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ORIGINAL ARTICLE

Outcomes of Aspiration Prevention Surgery: A Retrospective Cohort Study Using a Japanese Claims Database

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Abstract

Aspiration prevention surgeries, such as laryngotracheal separation and total laryngectomy are performed to prevent aspiration pneumonia. We aimed to investigate the outcomes of surgery for intractable aspiration and relevant factors. This retrospective cohort study used a nationwide insurance claims database that included company employees and their family members aged < 75 years in Japan. We extracted the data of patients who underwent aspiration prevention surgeries between January 2005 and March 2019. We identified 127 patients (males, 55.9%), of whom 59.8% were aged < 18 years at the surgery. The most common comorbidity was neurological disease (99.2%). The frequency of pneumonia episodes decreased by 1.5 per year after surgery compared with before surgery ($p < 0.001$). Among patients who received parenteral and enteral nutrition before surgery ($n = 92$), the adjusted hazard ratio (aHR) for oral intake without parenteral and enteral nutrition was lower in the longer preoperative duration (≥ 14.7 months) for the parenteral and enteral nutrition. However, the difference was not statistically significant (aHR 0.55; 95% confidence interval: 0.15–2.08, $p = 0.38$). The aHR for oral intake was higher in the ≥ 30 years group than in the < 30 years group (aHR 13.76; 95% confidence intervals: 4.18–42.24; $p < 0.001$). This study demonstrated that postoperative oral intake was achieved more frequently in patients aged ≤ 30 years than in those aged > 30 years, and supported the effectiveness of aspiration prevention surgery for reducing aspiration pneumonia. Further research is necessary to investigate factors related to postoperative oral intake.

Keywords Deglutition disorders · Aspiration · Pneumonia · Laryngectomy · Eating

Introduction

Swallowing disorders are seen in patients with neurologic disorders and with altered anatomy of the upper aerodigestive tract [1]. Severe swallowing disorders lead to intractable aspiration which may lead to aspiration pneumonia [2]. Intractable aspiration initially requires discontinuation of oral intake. Alimentary routes are shifted to enteral routes for cases requiring nasogastric tube feeding, gastrostomy, or central venous hyperalimentation. If such management is unsuccessful, an effective way to prevent intractable aspiration is to completely separate the digestive and respiratory tracts by surgical procedures [3]. The criteria for diversion include repeated pneumonia due to intractable aspiration and lack of speech communication [4].

There are some types of surgical procedures for intractable aspiration. Lindeman et al. first reported the tracheoesophageal diversion (TED) in 1975, and introduced the laryngotracheal separation (LTS) in 1976 as a reversible surgery for intractable aspiration [5, 6]. Both TED and LTS are surgeries undertaken to separate the trachea from the larynx. TED employs a trachea-esophageal anastomosis, whereas LTS employs blind-end closure of the proximal trachea. Modified procedures such as subglottic laryngeal closure have been reported by others [6–9]. TED, LTS, and subglottic laryngeal closure are reversible procedures that

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preserve the larynx. On the other hand, total laryngectomy (TL) is an alternative, irreversible method to control intractable aspiration in which the larynx is removed [10].

The risk of aspiration pneumonia is reduced after TL, TED, and LTS [1, 3, 4, 7, 10–16]. However, the outcomes of feeding conditions after these surgeries were inconsistent among previous studies [2–4, 16]. The studies on surgeries for intractable aspiration are only derived from single-center experiences, and the results from single-institutional studies could be influenced by specific practices of the institution such as the indication for surgery, the preference on the type of surgery and the timing of surgery. The association between the duration of parenteral and enteral nutrition before surgery and postoperative feeding conditions remains unclear. Moreover, the differences in surgical indications and outcomes depending on age have not been thoroughly elucidated.

In this study, we hypothesized that the surgical outcomes such as postoperative feeding condition are affected by preoperative clinical features such as ages, underlying diseases, and the duration of preoperative parenteral and enteral nutrition, and we investigated the effects of these factors using a nationwide claims database. The objective of this study was to determine the comorbidity of patients who underwent surgery for intractable aspiration, and the surgical outcomes such as postoperative pneumonia prevention, and feeding conditions. We also aimed to investigate the effectiveness of surgery and to compare the differences in surgical indications and outcomes among different patient ages.

