Percutaneous endoscopic gastrostomy feeding effects in patients with neurogenic dysphagia and recurrent pneumonia

Jung Hwan Lee*, Hea Yoon Kwon*, Kye Sook Kwon, Soo-Hyun Park, Young Ju Suh, Jung-Soo Kim, Hyungkil Kim and Yong Woon Shin

Abstract

Background: Percutaneous endoscopic gastrostomy (PEG) feeding provides enteral nutrition to patients with neurological dysphagia. However, the conditions in which PEG should be applied to prevent pneumonia remain unclear. We aimed to evaluate the effect of PEG for patients with neurological dysphagia in preventing pneumonia.

Methods: We undertook a retrospective data review of 232 patients with neurological dysphagia who had undergone PEG from January 2008 to December 2018 at Inha University Hospital, in Incheon, Korea. We excluded patients who had not been followed up 6 months pre- and post-PEG feeding. In total, our study comprised 42 patients. We compared pneumonia episodes and incidence pre- and post-PEG.

Results: During the median post-PEG follow-up period, the 6-month pneumonia incidence among patients who had undergone PEG had decreased [median 0.3 (interquartile range (IQR) 0.0–0.7) versus 0.1 (IQR 0.1–0.3) episodes, \(p=0.04\)]. In a multiple mixed model, PEG did not decrease the incidence of pneumonia \(p=0.76\). However, the association between PEG and the incidence of pneumonia differed significantly depending on the presence or absence of recurrent pneumonia \(p<0.001\).

Conclusions: PEG could effectively reduce the incidence of pneumonia in patients with neurogenic dysphagia, especially in those who had experienced recurrent pneumonia.

The reviews of this paper are available via the supplemental material section.

Keywords: dysphagia, enteral nutrition, gastrointestinal, intubation, nervous system disease, percutaneous endoscopic gastrostomy, pneumonia

Received: 25 April 2020; revised manuscript accepted: 5 January 2021.

Introduction

Neurological diseases are common in older adult patients, affecting approximately 5–55% of people aged over 55 years. They are associated with a high risk of adverse health outcomes, including mortality, disability, falls, institutionalization, and hospitalization. Neurological conditions such as stroke incidents (the most common cause of dysphagia), traumatic brain injury, cerebral palsy, Parkinson’s disease, and other degenerative neurological disorders, including amyotrophic lateral sclerosis or advanced dementia, may cause swallowing difficulties and malnutrition. Pneumonia can be a frequent complication in patients with dysphagia due to central nervous system disease, partly because of unawareness of issues concerning swallowing and silent aspiration. Furthermore, impaired physical and cognitive abilities, which frequently accompany specific neurological diseases, may be exacerbating factors. Approximately 38% of all deaths associated with a neurological condition are reported to have had a comorbidity related to respiratory diseases. Therefore, in patients with neurological diseases, preventing recurrent pneumonia is very important.
Enteral feeding can provide nutritional support in patients for whom oral intake is unsafe and contraindicated. Nasogastric tube (NGT) or gastrostomy tube feeding provide two options for enteral tube feeding. Percutaneous endoscopic gastrostomy (PEG), first introduced in 1980, involves an endoscopy to insert a feeding tube into the stomach. Nutritional support through PEG has been shown to result in increased nutritional indicators, weight gain, and lower treatment failure compared with NGT feeding. However, it remains unclear whether PEG has effectively altered the incidence of pneumonia or decreased mortality. It is also still not well known which condition of patients can be prevented from pneumonia when PEG is applied.

Therefore, we aimed to determine whether PEG can prevent pneumonia development in patients with neurogenic dysphagia through long-term follow-up observation pre- and post-PEG, considering covariates likely to affect the development and incidence of pneumonia.

Materials and methods

Study population and data collection
This study was reviewed and approved by the Ethics Committee of Inha University Hospital (approval no. INHAUH 2019-11-042). A retrospective analysis of patient data was undertaken involving 232 consecutive patients who had developed pneumonia after having undergone PEG, from January 2008 to December 2018, at Inha University Hospital in Incheon, Korea. All patients had been diagnosed with a neurological disease, such as a stroke incident, cerebral hemorrhage, amyotrophic lateral sclerosis, Parkinson’s disease, and dementia, at least 6 months pre-PEG. We included patients able to be followed up for 6 months pre- and post-PEG. For each patient, we only considered the 2-year pneumonia incidence pre-PEG. The requirement for informed consent was waived, as the analysis used anonymous clinical patient data, which had previously been gathered with written patient consent.

