Literature Review

Nutritional Formula Selection in Pediatric High-Output Stoma with Acute Kidney Injury: A Review Article

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Abstract:

Background: High-output stoma (HOS) is a common complication in pediatric patients with ileostomy, often leading to dehydration, electrolyte imbalance, and malnutrition. These complications increase the risk of acute kidney injury (AKI), which is associated with high morbidity and mortality. Nutritional management in children with HOS and AKI is challenging, requiring careful formula selection to maintain adequate energy and protein intake, fluid and electrolyte balance, and optimize gastrointestinal tolerance.

Discussion: In children with HOS and AKI, the selection of an appropriate enteral formula represents a critical component of nutritional management, aiming to mitigate dehydration, electrolyte disturbances, and protein-energy malnutrition. Isotonic or mildly hypotonic solutions are preferred to minimize osmotic losses. Electrolyte composition must be adjusted to account for impaired renal handling in AKI. Semi-elemental formulas are generally recommended as first-line therapy due to their enhanced absorptive properties and relatively lower potassium and phosphate content compared with polymeric preparations. Transition to polymeric formulas may be considered once stoma output stabilizes and renal function improves. Elemental formulas are reserved for severe malabsorption, intolerance, or when strict electrolyte restriction is required. Continuous enteral infusion is preferred during the acute phase to reduce stoma output volume and nutrient loss, with a gradual transition to intermittent bolus feeding to promote intestinal adaptation and stimulate gut hormone.

Conclusion: Individualized nutritional management is essential in pediatric patients with HOS and AKI. Semi-elemental formulas, electrolyte adjustments based on renal function, and tailored feeding strategies help maintain fluid–electrolyte balance, prevent malnutrition, and support recovery and growth.

Keywords: acute kidney injury, formula, high-output stoma, nutrition, pediatric

Introduction

High-output stoma (HOS) is a common complication among pediatric patients with ileostomy, frequently resulting in dehydration, electrolyte disturbances, and malnutrition. Persistent fluid loss associated with HOS increases the risk of acute kidney injury (AKI), which is closely linked to higher morbidity and progression to chronic kidney disease (CKD).[1-3] Nutritional therapy plays a pivotal role in mitigating these complications; however, no standardized guideline currently exists for formula selection or dietary management in pediatric patients with both HOS and AKI. The osmolarity of enteral formulas directly influences stoma output, while electrolyte composition must be adjusted according to renal function. In patients with acute renal failure, protein intake also warrants particular attention, not only to meet energy and growth requirements, but also to accommodate the kidney's reduced capacity to metabolise nitrogenous waste products derived from protein. Despite its clinical importance, this aspect has been insufficiently addressed in previous literature.

Furthermore, energy and protein requirements must be met while considering the absorptive capacity of the gastrointestinal tract. Appropriate formula selection is therefore crucial to maintaining fluid–electrolyte balance, supporting intestinal adaptation, and meeting the needs of growth and development.[4-6] This narrative review aims to discuss evidence-based strategies for nutritional management and formula selection in pediatric patients with HOS and AKI to support rational, safe, and effective therapy.

Methods

This narrative review examined literature published between 2015 and 2025 concerning the nutritional management of pediatric patients with high-output stoma (HOS) and acute kidney injury (AKI). Relevant studies were identified through comprehensive searches of PubMed and Google Scholar, supplemented by targeted Google searches to capture additional gray literature. Search keywords included pediatrics, high-output stoma, ileostomy, acute kidney injury, nutritional medical therapy, and feeding strategies.

Studies were included if they met the following criteria: (1) published in peer-reviewed journals between 2015 and 2025; (2) written in English; (3) involved pediatric patients (<18 years) diagnosed with HOS, AKI, or both; and (4) discussed nutritional management, formula composition, or feeding strategies. Given the limited number of studies focusing exclusively on ileostomy, articles addressing nutritional management across all stoma types, including jejunostomy, ileostomy, and colostomy, were also included, provided that relevant information could be applied to HOS management.