Materials and Methods

Data Source

This retrospective cohort study used a nationwide insurance claims database that tracks data for each patient, even if the patient visited or was hospitalized at multiple medical institutions in Japan. It is constructed by JMDC Inc. (Tokyo, Japan) which is a commercial data vendor that collects data from > 100 employer-based insurances [17–19]. The database has accumulated reimbursement data from about 6 million insured persons, comprised mainly of company employees and their family members since 2005. People aged 75 and over are not included in the database because they are obliged to enroll in a special insurance plan for the elderly under the Japanese healthcare system. The database contains information such as patient characteristics (age and sex), medical and pharmacy claims data, clinical diagnoses coded using the International Classification of Diseases 10th revision (ICD-10), and medical procedures coded using medical billing codes. The database can also track data for each patient in chronological order for patients managed at multiple medical institutions. The requirement for informed consent was waived because this study was a secondary analysis of anonymous patient data.

Study Cohort

From the database, we extracted data of patients who underwent aspiration prevention surgery from April 1, 2010, to March 31, 2019. We excluded patients who underwent laryngeal suspension or cricopharyngeal myotomy. Patients who underwent surgery coded LTS or TL for head and neck cancer were also excluded. Surgery for intractable aspiration pneumonia was identified using the medical billing codes for aspiration prevention surgeries. In medical billing codes, the codes for surgeries for intractable aspiration include only total laryngectomy and LTS. The medical billing codes are '150,345,310' for LTS and '150,345,410' for TL. Therefore, reversible surgeries such as TED, subglottic laryngeal closure, and other modified procedures are collectively coded as LTS in most cases. TL is an irreversible procedure, whereas LTS, TED and subglottic laryngeal closure are reversible procedures because they preserve the larynx. Therefore, we divided patients into two groups, namely, a patient group who underwent aspiration prevention surgery coded LTS as "non-TL group" and a patient group who underwent surgery coded TL as "TL group".

We collected the following clinical data: sex, age at aspiration prevention surgery, comorbidities, feeding route, prior tracheotomy, pneumonia episodes in the preoperative and postoperative periods, and death. To identify comorbidities, we reviewed the ICD-10 codes during hospitalization when aspiration prevention surgery was performed. Comorbidities were categorized into the following groups: neurological disease, chronic lung disease, prematurity, upper airway obstruction, heart disease, and trauma. For patients with multiple comorbidities, classification for a patient into multiple groups was allowed. These comorbidities do not always cause intractable aspiration, but they may affect the indications for surgery. We estimated the feeding route based on the management fees for nasogastric tube nutrition or gastrostomy as enteral nutrition, and central venous hyperalimentation as parenteral nutrition. We assumed that the patients who did not have management fee for enteral or parenteral nutrition for more than 90 days as patients who were not dependent on enteral or parenteral nutrition, which means that they were fed completely by oral intake. Patients who were fed enterally and orally were classified under enteral nutrition. We estimated the duration of parenteral and enteral nutrition before surgery and the duration of postoperative parenteral and enteral nutrition. Prior tracheotomy was defined as tracheotomy performed prior to aspiration prevention surgery. We calculated the number of pneumonia episodes per year before and after aspiration prevention surgery. Only patients whose data were available

one year pre- and postoperatively were included. A pneumonia episode was identified based on hospitalization under the disease name of pneumonia, and the fee for intravenous administration of antibiotics. To compare the comorbidity and the outcome of surgeries between ages, the patients were divided into two groups based on age at the time of aspiration prevention surgery: < 30 years group and ≥ 30 years group. We used the 30 years as a cut-off to divide the cohort for the analysis because some patients with motor and intellectual disabilities since infancy underwent aspiration prevention surgery in their twenties [9, 15, 20]. To evaluate postoperative feeding conditions according to the timing of surgery, patients were divided into two groups according to the median duration of preoperative parenteral and enteral nutrition as a cut-off.