Definition of diseases
Pneumonia episodes were recorded when patients visited the emergency room or outpatient clinics, at admission or during hospitalization. To differentiate between relapse and recurrence rates, recurrence was considered only when there had been infections separated by at least a 1-month asymptomatic interval, or complete radiographic clearing of the acute infiltrate. The incidence of pneumonia pre-PEG was defined as the number of pneumonia episodes divided by the follow-up period within 2 years. The incidence of pneumonia post-PEG was defined as the number of pneumonia episodes divided by the period post-PEG to the last follow up. For patients who could not be examined during the follow-up period, clinical information was obtained through telephone contact.

Cerebrovascular accidents (CVAs) were divided into acute and chronic phases, based on a 6-month history following symptom onset.

Indices for comorbidity, nutrition, activities of daily living, and dysphagia
Each patient’s comorbidities were measured using an age-adjusted Charlson Comorbidity Index (CCI). The controlling nutritional status (CONUT) score (calculated using serum albumin and total cholesterol concentration levels, and the total peripheral lymphocyte count) were used to evaluate the patients’ nutritional status. The physical functional status was measured using a simplified and modified version of the Katz Index of five activities of daily living (ADLs), namely, bathing, dressing, moving from a bed to a chair, using a toilet, and eating. Dysphagia severity was assessed in a videofluoroscopic swallowing study, using the Dysphagia Outcome and Severity Scale (DOSS). Patients unable to perform the swallowing study were recorded as DOSS level 1. Laboratory data comprised the CONUT score, and elements in the ADL (Katz) score and in the DOSS score (measured using the videofluoroscopic swallowing study) were evaluated using values that had been recorded pre-PEG and within 6–12 months post-PEG.

The PEG procedure
Three experienced endoscopists evaluated the suitability for gastrostomy and performed the PEG using a readily available PEG kit. Most PEG tubes were placed with a pull-through technique.
Statistical analysis
We used the Wilcoxon signed rank test for statistical analysis to compare pneumonia episodes and incidence pre- and post-PEG. The distribution of 6-month pneumonia incidence was shown to be positively skewed; therefore, a log-transformed value was used to approximate a normal distribution. A multiple mixed model with a random subject effect was used to analyze the association of covariates that could affect pneumonia incidence.

Multiple linear regression was used to determine the factors associated with post-PEG pneumonia incidence. Statistical significance was set at $p < 0.05$. Statistical analysis was performed using SPSS software version 19.0 (IBM Corp., Armonk, NY, USA) and an R statistics package (R Foundation, Vienna, Austria; https://www.r-project.org).

Results
PEG was performed in 232 patients with neurodysphagia. Of these, 54 patients who had undergone PEG due to other causes, such as cancer, were excluded. We excluded 58 and 49 patients who could not be followed up 6 months pre- and post-PEG, respectively. To check the occurrence of pneumonia for a specific period post-PEG, 28 patients whose pre-PEG follow-up period was longer than their post-PEG period were also excluded. Finally, 42 patients who had undergone PEG were included in our study (Figure 1).

The median patient age was 66 years [interquartile range (IQR), 58.0–75.0 years; Table 1]. More than 80% (81.0%, 34/42) of the patients had experienced a CVA. The median CCI score was 5 (IQR, 4–7). The median symptom duration pre-PEG was 585 (IQR, 243–1059) days, which equates to a symptom duration of approximately 1.5 years. More than two thirds (30/42, 71.4%) of the patients had dysphagia due to a CVA, and 27 (64.3%) patients who had experienced a CVA had undergone PEG 6 months following symptom onset.

Although some nutritional index scores were shown to have improved, no statistically significant difference was found in nutritional
Table 1. Baseline clinical characteristics of patients who had undergone percutaneous endoscopic gastrostomy.