Exclusion criteria included studies involving only adult populations, animal or in vitro models, conference abstracts without full text, and papers unrelated to nutrition or feeding management. Given the scarcity of randomized controlled trials and the heterogeneity of the available evidence, a narrative review design was selected to allow a comprehensive synthesis of current knowledge. All eligible articles were reviewed in full, and findings were thematically organized into three main domains: (1) nutritional management in children with ileostomy and HOS, (2) nutritional management in children with AKI, and (3) considerations for formula selection in patients presenting with both conditions.

Children with High-Output Ileostomy

Ileostomy is a surgical procedure in which a portion of the small intestine (ileum) is brought to the surface of the skin, creating an opening on the anterior abdominal wall. In the pediatric population, this procedure is most performed for congenital conditions such as intestinal atresia, intussusception, and Hirschsprung's disease.[7] In a study by Massenga et al., the most frequent indications for intestinal stoma in children were anorectal malformations (89.4%) and Hirschsprung's disease (9.8%).[8]

Following postoperative recovery, ileostomy output generally follows the normal pattern of intestinal fluid transport. Over the course of several days to weeks, the output volume typically decreases through a process known as intestinal adaptation. This adaptation occurs through a combination of hormonal, luminal, and mechanical stimuli, leading to structural changes in the intestinal mucosa. Mucosal hypertrophy and hyperplasia are frequently observed as part of this adaptive process.[3]

High-output stoma (HOS) represents one of the most frequent complications in pediatric patients with enterostomy, with an estimated incidence of approximately 6%.[3] High-output ileostomy (HOI) may present as a transient phenomenon prior to the completion of intestinal adaptation or may be precipitated by intercurrent conditions such as infection. A universally accepted definition of HOI in children has not been established, and threshold criteria remain heterogeneous across studies. Vriesman et al. defined HOI as a stoma output exceeding 20 mL/kg/day in infants or >2 L/day in older children. Van Zoonen et al. applied a cutoff of >50 mL/kg/day, whereas Wessel et al. proposed >40 mL/kg/day as a diagnostic criterion.[2, 5, 9, 10]

The acute phase of HOS generally refers to the early postoperative period, typically within the first few weeks after stoma creation, when output is excessively high due to mucosal inflammation, edema, and incomplete intestinal adaptation. During this phase, aggressive fluid and electrolyte management is prioritized, while nutritional therapy is carefully initiated. As intestinal adaptation progresses and stoma output decreases, patients enter the stabilization phase, in which formula composition and nutrient density can be gradually optimized to support long-term growth and recovery.[2, 5, 9, 10]

Excessive stoma output is associated with dehydration, electrolyte imbalances, and malnutrition, and therefore necessitates prompt and comprehensive management. Tight regulation of enteral fluid intake is essential. Both hypo-osmolar and hyperosmolar solutions should be avoided, as they may exacerbate stoma losses. Hypotonic fluids with osmolarity <200 mmol/L (e.g., plain water, sugar-free beverages) promote sodium efflux into the intestinal lumen, increasing stomal sodium loss and output volume. This further stimulates thirst and perpetuates a deleterious cycle of fluid loss and worsening dehydration.[5, 6]

Similarly, hyperosmolar solutions such as fruit juices induce luminal fluid shifts into the duodenum and jejunum, further augmenting stoma output. Optimal fluid absorption is achieved with isotonic (270–290 mmol/L) or mildly hypotonic (240–250 mmol/L) oral solutions containing both glucose and electrolytes to maximize sodium-coupled transport. During the acute phase of HOI, intravenous fluid therapy is frequently required to achieve hemodynamic stabilization.[5, 6]