Statistical Analysis

The characteristics of the study population were summarized using proportions for categorical variables, and medians and interquartile ranges (IQR). The annual number of pneumonia episodes before and after surgery is summarized using the mean and standard deviation (SD). The Mann–Whitney *U* test and Fisher's exact test were used to compare continuous and categorical variables, respectively. Paired *t*-tests were used to compare the number of episodes of pneumonia in the preoperative and postoperative periods. We calculated the rate of decrease of pneumonia episodes (*R*) using the following equation:

$$R = \mathrm{Na}/\mathrm{Nb} - 1$$

In this equation, Nb is the average number of pneumonia episodes before surgery, and Na is the average number of pneumonia episodes after surgery. The Kaplan–Meier method and the log-rank test were used to evaluate the dependence of postoperative parenteral and enteral nutrition on patients receiving preoperative parenteral and enteral nutrition. We compared between the < 30 years group and the ≥ 30 years group, two groups with a median duration of preoperative parenteral and enteral nutrition of 14.7 months as a cut-off, and the types of surgery (non-TL and TL). Deaths or dropouts from the database during periods were treated as censors. Multivariable Cox proportional hazards modeling was used to analyze hazard ratios (HRs) of the dependence on postoperative parenteral and enteral nutrition in the two groups divided by the duration of preoperative parenteral and enteral nutrition, and 95% confidence intervals (CIs) were calculated. The models were adjusted for the duration of preoperative parenteral and enteral nutrition, and age. These variables were categorized into two groups with a median duration of preoperative parenteral and enteral nutrition as a cut-off, and two age groups with a cut-off of 30 years.

As post hoc analyses, among adult patients (≥ 18 years), we compared the duration of preoperative parenteral and enteral nutrition of the two groups with 14.7 months as a cut-off, and the types of surgery (non-TL and TL) using univariable Cox proportional hazards modeling to evaluate the dependence of postoperative parenteral and enteral nutrition. In the post hoc analyses, a multivariable analysis was not performed because the number of events was insufficient. As other post-hos analyses, we performed multivariable Cox proportional hazard analyses to analyze the HRs of the dependence on postoperative parenteral and enteral nutrition according to underlying neurological diseases among patients of all ages.

All statistical tests were two-sided, and statistical significance was set at $p < 0.05$. SAS for Windows (version 9.4; SAS Institute) was used for all data analyses.

Sensitivity Analysis

To check the robustness of our results, we changed the definition of patients who were dependent for their nutrition orally to those who did not have a fee for enteral nutrition or parenteral nutrition for more than 60 and 120 days. We performed sensitivity analyses for patients receiving preoperative parenteral and enteral nutrition.

Results

We identified 127 patients (71 males, 55.9%) who underwent aspiration prevention surgery coded as LTS or TL as an aspiration prevention procedure between January 1, 2005, and March 31, 2019. Table 1 presents the demographic and clinical characteristics of the study cohort. The median age at aspiration prevention surgery was 13.5 years (interquartile range [IQR]: 5.0–27.5 years). Patients aged < 18 years comprised 59.8% of the total study population. Patients aged 18–29 years comprised 16.5%, and those aged ≥ 30 years comprised 23.6%. Non-TL, which was defined as aspiration prevention surgery coded as LTS, was performed in 111 patients (87.4%), while TL was performed in 16 patients (12.6%). The most common comorbidity was neurological disease ($n = 126$, 99.2%), followed by chronic lung disease ($n = 82$, 64.6%), prematurity ($n = 35$, 27.6%), upper airway obstruction ($n = 27$, 21.3%), heart disease ($n = 21$, 16.5%), and trauma ($n = 6$, 4.7%). Neurological disease included hypoxic brain damage; congenital disease; degenerative disease; cerebrovascular disease; brain tumors; and muscle diseases. Only one patient with upper airway obstruction and esophageal obstruction due to chemical trauma did not have a diagnosis of neurological disease. Upper airway

Table 1 Clinical characteristics of patients undergoing aspiration prevention surgery