| Variable                        | \(n\) | (%)   | \(p\) value |
|---------------------------------|-------|-------|-------------|
| Median age, years [IQR]         | 66.0  | [58.0–75.0] |            |
| Sex                             |       |       |             |
| Male                            | 22    | (52.4)|             |
| Female                          | 20    | (47.6)|             |
| Comorbidity                     |       |       |             |
| Diabetes                        | 11    | (26.2)|             |
| Liver disease                   | 3     | (7.2) |             |
| Malignancy                      | 4     | (9.5) |             |
| Chronic kidney disease          | 0     | (8.3) |             |
| Congestive heart failure or AMI | 1     | (2.4) |             |
| COPD                            | 1     | (2.4) |             |
| Cerebrovascular accident        | 34    | (81.0)|             |
| Neurological disease            |       |       |             |
| Amyotrophic lateral sclerosis   | 5     | (11.9)|             |
| Brain tumor                     | 1     | (2.4) |             |
| Ischemic stroke                 | 13    | (31.0)|             |
| Hemorrhagic stroke              | 20    | (47.6)|             |
| Parkinsonism                    | 4     | (25.0)|             |
| Dementia                        | 5     | (10.4)|             |
| Hemiplegia                      | 38    | (90.5)|             |
| CCI, median IQR                 | 5.0   | [4.0–7.0] |            |
| Symptom duration pre-PEG, median IQR, days | 584 | [243–1059] |     |
| Cause of dysphagia              |       |       |             |
| Cerebrovascular accident        | 30    | (71.4)|             |
| Acute phase (\(\leq 6\) months) | 3     | (7.1) |             |
| Chronic phase (>6 months)       | 27    | (64.3)|             |
| Others                          | 12    | (28.4)|             |
| Nutrition and ADL               | 0.33  |       |             |
| Albumin, median IQR, mg/dL      |       |       |             |
| Pre-PEG                         | 3.6   | [3.1–4.0] |            |
| Post-PEG                        | 3.6   | [3.3–3.9] |            |
| Total cholesterol, median IQR, mg/dl | 0.70 |       |             |
| Pre-PEG                         | 148   | [117–174] |            |
| Post-PEG                        | 157   | [126–167] |            |

(Continued)
Table 1. (Continued)

| Variable (n = 42)                          | n (%)          | p value |
|--------------------------------------------|----------------|---------|
| Lymphocyte count, median IQR, /mm²         | 1456 (1020–1780) | 0.71    |
| Pre-PEG                                    | 1527 (1161–1750) |         |
| Post-PEG                                   |                |         |
| CONUT score, median IQR                    | 3 [2–5]        | 0.98    |
| Pre-PEG                                    | 3 [3–4]        |         |
| Post-PEG                                   |                |         |
| ADL score, median IQR                      | 0 [0–0]        | 0.82    |
| Pre-PEG                                    | 0 [0–1]        |         |
| Post-PEG                                   |                |         |
| Feeding                                    |                |         |
| Oral feeding pre-PEG                       | 3 [7.1]        |         |
| NGT pre-PEG (<6 months)                    | 15 [35.8]      |         |
| NGT pre-PEG (⩾6 months)                   | 24 [57.1]      |         |
| Follow-up days from NGT to PEG, median IQR, days | 200 [85–261]  |         |
| Dysphagia score (DOSS), median IQR         | 1 [1–2]        | 0.57    |
| Pre-PEG                                    | 1 [1–2]        |         |
| Post-PEG                                   |                |         |
| Possible oral feeding post-PEG             | 4 [9.5]        |         |
| Recurrent pneumonia pre-PEG                | 11 [26.2]      | 0.31    |
| Number with pneumonia, median IQR          | 1 [0–2]        |         |
| Pre-PEG                                    | 1 [0–1.3]      |         |
| Follow-up days, median IQR                 |                | <0.001* |
| Pre-PEG                                    | 534 [247–730]  |         |
| Post-PEG                                   | 973 [759–1265] |         |
| Incidence of pneumonia, median IQR, 6 months | 0.3 [0.0–0.7] | 0.04*   |
| Pre-PEG                                    | 0.1 [0.1–0.3]  |         |
| Discharge destination                       |                |         |
| No discharge to death                      | 2 [4.8]        |         |
| Home                                       | 13 [31.0]      |         |
| Long-term care facility                    | 27 [64.2]      |         |
| Death                                      | 14 [33.3]      |         |

*Statistically significant (p < 0.05).
ADL, activity of daily living; AMI, acute myocardial infarction; CCI, Charlson Comorbidity Index; CONUT, controlling nutritional status; COPD, chronic obstructive pulmonary disease; DOSS, Dysphagia Outcome and Severity Scale; IQR, interquartile range; NGT, nasogastric tube feeding; PEG, percutaneous endoscopic gastrostomy.
indicators in terms of the CONUT score ($p = 0.90$). No significant difference was observed in the laboratory examination findings in relation to albumin levels ($p = 0.33$), total cholesterol levels ($p = 0.70$), and lymphocyte counts ($p = 0.71$) pre- and post-PEG, nor was there a difference in ADL scores or in the DOSS pre- and post-PEG.

Aside from three (7.1%) patients, NGT feeding had been performed prior to PEG. More than 50% (57.1% 24/42) of the patients had been fed via NGT feeding for $\geq 6$ months prior to PEG. The median follow-up NGT feeding duration was 200 (IQR, 85–261) days. Four (4/42, 9.5%) patients were able to undertake oral feeding post-PEG.