At present, there are no evidence-based guidelines specifically addressing the nutritional management of infants or children with ileostomy. Existing recommendations are largely based on expert opinion and clinical experience rather than robust clinical trials. Breast milk remains the preferred source of nutrition for infants aged 0–6 months, and several studies have suggested that breastfeeding is associated with a shorter duration of parenteral nutrition in neonates with short bowel syndrome. For infants in whom breastfeeding is not feasible, extensively hydrolysed or amino acid–based formulas are commonly recommended. Amino acid–based formulas have demonstrated clinical benefit in children with short bowel syndrome, while extensively hydrolysed formulas may be advantageous in those with persistent feeding intolerance. Nevertheless, comparative evidence between standard polymeric, extensively hydrolysed, and amino acid–based formulas remain scarce.[6, 11]

Insoluble fiber should be avoided in patients with an ileostomy, as it may increase stoma output by 20–25%. In contrast, soluble fiber improves stool consistency and slows intestinal transit. Partially hydrolyzed guar gum has been shown to reduce stoma output and improve stool form in both adults and children with short bowel syndrome when given at 2–6 g per meal.[6, 12]

Children with Acute Kidney Injury

Acute kidney injury (AKI) occurs in approximately 1–25% of intensive care unit patients and 1–7% of all hospitalized patients. Even mild AKI increases the risk of hypertension and progression to CKD. Management is primarily supportive, emphasizing hemodynamic stability, fluid balance, electrolyte correction, and acid-base homeostasis. No targeted pharmacologic therapy currently exists. Initial steps include clinical assessment and individualized fluid therapy guided by volume status, with close monitoring of urine output and fluid balance. Electrolyte management is critical—potassium and phosphate restriction is necessary in oligouria or anuria, as hyperkalemia poses a life-threatening risk for arrhythmia. Sodium intake should be limited to 2–3 mEq/kg/day to prevent fluid overload and hypertension.[13, 14]

Nutritional disturbances are common in pediatric patients with AKI, arising from reduced intake, malabsorption, increased nutrient losses, hypermetabolism, and altered nutrient utilization. In the acute phase, management focuses on maintaining fluid balance and optimizing electrolyte and mineral levels, while post-stabilization goals include supporting metabolic recovery, preventing muscle loss, and promoting functional rehabilitation. Adequate energy provision from protein, carbohydrates, and fat is critical but challenging due to risks of under- or overfeeding; indirect calorimetry is the gold standard, with predictive equations such as the Schofield formula as alternatives. Critically ill children or those on continuous kidney replacement therapy (CKRT) may require 120–130% of calculated energy needs.[4, 14, 15]

Children have higher protein requirements due to growth and development. AKI and advanced CKD increase catabolism and negative nitrogen balance, necessitating sufficient protein to preserve muscle mass, support tissue repair, and improve outcomes. Protein intake of 1–1.5 g/kg/day is recommended for non-dialyzed AKI, increasing to 1.5–3 g/kg/day during CKRT to offset amino acid losses. Polymeric formulas are preferred, with semi-elemental options reserved for gastrointestinal dysfunction or malabsorption.[4, 15]

Electrolyte disturbances are common in pediatric AKI and CKD. In the absence of pediatric-specific guidelines, daily reference intakes for healthy children can guide initial management, with adjustments for fluid losses, urine output, and dialysis modality **(Table 1).**[4] Hyperkalemia, due to impaired renal excretion, often requires dietary potassium restriction, while replacement may be needed in cases of gastrointestinal loss. Hyperphosphatemia is frequent, and dietary phosphate restriction is recommended, especially in CKD stages 4–5. Sodium intake should be individualized, with fluid restriction for dilutional hyponatremia; most non-dialyzed AKI patients require both sodium and fluid limitation until renal function improves.[4, 14, 16]

Table.1 Electrolyte Requirements in Healthy Children and AKI[4]

