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The Role of G-tube Placement for Neurologic Injury Patients

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Abstract

Neurologic injury often influences various bodily functions associated with digestion. It is imperative for an individual to obtain proper nutrients to maintain a healthy lifestyle and recover from injury. In this review, we explore variables and methods of enteral tube placement in neurologic injury patients influencing recovery, specifically G- and J-tubes. We will first review the patient population by identifying leading causes for enteral tube placement among both pediatric and adult neurologic patients. We will then discuss the general procedures for placement and safety considerations for specified patient populations. We will explore interventions limiting placement of the G- and J-tubes by focusing on two interventions: ventriculoperitoneal shunt (VPS) and intrathecal baclofen (ITB). Then, we will highlight nutritional enhancers that may influence general treatment. Finally, we discuss proper weaning procedures and eJective methods fitting patient needs.

Keywords

G-tube; J-tube; Enteral Tube; Neurologic Injury; Nutritional Support; Enteral Tube Interventions; Enteral Tube Weaning

Introduction

Neurologic injury can provoke a cascade of bodily reactions leading to symptoms damaging a patient's ability to carry out necessary functions for recovery such as proper intake of nutrients. Neuroinflammation, free radical generation, excitotoxicity, and increased oxidative stress occur as a result of neurologic injury. These changes cause the body to enter a hypercatabolic state in attempts to repair neuronal damage [1]. Such events induce pathological changes downstream in adjacent tissues and related organs

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systems that increase morbidity and mortality rates [1]. Dysphagia, a broad term used to describe a variety of impairments that compromise swallowing function, commonly occurs following neurologic injury [2]. Decreased absorption of nutrients may lead to malnutrition and suboptimal recovery. A gastrostomy tube (G-tube) or jejunostomy tube (J-tube) is often placed during treatment to allow for patient intake of necessary nutrients and to reach caloric requirements [3, 4]. Early enteral feeding has resulted in positive effects on reducing infection complications stemming from the gut [5]. The close association between neurologic injury and enteral tube placement highlights the importance of understanding patient demographics, general procedure for placement and weaning, candidate requirements, interventions complicating placement, administration methods and the consumed diet solution itself. This review aims to examine the role of G- and J-tube feeding in neurologic patients.

Patient Population

Neurologic patient demographics requiring alternative feeding devices largely consist of children and older adults. These devices are implemented through post-injury, post-procedure, and diseases.

G-tube placement is one of the most common procedures performed in pediatric patients [6]. A 2021 study by Jackson et. al reported neurological indications to be the leading cause for G-tube placement among their sample (n=142) [7]. Pediatric patients that require G-tubes typically have neuromuscular disorders associated with swallowing difficulties [8]. This patient population has been found to have congenital myopathies, spinal muscular atrophy, and duchenne muscular dystrophy [8]. Eternal tube devices are often placed to minimize the risk of aspiration pneumonia putting patients at risk of death. Cerebral palsy, central nervous system degeneration, brain and spinal cord malformations, epilepsy, among other diseases affecting the central nervous system can lead to swallowing and eating reflex impairments (Figure 1) [9]. Patient population may be further grouped into short- and long-term placement. The leading cause for short term G-tube placement in pediatric patients are traumatic brain injuries (TBI) which result in damage due to lack of oxygen in neonates or during episodes of cardiac arrest [7]. Long term placement of G-tubes increases the risk of gastrocutaneous fistulas [7]. It is important to consider the consequences of placement and duration of treatment especially among pediatric patients. While reported survival rates of the mentioned studies cannot be solely attributed to effects of G-tube placement, it is important to consider that they may have played a role in declining survival rates [7, 10]. Further research is required to understand how the placement of G-tubes affects hospitalizations. While there is minimal reported evidence that the placement of G-tubes leads to more hospitalization in younger children, more data is needed to determine if rates of hospitalizations have decreased post G-tube placement or if they remained the same [9, 10].