Total, *n*	127
Male sex, *n* (%)	71 (55.9)
Age at surgery, median (IQR), years	13.5 (5.0–27.5)
0–9 years, *n* (%)	49 (38.6)
10–17 years, *n* (%)	27 (21.3)
18–29 years, *n* (%)	21 (16.5)
30–59 years, *n* (%)	20 (15.8)
> 60 years, *n* (%)	10 (7.9)
Type of surgery	
Non-TL[a], *n* (%)	111 (87.4)
TL, *n* (%)	16 (12.6)
Patients who received parenteral and enteral nutrition before surgery, *n* (%)	92 (72.4)
Patients who begun parenteral and enteral nutrition after surgery, *n* (%)	27 (21.1)
Patients who never received parenteral or enteral nutrition during the follow-up period, *n* (%)	8 (6.3)
Comorbidity	
Neurological disease, *n* (%)	126 (99.2)
Chronic lung disease, *n* (%)	82 (64.6)
Prematurity, *n* (%)	35 (27.6)
Upper airway obstruction, *n* (%)	27 (21.3)
Heart disease, *n* (%)	21 (16.5)
Trauma, *n* (%)	6 (4.7)
Tracheotomy before surgery, *n* (%)	32 (25.2)
Complication related with surgery, *n* (%)	14 (11.0)
Mortality, *n* (%)	6 (4.7)

IQR interquartile range; *TL* total laryngectomy

[a]"Non-TL" included tracheoesophageal diversion, subglottic laryngeal closure and other modified procedures

obstruction included laryngeal and tracheal stenosis after tracheotomy, bronchomalacia, laryngomalacia, and micrognathia. There was no patient with a history of head and neck cancer before aspiration prevention surgery in the study cohort. Preoperative parenteral and enteral nutrition was provided to 92 patients (72.4%). Thirty-two patients (25.2%) underwent tracheotomy before surgery. The data were available for the subjects for a median of 29.4 months (IQR 12.2–54.8 months) before aspiration prevention surgery and a median of 19.2 months (IQR 8.1–47.7 months) after surgery.

Table 2 shows the clinical characteristics of patients according to age. In the < 30 years age group, the most common underlying neurological condition was hypoxic brain damage (n = 56, 57.7%), followed by congenital disease ($n = 29$, 29.9%). In the ≥ 30 years age group, degenerative neurological disease was the most common ($n = 18$, 60.0%), followed by cerebrovascular disease ($n = 9$, 30.0%). The underlying neurological diseases differed between the < 30 years age group and the ≥ 30 years age group. Non-TL was more likely to be performed than TL in the < 30 years age group compared to ≥ 30 years age group ($p < 0.001$). Two patients younger than 18 years had tracheo-innominate artery fistula.

The number of pneumonia episodes decreased by 1.5 per year after surgery compared to before surgery (mean: 1.3; SD: 1.1 vs, mean: 2.8; SD: 1.6, $p < 0.001$, Fig. 1). The rate of decrease was 53.6%. Seventy patients whose data were available on the database one year pre- and postoperatively were included in this analysis.

Analyses for Patients Who Received Preoperative Parenteral and Enteral Nutrition

The median of duration of parenteral and enteral nutrition before surgery was 14.7 months among patients who received parenteral and enteral nutrition before surgery ($n = 92$), and it was shorter in age ≥ 30 years group than in age < 30 years group (median: 8.1 months; IQR 6.1–14.2 months vs, median: 22.3 months; IQR 6.1–43.6 months, $p = 0.027$). More patients in the ≥ 30 years group received oral nutrition after surgery than patients in the < 30 years group during the follow-up period of this study ($n = 9$; 42.9% vs, $n = 5$; 7.0%, $p < 0.001$).