Electrolyte	Healthy children			Children with AKI		
	ASPEN		ESPEN	AKI without KRT	PD	CKRT
	Infant/ children	Teenager and children >50 kg	0 – 18 years			
Natrium (mEq/kg/day)	2–5	1–2	1–3	↓	↓	↓
Potassium (mEq/kg/day)	2–5	1–2	1–3	↓	=	↑
Phosphate (mMol/kg/day)	0,5–2	10–40 mmol/day	0–6 months: 0,7– 1,3 7–12 months: 0,5 1–18 months 0,2–0,7	↓	=↓	↑
Magnesium (mMol/kg/day)	0,15–0,25	5–15 mmol/day	0–6 months: 0,1–0,2 7–12 months: 0,15 1–18 months 0,1	=	=	↑

ASPEN: American Society for Parenteral and Enteral Nutrition; ESPEN: European Society for Clinical Nutrition and Metabolism; AKI: acute kidney injury; KRT: kidney replacement therapy; PD: peritoneal dialysis; CKRT: continuous kidney replacement therapy

Nutritional Formula Selection for Children with HOS and AKI

In patients with HOS and AKI, prompt rehydration with sodium-rich fluids (100–150 mmol/L) is critical to prevent progression to CKD. Oral fasting may be used temporarily to reduce stoma output, and dialysis is generally avoided to prevent further fluid loss. After renal function stabilizes, management focuses on reducing stoma output, tapering intravenous fluids, and following short bowel syndrome principles when no underlying cause is identified.[5, 6]

A wide spectrum of pediatric formulas is available, each differing in energy density, protein quality, and electrolyte composition, which necessitates careful selection in children with HOS and AKI **(Table 2 and Table 3).** Polymeric formulas are generally suitable for patients with preserved gastrointestinal function, as they provide complete macronutrient and micronutrient profiles with moderate osmolarity.[17] However, these formulas typically contain relatively high concentrations of potassium and phosphate.

In patients with AKI accompanied by electrolyte imbalance, potassium and phosphate intake should be carefully adjusted to avoid hyperkalemia and hyperphosphatemia.[4]

Tabel 2. Comparison of Formula Types for Children with High-Output Stoma (HOS) and Acute Kidney Injury (AKI)[6, 17, 18]

Formula Type	Examples (Available in Indonesia)	Protein Source Content	Osmolarity	Electrolyte Content (K, P)	Advantages	Dis-advantages	Recommen-ded Use
Polymeric	Pediasure Complete®, Nutren Junior®, Nutrinidrink®	Intact whole protein	Moderate	Relatively high	Complete nutrition; well-tolerated if gut function intact; moderate osmolality	Risk of hyperkalemia or hyperphosphatemia in AKI/CKD; Nutrinidrink® has higher osmolality, may increase stoma output	Stable HOS with adequate gut function; no significant electrolyte imbalance
Semi-elemental	Peptamen Junior®	Hydrolyzed peptides (easily absorbed)	Moderate	Lower than polymeric	Easier digestion and absorption; supports mucosal integrity; contains soluble fiber that improves stool consistency	Slightly higher cost; limited availability in some settings	First-line choice in active HOS, malabsorption, or feeding intolerance
Elemental	Neocate LCP®, Neocate Junior®, Elecare® Infant	Free amino acids	High	Lowest among all formulas	Suitable for strict electrolyte control; hypoallergenic; best for severe malabsorption	Very high osmolarity (may worsen stoma output); risk of osmotic diarrhea; expensive	Severe intolerance, multiple food allergies, or refractory malabsorption unresponsive to other formulas

When malabsorption or feeding intolerance is present, semi-elemental formulas should be considered as the first-line option.[17] Semi-elemental formulas contain hydrolyzed protein peptides and have a moderate osmolarity, which facilitates digestion and absorption while minimizing the risk of osmotic diarrhea. Moreover, the presence of soluble fiber, such as partially hydrolysed guar gum, supports intestinal mucosal health, modulates gut microbiota, and improves stool consistency without significantly increasing stoma output. These properties make semi-elemental formulas particularly advantageous in children with active HOS or those with impaired intestinal adaptation.[5, 6]