In adult neurological injury patients, G-tubes are an important modality in the treatment of neurodegenerative diseases, cancer, stroke, and TBI. J-tubes have also been used in medicine administration to these patients as a method of improving quality of life [11]. Similar to pediatric populations, the most prevalent reason for placement of a J-tube is for disorders of the central nervous system [11]. In patients with dementia and Parkinson's disease, the indication for G- or J-tube placements depends on life expectancy and availability of correct monitoring [11]. Note that TBI has been associated with an increased incidence of Parkinson's disease [12]. Further conditions necessitating G-tube placement influence mental health and dysphagia [13]. Dysphagia is a common complication post-stroke and often requires the placement of a G-tube to provide adequate nutrition [14]. A 2016 systematic review by Takizawa reported a 8.1–80% prevalence of dysphagia in stroke patients and 27–30 % in TBI patients based on the analysis of thirty-three studies [15]. Larger ischemic strokes frequently have hemorrhagic conversion and subsequent disability increasing the likelihood of tube placement; stroke severity may be determined by the NIH Stroke Scale [16, 17]. TBI is another leading cause for J-tube placement among adults. Patients recovering from neurologic injury due to TBI require certain nutrients such as nitrogen in their diet. J-tube placement has been shown to reduce nitrogen loss and promote healing in patients [5].

General Procedure

Laparoscopic or Endoscopic procedures have been long preferred due to their less invasive nature, and quicker recovery [18]. Insertion of the G-tube is often performed similarly to that of a J-tube as the patient is in the same position, however the site of the G-tube is more medial and superior. This technique utilizes a foley catheter and balloon to insert the G-tube [18].

In pediatric patients, G-tubes are often placed under radiographic guidance without general anesthesia. This method is safe and has shown positive results in patient weight maintenance [19]. In infants, G-tubes may be inserted endoscopically or laparoscopically; although the former is associated with an increased need for second procedures [20].

The open Stamm gastrostomy technique involves accessing the stomach via the skin and using a purse-string suture to attach the gastric wall to the abdominal wall. While this method was originally intended to reduce complications by providing more security to the structure, it had led to an increase in complications among pediatric patients and is associated with tube dislodgement along with other complications requiring additional surgeries [21].

New approaches involving operational positioning of monitors utilizes technology and imaging computers to relieve the surgeon from looking over their shoulder to view the monitor and perform the camera guided procedure for placing the G- or J-tube: optical correctness [18]. These techniques are different to percutaneous endoscopic placement as they require the patient to be under general anesthesia, not conscious sedation and local anesthesia.

Although standard G-tube placement is considered low-risk, patients should be mindful of potential complications and long-term effects. A 2019 population-based exposure-crossover study by Nelson et. al examined G-tubes among children five years following placement and reported a decrease in survival rate from 100 to 75 percent based on the Kaplan-Meir survival curve when comparing the time of placement to five years post [9]. While these results may be attributed to external factors beyond the scope of this review such as the condition of the child, it is important to understand these potential risks.

Interventions Limiting the Placement of These Tubes

The placement of a G-tube or J-tube may not always be achievable due to various interventions and external factors limiting space, restricting procedure position, or increased risk to the patient. Ventriculoperitoneal shunts and intrathecal pumps are implantable neurosurgical devices that affect the placement of a G-tube.

Ventriculoperitoneal Shunt

A ventriculoperitoneal shunt (VPS) is a common neurological intervention used to treat hydrocephalus [22]. A VPS consists of a catheter connected to a valve and a distal catheter which drains cerebrospinal fluid to the peritoneal cavity [23]. It is common for VPS patients to require G-tubes for nutritional support, but complications may arise when the VPS catheter has already been implanted into the peritoneal cavity or from simultaneous placement. [24, 25]. Placing a G-tube following a VPS increases the risk of infection and shunt malfunction [25]. Due to the increased risk of ascending meningitis, the presence of a VPS is a relative contraindication to gastrostomy placement [26]. However, there are no neurosurgical guidelines on the matter and controversy still surrounds whether the concurrent procedures are contraindicated [24, 26, 27].

Early reports advise against the combination. An early 2001 study by Taylor et al. reported poor outcomes from combining G-tubes with VPS. The study looked at sixteen permanent cerebrospinal fluid (CSF) diversion procedures performed on thirteen patients, with half being prior to percutaneous endoscopic gastrostomy (PEG) placement. Findings showed that eight of the sixteen procedures (50%) required VPS revision for infection in the presence of PEG. It was concluded that simultaneous PEG and VPS placement should be avoided in the acute phase of the patient’s hospital admission [28]. It is important to note the small sample size in this study when considering the results.

Alternatively, recent studies deem the relationship between G-tube placement and VPS to be insignificant.