Eleven (26.2%) patients had developed pneumonia on more than one occasion pre-PEG. No significant difference was found in the number of pneumonia episodes pre- and post-PEG [median, 1 (IQR 0–2) versus 1 (IQR 1–1.3) episodes, $p < 0.31$]. The 6-month pneumonia incidence was significantly different pre- and post-PEG [median, 0.3 (IQR 0.0–0.7) versus 0.1 (IQR 0.1–0.3) episodes, $p = 0.04$]. Approximately one third of the patients had been discharged home and approximately two thirds of the patients had been discharged to long-term care facilities. Two (4%) patients had died prior to discharge. Fourteen (33.3%) patients died during the follow-up period. Eight patients died of pneumonia, and six patients found to have had a cardiac arrest had died on arrival to hospital.

**Significant factors associated with 6-month pneumonia incidence determined using a multiple mixed model**

Covariates including PEG (pre- and post-), sex, recurrent pneumonia pre-PEG, NGT feeding ($\geq 6$ months or not), CCI ($\geq 5$ or $< 5$), symptom duration pre-PEG ($\geq 1$ year or not), cause of dysphagia (CVA or not), CONUT score ($\geq 2$ or $> 2$), ADL score ($\geq 1$ or $< 1$), and dysphagia score ($\geq 3$ or $< 3$) were considered as fixed effects in the model for log-transformed 6-month pneumonia incidence (Figure 2). Of these, recurrent pneumonia and NGT feeding $\geq 6$ months were found to be significantly associated with the 6-month pneumonia incidence. Recurrent pneumonia $\times$ PEG interaction and NGT $\times$ PEG interaction were also considered to determine whether PEG affected pneumonia depending on the presence or absence of recurrent pneumonia or a

longer NGT feeding duration. In the multiple mixed model (Table 2), recurrent pneumonia pre-PEG ($t_{66} = 6.65$, $p < 0.001$) and NGT $\geq 6$ months pre-PEG ($t_{57} = 2.47$, $p = 0.02$) were positively correlated with the log-transformed 6-month pneumonia incidence. When controlling for these factors and interactive effects, PEG performance was shown not to differ significantly in terms of pneumonia incidence ($t_{66} = 0.3$, $p = 0.76$).

However, the effect of PEG on pneumonia incidence significantly differed depending on the presence or absence of recurrent pneumonia ($t_{59} = -3.61$, $p < 0.001$). No significant interaction was found between NGT feeding for $\geq 6$ months and PEG performance ($t_{59} = -1.02$, $p = 0.31$). The least squared mean of the log-transformed 6-month pneumonia incidence after adjusting for other covariates differed significantly, depending on the occurrence of recurrent pneumonia pre-PEG (Figure 3).

**Significant factors associated with the post-PEG 6-month pneumonia incidence determined using a multiple linear regression model**

The covariates including sex, recurrent pneumonia pre-PEG, NGT feeding ($\geq 6$ months or not), CCI ($\geq 5$ or $< 5$), symptom duration pre-PEG ($\geq 1$ year or not), cause of dysphagia (CVA or not), CONUT score ($\geq 2$ or $> 2$), ADL score ($\geq 1$ or $< 1$), dysphagia score ($\geq 3$ or $< 3$), and discharge destination (home or long-term care facility) were considered in the model for the post-PEG log-transformed 6-month pneumonia incidence (Figure 4). Of these, only NGT feeding $\geq 6$ months was significantly associated with the post-PEG 6-month incidence of pneumonia.

**Discussion**

This study investigated the risk of pneumonia development in patients with dysphagia, due to a neurological disorder, who had undergone enteral feeding. A statistically significant difference was found in the 6-month incidence of pneumonia pre- and post-PEG. PEG, recurrent pneumonia pre-PEG, and NGT feeding $\geq 6$ months were significantly associated with pneumonia development in patients with neuro-dysphagia. NGT feeding $\geq 6$ months was found to be a significant factor for the post-PEG incidence of pneumonia. The incidence of pneumonia significantly changed for patients post-PEG depending on whether they had experienced recurrent pneumonia pre-PEG,
after adjusting for other factors with fixed effects in the mixed regression model. Therefore, in patients with repeated episodes of pneumonia, PEG should be performed to prevent pneumonia.