Table 2 Clinical characteristics of patients according to age

	Total ($n=127$)	Age < 30 years ($n=97$)		Age ≥ 30 years ($n=30$, 23.6%)	p value*
		Age < 18 years ($n=76$, 59.8%)	18 ≤ Age < 30 years ($n=21$, 16.5%)		
Neurological diseases					
Hypoxic brain damage, n (%)	57 (44.9)	56 (57.7)		1 (3.3)	< 0.001
		46 (60.5)	10 (47.6)		
Congenital, *n* (%)	29 (22.8)	29 (29.9)		0	< 0.001
		23 (30.3)	6 (28.6)		
Degenerative disease, *n* (%)	23 (18.1)	5 (5.1)		18 (60.0)	< 0.001
		2 (2.6)	3 (14.3)		
Cerebrovascular disease, *n* (%)	12 (9.4)	3 (3.1)		9 (30.0)	< 0.001
		3 (4.0)	0		
Brain tumors, *n* (%)	3 (2.4)	2 (2.1)		1 (3.3)	0.56
		1 (1.3)	1 (4.8)		
Muscle diseases, *n* (%)	2 (1.6)	2 (2.1)		0	1.00
		1 (1.3)	1 (4.8)		
Without neurological disease, *n* (%)	1 (0.8)	0		1 (3.3)	
Type of surgery					
Non-TL[a], *n* (%)	111 (87.4)	92 (94.8)		19 (63.3)	< 0.001
		75 (98.7)	17 (81.0)		
TL, *n* (%)	16 (12.6)	5 (5.2)		11 (36.7)	
		1 (1.3)	4 (19.0)		
Tracheotomy before surgery, *n* (%)	32 (25.1)	21 (21.7)		11 (36.1)	0.17
		15 (19.7)	6 (28.6)		

TL total laryngectomy

[a]Non-TL included tracheoesophageal diversion, subglottic laryngeal closure and other modified procedures

*The results of *p* value of Fisher's exact test between the < 30 years group and the ≥ 30 years group

Unadjusted curves of postoperative dependence on parenteral and enteral nutrition in the < 30 years and ≥ 30 years groups are shown in Fig. 2. Postoperative dependence on parenteral and enteral nutrition was lower in the ≥ 30 years group than in the < 30 years group (log-rank test $p < 0.001$). Figure 3 illustrates the cumulative probabilities free from post-surgical parenteral and enteral nutritional support. The curves were grouped according to the duration of preoperative parenteral and enteral nutrition, with a cut-off value of 14.7 months. Dependence on parenteral and enteral nutrition was lower in the shorter duration of preoperative parenteral and enteral nutrition groups than in the longer duration group (log-rank test $p = 0.041$). There was no statistical difference in the postoperative dependence on parenteral and enteral nutrition between patients who underwent non-TL and those who underwent TL (log-rank test, $p = 0.46$). In the multivariable Cox proportional hazards analysis, the HR for oral intake without parenteral and enteral nutrition was lower in the longer preoperative duration of parenteral and enteral nutrition groups. However, the difference was not statistically significant (HR 0.55; 95% CI 0.15–2.08, $p = 0.38$). The HR for oral intake was significantly higher in the ≥ 30 years group than in the < 30 years group (HR 13.76; 95% CI 4.18–42.24; $p < 0.001$).

In the post hoc analyses, no statistical difference was observed among adult patients (aged ≥ 18 years) in the postoperative dependence on parenteral and enteral nutrition between patients who underwent non-TL and those who underwent TL (HR 1.407; 95% CI 0.292–6.79; $p = 0.67$), nor between patients with ≥ 14.7 months duration of preoperative parenteral and enteral nutrition group and those with < 14.7 months duration (HR 0.28; 95% CI 0.034–2.21; $p = 0.22$). In multivariable Cox proportional analysis for postoperative oral intake without dependence on parenteral and enteral nutrition according to underlying neurological diseases, we excluded patients without neurological disease and those with brain tumor or muscle disease because there was only one patient with each of these conditions. Multivariable Cox proportional analysis conducted among patients of all ages showed that the HRs for postoperative oral intake of patients with degenerative disease and cerebrovascular disease were significantly higher than the HRs for patients