A 2009 study conducted by Kim et al. performed a retrospective analysis of fifty-five PEG tube patients (seven with pre-existing VPS and forty-eight without VPS) and found no difference in complication rates between the two groups. [25]. Further studies have acknowledged the existence of the negative effects of a VPS and G-tube combination but concluded that the risk was acceptable. A 2015 systematic review by Oterdoom et al. on multiple studies involving VPS and G-tube placement found VPS infections in 12.5% of cases and VPS malfunction in 4.4%. Overall, they concluded that the rate of VPS complications in patients with pre-existing VPS receiving a PEG tube was high but acceptable and that VPS insertion should not be classified as a contraindication for PEG tube placement [27]. To overcome the acknowledged risks associated with a VPS and concurrent PEG tube placement, a waiting period has been suggested. A 2019 retrospective review concluded that a one-month period between VPS placement and G-tube placement was safe in adult patients with an excellent prognosis [29]. This review examined thirty-one patients and found only a single case of VPS infection (a rate of 3.2%). They reported no statistically significant difference in infection rates compared to patients who received a VPS without a G-tube (p=0.57) or in survival rates of patients with cerebrovascular disease who underwent a G-tube placement without a VPS [29]. The waiting period recommendation of one month had been found amongst other analyses. A 2016 retrospective review by Nabika et al analyzed the risk factors for infection in the placement of a PEG and VPS. The review included twelve patients who underwent VPS following PEG and eleven patients who underwent PEG after VPS. Of this sample, four patients experienced shunt infection, three of which (75%) required shunt revision. Majority of these patients (three of the four) had received VPS following PEG with a time interval shortened by eighteen, nineteen, and twenty-five compared to the mean waiting period of 29.3 days. Therefore, a waiting period of at least one month between procedures is recommended [30]. With this, separate sources reported different conclusions regarding procedure waiting times. A 2022 retrospective study by Hallan and Rizk analyzed the rate of infection among 4,269 patients with a VPS and G-tubes in a retrospective database. The study reported no significant difference in infection or revision rates between the same-day G-tube and VPS placement when compared to placement within one to ten days, eleven to thirty days, or greater than one month [24].

The order in which the two interventions (VPS and G-tube) are placed does not appear to influence the risk of adverse outcomes. A 2007 study by Roeder et. al looked at shunt infection and survival and found shunt infection to occur in seven of the fifty-five patients included (12.5%). They found no difference in risk of ventriculoperitoneal infection based on the order of placement and were unable to identify predictors of patient survival [31]. They concluded that placement of G-tubes in patients with shunts is safe and the order of placement does not affect the incidence of shunt infection or survival [31].

Intrathecal Pump

Intrathecal pumps are small battery powered pumps that are connected to a catheter to deliver medication directly to the intrathecal space [32]. Various medications are administered through intrathecal pumps including, but not limited to, opioids, local anesthetics, adrenergic agonists, and N-methyl-D-aspartate receptor agonists [32]. Another medication which may be continuously infused by these pumps is Baclofen, a derivative of gamma-aminobutyric acid (GABA) [33]. Baclofen has proven effective in controlling spasticity following spinal cord injuries or due to cerebral palsy [34]. The intrathecal pump is placed under the subcutaneous tissue of the abdomen [32]. It may be reasonable to question whether the close proximity of the intrathecal pump to the abominable contents increased infections when combined with a PEG. There are limited sources examining this topic and the findings are conflicting. A study by Fjestad et al. found an increase in cases of infection amongst the patients that received intrathecal baclofen (ITB) pumps (n=163, chi-square 7.06, p=0.0080 [35]. Furthermore, a 2016 review by Bayhan et al. analyzed pediatric patients with cerebral palsy and spasticity (n=294). Of this sample, forty-four had pre-existing G-tubes and were managed with ITB pumps. There was a statistically significant number of patients who developed an infection following ITB pump placement

(25%) ($p<0.05$) [36]. Conversely, a 2016 study by. Spader et al. conducted a retrospective review of pediatric patients who underwent ITB pump insertion (n=254) to identify risk factors for infection. The overall infection rate was 9.8%. However, it was also reported that the presence of a G-tube was not associated with increased infection rates and was not considered a contraindication for ITB pump implantation [37]. Later studies supported the claim of increased infection independent of G-tubes. A 2018 analysis by Desai et al. attempted to reduce pediatric baclofen pump infections through the introduction of a quality improvement protocol. Their study reported comorbidities, including the 100 of 128 included patients having a prior history of G-tubes. There was no reported significant association between G-tube placement and adverse ITB pump placement outcome [38].