Like our study, previous studies have identified several risk factors that contribute to the occurrence of pneumonia. Multiple comorbidity has been reported as a definite risk factor affecting the incidence of pneumonia and long-term mortality.23 The CCI is shown to be a good marker for patients with pneumonia in evaluating the severity and mortality of this condition.24 CCI has proven to be a significant risk factor for post-stroke or hospital-acquired pneumonia but not significant in this study due to the small number of subjects.25,26

Table 2. The association between percutaneous endoscopic gastrostomy and recurrent pneumonia and the 6-month incidence of pneumonia.

| Variable                                      | Estimatea | SE  | DF  | t value | p value |
|-----------------------------------------------|-----------|-----|-----|---------|---------|
| (Intercept)                                   | 0.05      | 0.06| 66.01| 0.95    | 0.35    |
| Recurrent pneumonia                           | 0.53      | 0.08| 66.01| 6.65    | <0.001***|
| NGT ≥6 months                                 | 0.17      | 0.07| 66.01| 2.47    | 0.02*   |
| (Pre- and post-) PEG                          | 0.02      | 0.06| 39.00| 0.30    | 0.76    |
| Recurrent pneumonia × PEG interaction         | −0.31     | 0.09| 39.00| −3.61   | <0.001***|
| NGT ≥6 months × PEG interaction               | −0.08     | 0.08| 39.00| −1.02   | 0.31    |

*aLog-transformed value was regressed due to non-normality on residuals.

ADL, activity of daily living; CCI, Charlson Comorbidity Index; CONUT, controlling nutritional status; CVA, cerebrovascular accident; DOSS, Dysphagia Outcome and Severity Scale; NGT, nasogastric tube feeding; PEG, percutaneous endoscopic gastrostomy.
Dysphagia has been reported in patients with stroke (8.1–80%), with Parkinson’s disease (11–81%), and with traumatic brain injury (27–30%), as well as in older adult patients with community-acquired pneumonia (91.7%). Therefore, the occurrence of dysphagia is more important than the precise neurological disease category, and early diagnosis of dysphagia has been shown to be helpful in preventing pneumonia. However, in patients who have experienced a CVA, the swallowing function can recover through rehabilitation; therefore, this could explain the lower incidence of pneumonia in these patients over time compared with patients diagnosed with other diseases. A longer NGT feeding time has been shown a risk factor for aspiration pneumonia. Longer NGT feeding results in reflux of gastric contents through the oropharynx, and the materials can be easily aspirated into the lungs.

**Figure 3.** The different effect of PEG on incidences of pneumonia according to the presence or absence of recurrent pneumonia pre-PEG. PEG, percutaneous endoscopic gastrostomy.

**Figure 4.** Estimated effects of covariates on log-transformed 6-month pneumonia incidence post-PEG. *Statistically significant (p < 0.05). ADL, activity of daily living; CCI, Charlson Comorbidity Index; CONUT, controlling nutritional status; CVA, cerebrovascular accident; DDSS, Dysphagia Outcome and Severity Scale; NGT, nasogastric tube feeding; PEG, percutaneous endoscopic gastrostomy.
lower airways. The following mechanisms have been reported to be responsible for aspiration in patients who undergo NGT feeding: (a) a loss of anatomical integrity of the upper and lower esophageal sphincters; (b) an increase in frequency of transient lower esophageal sphincter relaxations; and (c) a desensitization of the pharyngoglottal adduction reflex.32

In our study, PEG was found to be significantly negatively correlated with the incidence of pneumonia; however, in our multivariable analysis that considered this association, our findings indicated that PEG did not reduce the risk of pneumonia. Contrasting findings have been reported in several studies in terms of the extent to which PEG could prevent pneumonia.5,14,33 In addition, longer NGT feeding times have not been significantly associated with PEG. Therefore, it remains unclear whether a change from NGT feeding to PEG is effective in preventing pneumonia. Previous studies have also reported contrasting findings concerning whether PEG reduces the incidence of pneumonia, compared with NGT feeding. Large prospective studies have shown no differences in pneumonia, mortality, and hospitalization rates, between patients who received PEG and those who received NGT feeding.34,35 However, a recent cohort study indicated that patients with direct enteral tube feeding had higher odds of pneumonia in a 2-year period compared with those with temporary NGT feeding only.36 Therefore, there is insufficient evidence to recommend simply switching from NGT feeding to PEG to prevent pneumonia in patients with neuro-dysphagia. In the analysis of post-PEG pneumonia, longer NGT feeding was found to be a significant factor. This may mean that the patients who had undergone a long period of NGT feeding already had a high aspiration risk. Long-term NGT placement could lead to sensory disorders, such as sensory deficits or desensitization in the laryngopharyngeal structures.37 As a result, secretion accumulation in the piriform sinus or a leak into the laryngeal vestibule could result in aspiration in these patients.38

