HMFs to increase caloric density beyond 24 calories/ounce [113, 114], against adding powders in the NICU to prevent cross-contamination [115], advice to keep enteral feedings' osmolality below 450 mOsm/kg of water [85], and the fact that adding other liquids dilutes the mother's milk's overall supply [85].

In previous research, 59 VLBW babies had significant macronutrient and energy deficits throughout the transition phase [22], while 115 VLBW newborns had falling protein consumption [21]. These results were consistent with Immelia et al.'s study,

which depicted a linear correlation between the duration of the TP and nutritional inadequacies [18].

Immeli et al. discovered that in VLBW infants, the duration of the transition phase correlated negatively with growth and postnatal macronutrient intake and a swift transition to complete enteral feeding may be advantageous for these newborns [18]. In this study, when comparing boys with an intermediate (8-12 days) or long (13-22 days) transition phase, those with a short phase (4-7 days) showed statistically significant less weight dropping and better head circumference development at term comparable age [18]. They also demonstrated that at 28 days of life, VLBW infants with a short TP had the largest cumulative intake of calories, protein, and fat ($p < 0.05$) [18]. According to a different study, preterm babies with insufficient weight growth velocity had reduced TP total energy and protein [20]. Liotto et al. suggested a seven-day weaning period. We propose increasing the enteral volume intake by 10 ml/kg/day during the first 4 days of TP and by 20 ml/kg/day for the final 3 days, while reducing the volume of PN, starting from 100 ml/kg/day of PN emulsion and 60 ml/kg/day of enteral nutrition. Target fortification of human milk is used to meet the enteral protein intakes, and it begins on the third day of the transition phase (with an enteral volume of 80 ml/kg/day) [20]. After meticulously reviewing and considering the recommendations from present guidelines, we propose the following transitional nutrition strategies for clinical practices as shown in [Table 4](#).

Conclusion

This review presents significant advancements in the understanding and management of the transitional phase from parenteral to enteral nutrition in very low birth weight infants. It emphasizes the critical need for individualized nutritional strategies, highlighting the importance of optimizing macronutrient intake during this vulnerable period to prevent postnatal growth deficits. It is crucial to acknowledge that the transition stages (PN, PN to EN transition, and complete EN) are not always linear for preterm newborns, especially VLBW infants, who may experience multiple cycles of these phases due to dietary intolerances or disorders. The research introduces a novel approach to progressive enteral feeding, which ensures adequate nutrient delivery while mitigating the risks of feeding intolerance and necrotizing enterocolitis. Furthermore, this review offers an innovative protocol for tailoring human milk fortification, starting at specific enteral volumes to meet protein and energy needs without inducing feeding intolerance. These findings offer new perspectives on improving neonatal outcomes, addressing existing gaps in clinical guidelines, and providing a framework for more effective nutritional interventions during this critical transitional phase.

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Conflict of interest

The authors declare no conflict of interest.

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