Note the majority of studies examined outcomes of ITB pump placement in patients with a pre-existing G-tube, but not the reciprocal order. This is likely due to discrepancy in timing of patient needs. Nutritional support is often identified early and requires immediate intervention compared to ITB pumps which are typically considered following the failure of medication and therapies to control symptoms. However, a case report by Yoon et al. did describe outcomes of patients receiving a PEG tube with pre-existing ITB pumps. There was no report of any adverse outcomes [34]. Further studies examining the effects of the order at which ITB pump and G-tube placement may be warranted.

Emerging Nutritional Enhancers

It is important to continue to improve treatment for patients with conditions requiring an unidentified specialized feeding or to improve the efficacy of treatment. Neurological injury patients may be left with impairments warranting the placement of a G-tube such as dysphagia, a common symptom of neurotrauma. Dysphagia poses a risk of malnutrition and dehydration as the body is unable to intake essential nutrients required for recovery [2, 39]. Additional risks following neurologic injury include the loosening of enteric tight junctions, disruption of enteric microbiota, and dysregulation of digestive secretions which compromise the physiology of the intestines. This can result in further malnourishment which puts patients at risk for mortality rates, decreased home discharge rates, and poor functional outcomes [1, 2, 39, 40]. Inadequate nutritional intake during the initial healing phase may also result in bacterial translocation which increases the risk for systemic infection and multiple organ failure [1]. To preserve the unique microenvironment and provide nutrient absorption, patients are often administered nutrients through an enteral tube following neurologic injury [1]. However, some patients suffer from adverse reactions and effects to enteral feeding modalities which impair nutrient absorption including nausea, vomiting, and diarrhea [41, 42].

The vital role nutrition plays in the recovery of neurological injury patients, especially those suffering from dysphagia among other modalities that impair nutritional absorption, emphasizes the importance of the development and utilization of novel nutritional enhancers to control detrimental metabolic response to malnutrition. Note that there are limited sources reporting the emerging nutritional enhancers for G- and J-tubes in neurologic injury patients. However, a variety of nutritional enhancers have been administered through alternative enteral feeding routes which may be used similarly in a G-tube.

Immune-enhancing nutritional (IEN) solutions containing glutamine, arginine, omega-3 fatty acid, probiotic, symbiotic and nucleotide additives work to promote the recovery of damaged brain tissue while preserving adjacent regions (Figure 2) [43, 44]. The macronutrients included in IEN solutions such as protein have been shown to reduce mortality rate and improve patient outcomes. A 2022 retrospective analysis including twenty-one stroke patients reported a significant increase in total energy, muscle mass, and muscle quality in patients receiving high quantities of proteins through enteral tubes [45]. This can be attributed to the loss of protein associated with the elevated levels of urinary urea nitrogen following neurologic injury [46]. This further highlights the importance of nitrogen supplementation following neurologic injury to ensure adequate levels of dietary protein [46]. In clinical practice, enteral diets may be generally organized into two formulas: oligomeric or polymeric depending on the nitrogen source [47]. Oligomeric formulas derive their nitrogen primarily from amino acids or peptides. Polymeric formulas derive their nitrogen primarily from proteins [46, 47]. Oligomeric formulas are generally considered superior to polymeric formulas due to the oligomeric formula's ability to absorb more efficiently and reduce the prevalence of malnutrition and diarrhea in neurologic injury patients [47].

Protein supplementation can be maximized when amino acids are specific to the needs of the patient. Specific supplementing with leucine-enriched amino acids triggers post-prandial muscle protein synthesis through the mammalian target of rapamycin (mTOR) pathway which was shown to be beneficial for stroke patients with sarcopenia [48].

Dietary supplements should be considered when reviewing modern nutritional enhancers. Curcumine, a compound in turmeric, has been reported to improve motor and learning performance in TBI-induced rodents (Figure 2) [49]. Each with its own benefit for neurologic injury recovery resveratrol, lipoic acid, and sulforaphane have also been reported to assist in recovery (Figure 2) [49].

Researchers have also turned to marine organisms to derive supplements for use in rodent models. Sea algae contains anti-inflammatory antioxidants, and anti-amyloidogenic metabolites which reduce neurotoxicity and free radical production (figure 2) [48]. Further reports of fucoxanthin in brown seaweed reducing stroke volume and neurologic deficits through the activation of cAMP-dependent protein kinase and Nrf2/HO-1 pathways [48]. Activation of these pathways allows fucoxanthin to promote cell survival through the inhibition of hydrogen peroxide-induced DNA damage [48]. Efficacy of supplements derived from marine organisms is promising for various future therapies.