Therefore, it is important when selecting patients for PEG to be aware that certain conditions respond more favorably in terms of preventing pneumonia. Our multivariable analysis indicated that PEG reduced the incidence of pneumonia in patients with recurrent pneumonia. Additionally, a past history of pneumonia or hospitalization has been identified as a risk factor for further pneumonia.23,39,40 Patients with repeated episodes of pneumonia have several aspiration risk factors, such as orientation disturbance, poor performance, neurological disease, sleep medication, gastroesophageal disease, or malnutrition,41,42 and PEG may mitigate some of these risk factors. Previous studies have reported a reduced incidence of gastroesophageal reflux in patients with PEG feeding.43,44 In patients with repeated pneumonia, PEG feeding has been found to result in decreased gastric acid reflux compared with NGT feeding.45 Malnutrition or incomplete functional status has been identified as a risk factor for pneumonia development in older adults.42,46 It has previously been reported that PEG improves nutritional status in patients with amyotrophic lateral sclerosis.47 Recent studies have reported that PEG contributed to improved survival rates in patients with amyotrophic lateral sclerosis, and that this was considered to be associated with a decrease in the incidence of pneumonia.48,49 PEG feeding can improve a patient’s nutritional status, quality of life, or functional status, as it has been shown to prevent advanced pneumonia.50–52 Our study findings did not show any significant results due to the small study size; however, our patients’ nutrition laboratory examination results showed some improvement 6 months post-PEG. The reason no improvement in the ADL score was observed is likely because most of the patients who had undergone PEG were sufficiently uncomfortable to not undertake self-feeding. However, many patients were able to visit outpatients using wheelchairs post-PEG (data not shown).

The strength of our study was the comparison of pre- and post-intervention outcomes regarding pneumonia episodes in the same patients after long-term follow-up examination. We also investigated whether there was a change in the incidence of pneumonia in patients with the presence or absence of recurrent pneumonia and a long NGT feeding time. Additionally, the incidence of pneumonia was examined for at least 6 months pre- and post-PEG. To demonstrate the effect of PEG, we adjusted risk factors to evaluate the incidence of pneumonia. To our knowledge, few studies have examined risk factors affecting the incidence of pneumonia. Considering risk factors, we were able to identify optimal patient conditions in which to perform a PEG procedure to prevent advanced or recurrent pneumonia.
Our study had some limitations. First, a limited number of patients were included. Second, pneumonia episodes had been counted and recorded during visits to the emergency room or the outpatient clinics, at admission, or through clinical confirmation during hospitalization. Therefore, it was not possible to estimate the exact number of pneumonia episodes that may have occurred external to our hospital setting. However, most patients had been consistently followed up at our hospital. Even when they had been referred to long-term care facilities, they were finally admitted to our hospital. Third, we examined patients with a mixture of several heterogeneous neurological diseases. However, most of them were in an advanced state of neurogenic dysphagia.

In conclusion, PEG could effectively reduce the incidence of pneumonia in patients with neurogenic dysphagia in optimal conditions, such as experiencing recurrent pneumonia pre-PEG. PEG feeding could improve nutritional status and gastroesophageal reflux in relation to neurological disability that resulted in the prevention of further pneumonia. Nevertheless, future largescale and multi-center studies are required to confirm our study findings.

Conflicts of interest statement
The authors declare that there is no conflict of interest.

Funding
The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: this work was supported by Inha University Hospital 2020.

ORCID iD
Kye Sook Kwon https://orcid.org/0000-0003-3990-3963

Supplemental material
The reviews of this paper are available via the supplemental material section.

References
1. Murray CJ, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the global burden of disease study 2010. Lancet 2012; 380: 2197–2223.
2. Hofman A, Darwish Murad S, van Duijn CM, et al. The Rotterdam study: 2014 objectives and design update. Eur J Epidemiol 2013; 28: 889–926.
3. Daniels SK. Neurological disorders affecting oral, pharyngeal swallowing. GI Motility Online. Epub ahead of print 16 May 2006. DOI: 10.1038/gimo34.
4. Ertekin C and Aydogdu I. Neurophysiology of swallowing. Clin Neurophysiol 2003; 114: 2226–2244.
5. Mandell LA and Niederman MS. Aspiration pneumonia. N Engl J Med 2019; 380: 651–663.
6. Public Health England. Deaths associated with neurological conditions in England: 2001 to 2014. London: Public Health England, 2018.
7. Pearce CB and Duncan HD. Enteral feeding. Nasogastric, nasojejunal, percutaneous endoscopic gastrostomy, or jejunostomy: its indications and limitations. Postgrad Med J 2002; 78: 198–204.
8. Klein S. A primer of nutritional support for gastroenterologists. Gastroenterology 2002; 122: 1677–1687.
9. Gauderer MW, Ponsky JL and Izant RJ Jr. Gastrostomy without laparotomy: a percutaneous endoscopic technique. 1980. Nutrition 1998; 14: 736–738.
10. Gomes CA Jr, Andriolo RB, Bennett C, et al. Percutaneous endoscopic gastrostomy versus nasogastric tube feeding for adults with swallowing disturbances. Cochrane Database Syst Rev 2015; 2015: CD008096.
11. Rahmemai-Azar AA, Rahmemaizar AA, Naghsheidarian R, et al. Percutaneous endoscopic gastrostomy: indications, technique, complications and management. World J Gastroenterol 2014; 20: 7739–7751.
12. Dwolatzky T, Berezovski S, Friedmann R, et al. A prospective comparison of the use of nasogastric and percutaneous endoscopic gastrostomy tubes for long-term enteral feeding in older people. Clin Nutr 2001; 20: 535–540.
13. Norton B, Homer-Ward M, Donnelly MT, et al. A randomised prospective comparison of percutaneous endoscopic gastrostomy and nasogastric tube feeding after acute dysphagic stroke. BMJ 1996; 312: 13–16.
14. Finucane TE and Bynum JP. Use of tube feeding to prevent aspiration pneumonia. Lancet 1996; 348: 1421–1424.
15. Winterbauer RH, Bedon GA and Ball WC Jr. Recurrent pneumonia. Predisposing illness and...
clinical patterns in 158 patients. *Ann Intern Med* 1969; 70: 689–700.