Tabel 3. Comparison of Nutritional Composition of Formula (per 100 mL)

Formula	Energy (kcal)	Protein (g)	Lipid (g)	Carbo-hydrate (g)	Fiber (g)	Natrium (mEq)	Potassium (mEq)	Phosphate (mMol)
Pediasure Complete®[19]	100	4,0	3,3	14,0	0,7	1,65	4,9	1,12
Nutren Junior®[20]	100	3,1	4,3	12,0	1,1	1,65	3,85	0,95
Nutrinidrink ®[21]	150	3,3	6,8	18,8	0	2,91	3,59	0,79
Peptamen Junior®[22]	100	3,0	3,3	14,7	0,6	2,96	2,74	0,52
Neocate LCP®[23]	66	1,83	3,3	7,3	0	1,26	1,87	0,53
Neocate Junior®[24]	100	3,4	4,6	11,3	0,4	2,65	2,95	0,79
Elecare®[25]	68	2	3,2	7,3	0	1,3	2,59	0,6

Elemental formulas consist of free amino acids as their primary protein source. Compared with other formulas, they provide lower amounts of energy, protein, and electrolytes. Their reduced electrolyte content may be advantageous for children with AKI who require strict electrolyte control, such as those with hyperkalemia or hyperphosphatemia.[26] However, elemental formulas have a relatively high osmolarity, which may increase stoma output. Therefore, their use should be limited to cases with severe gastrointestinal intolerance or when other formula types are not tolerated.[5, 26]

Nutritional management of children with HOS and AKI should be individualized, targeting fluid–electrolyte homeostasis and sufficient energy–protein intake to prevent catabolism and support growth. Semi-elemental formulas are preferred during the active phase because of their enhanced absorption, moderate osmolarity, and relatively lower potassium and phosphate content compared with polymeric formulas—an important consideration in AKI, where restriction of these electrolytes is often required. Once output stabilizes and gastrointestinal function improves, polymeric formulas can be gradually reintroduced to support intestinal adaptation, while elemental formulas should be reserved for severe malabsorption or intolerance due to their high osmolarity and risk of exacerbating fluid losses.

Feeding Technique Considerations in Children with HOS and AKI

The mode of formula delivery is a critical determinant of nutritional outcomes in children with HOS and AKI. Two principal strategies are employed, such as intermittent bolus feeding and continuous enteral feeding, each with specific physiological implications.[18]

Intermittent bolus feeding most closely mimics normal feeding physiology, promoting cyclical gut hormone secretion and exerting a trophic effect on the intestinal mucosa; however, large bolus volumes may aggravate stoma output and are often poorly tolerated in the presence of vomiting or abdominal distension. In contrast, Continuous enteral feeding has been shown to reduce stool losses by approximately 31–62% and support weight gain in infants with chronic diarrhea or short bowel syndrome. Nevertheless, this method may decrease intestinal motility, predispose to small bowel bacterial overgrowth, and limit patient mobility due to the need for constant tube connection.[6, 18]

Given these factors, continuous feeding is generally preferred during the early phase of HOS or when stoma output is very high, as it minimizes fluid and energy losses. Transition to intermittent bolus feeding should be considered once stoma output becomes more controlled to promote long-term intestinal adaptation and improve patient quality of life.[6, 18]

Conclusion

Nutritional management of pediatric patients with high-output stoma (HOS) and acute kidney injury (AKI) requires an individualized and integrated approach. Formula selection should balance the need to reduce stoma output with careful electrolyte and protein control according to renal function. Semi-elemental formulas are preferred during the acute phase, while polymeric formulas may be introduced once output and renal parameters stabilize. Continuous feeding limits losses during high-output phases, while intermittent bolus promotes intestinal adaptation. Close monitoring of hydration, electrolytes, and nutritional status is essential to ensure safe, effective, and growth-supportive therapy.

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Conflict of Interest

None declared.

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