Despite many models regarding these supplements pertaining to rodent models, murine success suggests the potential of these methods being applicable to humans. An active pilot study utilizing trehalose supplementation for TBI therapy has already begun to demonstrate this possibility. Trehalose, a natural non-reducing disaccharide, has been established to regulate cellular autophagy and inhibit inflammation in response to endotoxic shock following neurologic injury [50]. Though ongoing, this study aims to determine the effect of trehalose on inflammatory cytokine and oxidative factors levels in critically ill TBI patients [50].

Other macronutrients including lipid and carbohydrate regulation have also been implicated in neurologic repair. Fatty acids, especially omega-3, were reported to reduce inflammation and oxidative stress when incorporated into enteral tubes [1]. The ketogenic diet (KD) containing high amounts of medium-chain triglycerides and low carbohydrates has been reported to reduce cerebral edema and apoptosis while improving cerebral metabolism, blood flow, and behavioral outcomes in a 2017 rodent model (Figure 2) [1]. Recent human trials found the KD to be effective for the treatment of seizures and status epilepticus when administered enterally [1, 43]. A 2019 review by Kim et. al reported the benefits from a high fat KD based formula for seizure patients who are unresponsive to treatment [51]. This is promising for the potential of a KD based therapy for a variety of neurologic injuries.

The role of micronutrients in enteral feeding modalities may also be significant to treat neurologic injury [52]. Following TBI, zinc concentrations in the body are diminished which results in an increase in levels of oxidative stress and neuroinflammation [43]. Although zinc supplementation has the potential to be used as a post-TBI therapy, case reports and clinical trials remain scarce [43]. Alternatively, there have been various human and animal studies demonstrating the efficacy of magnesium supplementation for TBI [43]. This efficacy may be attributed to its ability to inhibit glutamate activity which allows it to improve cerebral blood flow, reduce vasospasm, delay cerebral ischemia, and prevent secondary infarctions following subarachnoid hemorrhage [1, 43].

Other micronutrients such as antioxidant vitamins including vitamin C, D, and We have been shown to Reduce free radical production and vascular endothelial damage following neurologic injury. Vitamin E was found to improve cognition in mouse models of TBI [53]. These results may be applicable to humans as vitamin E supplementation following TBI improved scores on the Glascow Coma Scale and mortality rates [1]. High doses of vitamin C following TBI have also displayed benefits in stabilizing perilesional edema [1]. Vitamin D supplementation following ischemic stroke have also contributed to the improvement of motor functions and ambulation in ischemic stroke patients [1, 54]. Vitamin D in combination with other micronutrients or hormones improved recovery, activity, and protection. Vitamin D supplementation with calcium resulted in improved Rankin scores in stroke patients and in combination with progesterone, vitamin D displayed neuroprotective implications for TBI patients [43]. These neuroprotective functions include regulation of excitotoxicity, apoptosis, and facilitation of myelin repair [43].

Intermediates of biochemical processes including lactate and succinate supplementation were also found to be beneficial in TBI recovery (Figure 2) [43]. Lactate, a byproduct of anaerobic metabolism, has been used as a neuronal energy substrate and signaling enhancer following TBI [43]. While succinate, an intermediate in the citric acid cycle, interacts directly with the electron transport chain to improve energy metabolism in TBI patients with mitochondrial dysfunction [43].

The adverse gastrointestinal symptoms that may arise from nutritional delivery through enteral feeding tubes highlight the importance of the gut-brain axis in neuronal repair [40]. The gut-brain axis consists of the hypothalamic–pituitary–adrenal axis, vagus nerve, and gut microbiota which allows for extensive communication between the central and enteric nervous systems. Gut microbiota function to stimulate the innate immune system, strengthen and protect the intestinal barrier, and assist with nutrient absorption in healthy individuals [40]. Though, following neurologic injury, the bidirectional pathway is significantly dysregulated. This may be observed in stroke patients who may experience a decrease in short-chain fatty acid producing bacteria which helps to heal neurologic injuries [40]. Bacteria observed to be at risk include Blautia, Faecalibacterium, Lachnospira, Roseburia, Dialister, Akkermansia, and Prevotella [40]. Reduction in bacteria such as Lachnospiraceae, Mogibacteriaceae, and Ruminococcaceae following TBI has been linked to increased neuroinflammation [55]. Note that the standard enteral diet often lacks nutrients to facilitate growth of beneficial bacteria [40]. To account for extensive dysbiosis of the gut microbiome, probiotic supplementation has been proven to be beneficial in improving patient outcomes through the restoration of this biome [40, 56]. Incorporation of probiotics into enteral feeding solutions of ischemic stroke patients has shown to reduce malnutrition, diarrhea, intestinal stress, esophageal reflex, bloating, constipation, gastric retention, gastrointestinal bleeding, mechanical ventilation days, and infections [1, 56–58].