16. O’Neill D, Horgan F, Hickey A, et al. Long term outcome of stroke: stroke is a chronic disease with acute events. *BMJ* 2008; 336: 461.

17. Charlson M, Szatrowski TP, Peterson J, et al. Validation of a combined comorbidity index. *J Clin Epidemiol* 1994; 47: 1245–1251.

18. Chang C-M, Yin W-Y, Wei C-K, et al. Adjusted age-adjusted Charlson comorbidity index score as a risk measure of perioperative mortality before cancer surgery. *PLoS One* 2016; 11: e0148076.

19. Ignacio de Ulibarri J, Gonzalez-Madrono A, de Villar NG, et al. CONUT: a tool for controlling nutritional status. First validation in a hospital population. *Nutr Hosp* 2005; 20: 38–45.

20. Mehta KM, Pierluissi E, Boscardin WJ, et al. A clinical index to stratify hospitalized older adults according to risk for new-onset disability. *J Am Geriatr Soc* 2011; 59: 1206–1216.

21. O’Neil KH, Purdy M, Falk J, et al. The dysphagia outcome and severity scale. *Dysphagia* 1999; 14: 139–145.

22. Tang S-j and Wu R. Percutaneous endoscopic gastrostomy (pull method) and jejunal extension tube placement. *Video J Encycl GI Endosc* 2014; 2: 40–45.

23. Torres A, Peetermans WE, Viegi G, et al. Risk factors for community-acquired pneumonia in adults in Europe: a literature review. *Thorax* 2013; 68: 1057–1065.

24. Wesemann T, Nullmann H, Pflug MA, et al. Pneumonia severity, comorbidity and 1-year mortality in predominantly older adults with community-acquired pneumonia: a cohort study. *BMC Infect Dis* 2015; 15: 2.

25. Phan TG, Kooblal T, Matley C, et al. Stroke severity versus dysphagia screen as driver for post-stroke pneumonia. *Front Neurol* 2019; 10: 16.

26. Sopena N, Heras E, Casas I, et al. Risk factors for hospital-acquired pneumonia outside the intensive care unit: a case-control study. *Am J Infect Control* 2014; 42: 38–42.

27. Takizawa C, Gemmell E, Kenworthy J, et al. A systematic review of the prevalence of oropharyngeal dysphagia in stroke, Parkinson’s disease, Alzheimer’s disease, head injury, and pneumonia. *Dysphagia* 2016; 31: 434–441.

28. Bray BD, Smith GJ, Cloud GC, et al. The association between delays in screening for and assessing dysphagia after acute stroke, and the risk of stroke-associated pneumonia. *J Neurol Neurosurg Psychiatry* 2017; 88: 25–30.

29. Gandolfi M, Smania N, Bisoﬁ G, et al. Improving post-stroke dysphagia outcomes through a standardized and multidisciplinary protocol: an exploratory cohort study. *Dysphagia* 2014; 29: 704–712.

30. Aoki S, Hosomi N, Hirayama J, et al. The multidisciplinary swallowing team approach decreases pneumonia onset in acute stroke patients. *PLoS One* 2016; 11: e0154608.

31. Gomes GF, Pisani JC, Macedo ED, et al. The nasogastric feeding tube as a risk factor for aspiration and aspiration pneumonia. *Curr Opin Clin Nutr* 2003; 6: 327–333.

32. DeMeo MT and Bruninga K. Physiology of the aerodigestive system and aberrations in that system resulting in aspiration. *JPEN J Parenter Enteral Nutr* 2002; 26: S9–S17; discussion S17–S18.