Pharmaceuticals have also been reported to be effective in minimizing adverse gastrointestinal reactions and therefore reducing cases of aspiration, malnutrition, and infections. A 2022 study reported improved functional status and decreased incidence of pneumonia infections in subacute stroke patients when administered metoclopramide, a prokinetic dopamine-receptor agonist [40].

While sources regarding nutritional enhancers specific to G- and J-tubes remain scarce, the success of the above supplements with other enteral tubes holds potential for application to G- and J-tubes. The recovery of neurological injury patients is highly dependent on nutritional availability to the patient. The various benefits from nutrients ranging from macronutrients to supplements derived from marine life offers much to account for when curating the diet of patients but could open opportunities to provide the most efficient recovery.

The Weaning Process

Although G-tube placement possesses various nutritional benefits, the complications that may arise from placement would require a proper weaning process from the G-tube treatment. The weaning process depends on the patient population and pre-existing treatments. A systematic review by Lively et. al, analyzed the wide variance in tube weaning protocol and identified three general predominant approaches to G-tube weaning: behavioral, biomedical, and child- and family-centered [59]. Behavioral and biomedical approaches were explored in a different retrospective study by Pollow et. al. This study involved appetite manipulation protocol to wean children from G-tube dependence. Children were evaluated for oral feeding readiness and underwent appetite manipulation through gradual restriction leading to the eventual elimination of G-tube treatment. This approach optimized the children's hunger response and addressed potential disruption of the hunger cycle generated from the G-tube feeding [60, 61]. The majority of patients undergoing this weaning approach achieved complete or substantial weaning from their G-tube treatment, but adverse effects persisted in others. Adverse effects such as ketonuria and hypoglycemia should be monitored in patients during the appetite manipulation process as this period of induced acute starvation may lead to appetite suppression [60, 62]. A combined approach is further supported in a 2014 study by Brown et. al which found similar success when employing a multidisciplinary approach to wean children from their G-tube [63]. Implementation of this approach worked to address the multifactorial nature of the adverse consequences of feeding as problems may arise from social and psychological factors, including negative attitudes on eating and negative learned behaviors, along with biological factors, including neurological and cardiac conditions [63]. To account for the various factors influencing the weaning process, this multidisciplinary approach involved behavior interventions, appetite manipulation, parental education and training, and close medical monitoring by a multidisciplinary team [63]. The three-week process achieved complete weaning from G-tube dependency in 90% of participants (n=30) [63, 64].

Despite the abundant body of sources regarding G-tube weaning in pediatric patients, information on weaning in adult patients remains scarce with no existing benchmark for G-tube weaning [65]. However, similar to children, G-tube complications emphasize the need for proper weaning procedure. In adults specifically, complications such as granuloma formation and local infection are of more concern compared to psychological complications which are more common in children [65]. A 2021 retrospective study by Jang et. al reported age and history of aspiration pneumonia as factors influencing the success of the weaning process in patients with dysphagia following a stroke [65]. Patient results on the Functional Dysphagia Score (FDS) and Penetration-Aspiration Score (PAS) correlated to their success with gastrostomy tube weaning as both indicated the severity of the patient’s dysphagia [65, 66, 67]. Despite the study pertaining to the weaning process in adults, dysphagia is an important factor in determining the success of G-tube weaning among pediatric patients as well, further highlighting the complex and multifactorial nature of the weaning process.

G-tube usage may range from temporary to long-term/permanent depending on the condition of the patient. Temporary G-tube usage is commonly used to help treat conditions such as post-stroke dysphagia and intestinal failure while extensive courses of feeding treatment are required for conditions such as certain cancers affecting oral alimentation. Head and neck cancer patients often develop dysphagia following treatment and are at risk of requiring a long-term G-tube [68]. A patient’s condition along with the consequences of undergoing treatment influence the period in which the patient requires a G-tube. A retrospective cohort study by Dong et. al, reported 25% of patients (n=112) developing pharyngeal-laryngeal toxicity following radiation of the head and neck, which necessitated permanent G-tube placement in all but five of the patients [69]. Similarly, a 2005 study by Guadagnolo et. al reported 7 of 29 patients (26%) with a nonfunctional larynx requiring permanent G-tube placement following advanced laryngeal cancer treatment including induction chemotherapy and hyperfractionated radiation therapy or chemoradiation [70]. Despite the relatively high frequency of permanent G-tube placement among head and neck cancer patients, a 2018 systematic review by van der Woerd et. al reported a lower rate of permanent placement among supraglottic cancer patients. A pooled data set extracted from four different studies showed only 5.3% (95% CI 2.6–10.5%) of the patients (n=198) required permanent G-tube placement following treatment [68]. Highlighting the variability that may arise among patients depending on their condition which should be accounted for throughout the weaning process. Though, the reportedly lower rate of permanent G-tube placement may be attributed to the stage at which the patients are treated – the van der Woerd et. al study was involved early-stage cancer treatment which may account for this difference.

The weaning process is variable among the patient, and it is important to account for the condition, prior-treatment, and psychology of the patient among other discussed influential factors. Overall, effective treatments utilized a multifaceted approach to account for the various branches of risks the patient faces when being weaned from enteral nutritional support. Though, in some cases, the weaning process is forgone due to permanent G-tube placement.

Conclusion

Proper nutritional support for neurologic injury patients takes into account various factors influencing the G- and J-tube process including placement, treatment, and removal. While generalizations may be identified, each experience may be unique to the patient in its own form. As the patient population includes individuals of all ages, conditions necessitating G-tube placement vary with some degree of similarity including disorders concerning the central nervous system. Placement procedure varies further by taking into account the condition of the patient and pre-existing obstructions, though they are largely noninvasive. It is also important to consider that patients who require G-tubes for only a short period of time such as adolescent patients who have undergone TBI. The patients may benefit from a less invasive placement of a nasogastric tube. Interventions influencing the placement of G- and J-tubes along with curating a proper diet pose further risks to be considered. Although there is controversy surrounding the relationship between G-tubes and VPS or ITB pumps, it is important to understand the existence of risks that may affect the patient. To meet the body's nutritional requirements, it is necessary to provide the patient with a diet that ensures an effective recovery. Symptoms of neurologic injury can lead to various downstream effects on available nutrients which should also be considered during treatment. Following treatment, those who are weaned from their nutritional support benefit from a multidisciplinary approach despite the possibility of each patient experiencing different reactions to the transition. It should also be noted that a portion of the G-tube patient population does not need to consider the weaning process – despite the above considerations including all G-tube patients – as they require permanent placement.

Moving forward, further exploration into nutrition provided via G- and J-tubes would be beneficial for effective treatment and to confirm the hypothesis translating findings regarding general enteral tubes to that of G- and J-tubes.

List of Abbreviations

G-tube	Gastrostomy tube
J-tube	Jejunostomy tube
TBI	Traumatic brain injury
CSF	Cerebrospinal fluid

PEG	Percutaneous Endoscopic Gastrostomy
VPS	Ventriculoperitoneal Shunts
ITB	Intrathecal baclofen pumps
IEN	Immune-enhancing nutritional
KD	Ketogenic diet