33. Stroud M, Duncan H, Nightingale J, et al. Guidelines for enteral feeding in adult hospital patients. *Gut* 2003; 52(Suppl. 7): vii1–vii12.

34. Dennis MS, Lewis SC and Warlow C. Effect of timing and method of enteral tube feeding for dysphagic stroke patients (FOOD): a multicentre randomised controlled trial. *Lancet* 2005; 365: 764–772.

35. Jaafar MH, Mahadeva S, Tan KM, et al. Long-term nasogastric versus percutaneous endoscopic gastrostomy tube feeding in older Asians with dysphagia: a pragmatic study. *Nutr Clin Pract* 2019; 34: 280–289.

36. Joundi RA, Saposnik G, Martino R, et al. Outcomes among patients with direct enteral vs nasogastric tube placement after acute stroke. *Neurology* 2018; 90: e544–e552.

37. Wang ZY, Chen JM and Ni GX. Effect of an indwelling nasogastric tube on swallowing function in elderly post-stroke dysphagia patients with long-term nasal feeding. *BMJ Neurol* 2014; 29: 704–712.

38. Chang WK, Huang HH, Lin HH, et al. Percutaneous endoscopic gastrostomy versus nasogastric tube feeding: oropharyngeal dysphagia increases risk for pneumonia requiring hospital admission. *Nutrients* 2019; 11: 2969.

39. Ishifuji T, Sando E, Kaneko N, et al. Recurrent pneumonia among Japanese adults: disease burden and risk factors. *BMC Pulm Med* 2017; 17: 12.

40. Almirall J, Bolibar I, Serra-Prat M, et al. New evidence of risk factors for community-acquired pneumonia after acute stroke in elderly patients: a literature review. *PloS One* 2010; 5: e12453.
pneumonia: a population-based study. *Eur Respir J* 2008; 31: 1274–1284.

41. Noguchi S, Yatera K, Kato T, *et al.* Impact of the number of aspiration risk factors on mortality and recurrence in community-onset pneumonia. *Clin Interv Aging* 2017; 12: 2087–2094.

42. Riquelme R, Torres A, El-Ebiary M, *et al.* Community-acquired pneumonia in the elderly: a multivariate analysis of risk and prognostic factors. *Am J Respir Crit Care Med* 1996; 154: 1450–1455.

43. Jung SH, Dong SH, Lee JY, *et al.* Percutaneous endoscopic gastrostomy prevents gastroesophageal reflux in patients with nasogastric tube feeding: a prospective study with 24-hour pH monitoring. *Gut Liver* 2011; 5: 288–292.

44. McClave SA, Lukan JK, Stefater JA, *et al.* Poor validity of residual volumes as a marker for risk of aspiration in critically ill patients. *Crit Care Med* 2005; 33: 324–330.

45. Douzinas EE, Tsapalos A, Dimitrakopoulos A, *et al.* Effect of percutaneous endoscopic gastrostomy on gastro-esophageal reflux in mechanically-ventilated patients. *World J Gastroenterol* 2006; 12: 114–118.

46. Riquelme R, Torres A, el-Ebiary M, *et al.* Community-acquired pneumonia in the elderly.

Clinical and nutritional aspects. *Am J Respir Crit Care Med* 1997; 156: 1908–1914.

47. Andersen P, Abrahams S, Borasio G, *et al.* EFNS task force on diagnosis and management of amyotrophic lateral sclerosis: EFNS guidelines on the clinical management of amyotrophic lateral sclerosis (ALS)—revised report of an EFNS task force. *Eur J Neurol* 2012; 19: 360–375.

48. Burkhardt C, Neuwirth C, Sommacal A, *et al.* Is survival improved by the use of NIV and PEG in amyotrophic lateral sclerosis (ALS)? A post-mortem study of 80 ALS patients. *PLoS One* 2017; 12: e0177555.

49. Cui F, Sun L, Xiong J, *et al.* Therapeutic effects of percutaneous endoscopic gastrostomy on survival in patients with amyotrophic lateral sclerosis: a meta-analysis. *PLoS One* 2018; 13: e0192243.

50. Burgos R, Breton I, Cereda E, *et al.* ESPEN guideline clinical nutrition in neurology. *Clin Nutr* 2018; 37: 354–396.

51. Löser C, Aschl G, Hebuterne X, *et al.* ESPEN guidelines on artificial enteral nutrition—percutaneous endoscopic gastrostomy (PEG). *Clin Nutr* 2005; 24: 848–861.

52. Geeganage C, Beavan J, Ellender S, *et al.* Interventions for dysphagia and nutritional support in acute and subacute stroke. *Cochrane Database Syst Rev* 2012; 10: CD000323.