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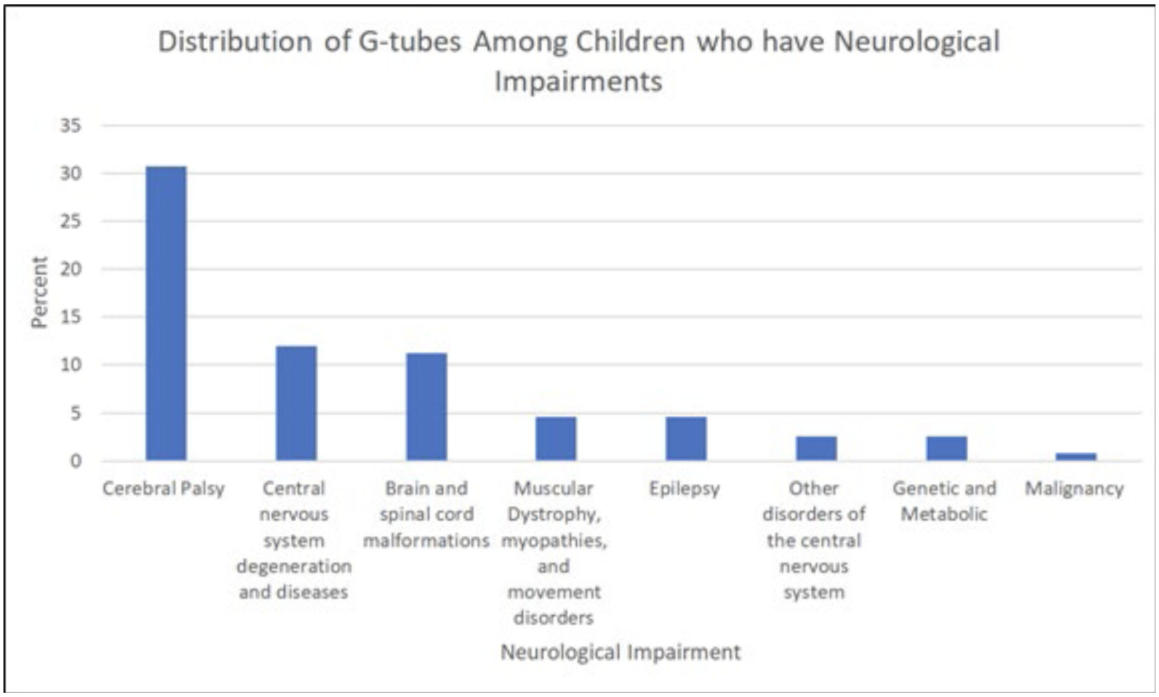

Figure 1:
The Distribution of G-tubes among Children with Neurologic Impairments [9]

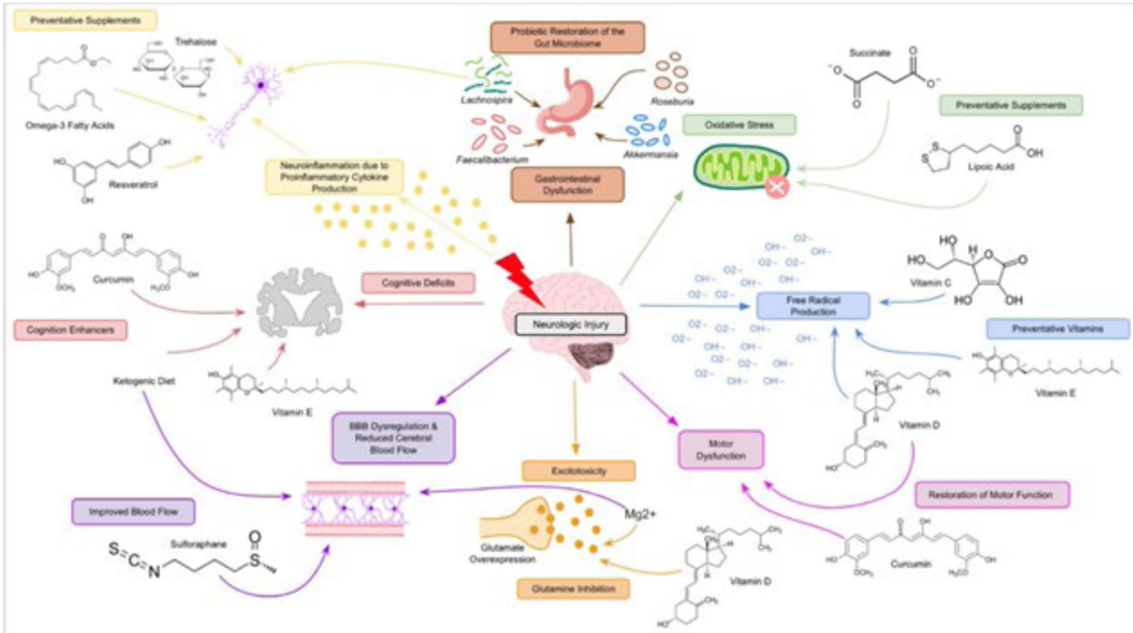

Figure 2:
Illustration of Relationships Between Downstream Effects of Neurologic Injury and Treatment [1, 40, 43, 49, 53–56].