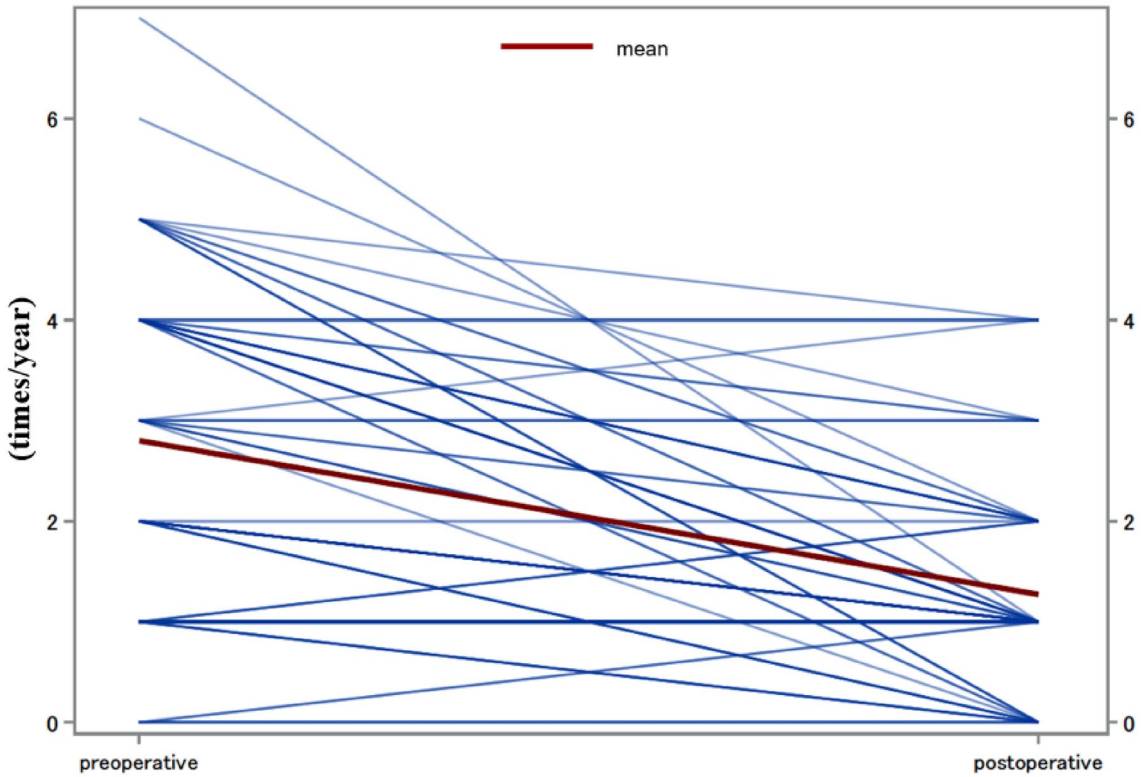

Fig. 1 Comparison of the number of pneumonia episodes (times/year) before and after surgery in 70 patients. The frequency of pneumonia was decreased by 1.52/year after surgery ($p < 0.001$)

with hypoxic brain damage (degenerative disease: HR 9.06; 95% CI; 2.14–38.3; $p = 0.0024$, cerebrovascular disease: HR 10.51; 95% CI 2.30–47.98; $p = 0.0027$; Table 3).

Sensitivity Analysis

In the analyses after changing the definition of patients taking oral nutrition to those without a fee for enteral nutrition or parenteral nutrition for more than 60 and 120 days, the postoperative dependence on parenteral and enteral nutrition was lower in the ≥ 30 years age group than in the < 30 years age group (log-rank test: 60 days, $p < 0.001$; 120 days, $p < 0.001$). There was no statistical difference in the postoperative dependence on parenteral and enteral nutrition between the ≥ 14.7 months duration of preoperative parenteral and enteral nutrition group than the < 14.7 months group (log-rank test: 60 days: $p = 0.075$, 120 days: $p = 0.064$). The dependence of patients on parenteral and enteral nutrition was lower in the TL group than in the non-TL group in the analysis, after changing the definition of patients taking oral nutrition (log-rank test: $p = 0.036$). However, there was no statistical difference in the analysis after changing the definition for 120 days (log-rank test: $p = 0.41$). In the multivariable Cox proportional hazards analysis, HRs for oral intake without parenteral and enteral nutrition were not significantly different between shorter and longer durations of preoperative parenteral and enteral nutrition (60 days: HR 0.56; 95% CI 0.14–2.08; $p = 0.38$, 120 days: HR 0.59; 95% CI 0.15–2.30; $p = 0.45$), and were significantly higher in the ≥ 30 years group than in the < 30 years group (60 days: HR 13.76; 95% CI 4.18–45.24; $p < 0.001$; 120 days: HR 11.71; 95% CI 3.43–39.93; $p < 0.001$).

Discussion

In this observational study of population under 75 years of age, we investigated the clinical characteristics and outcomes of patients who underwent surgery for intractable aspiration, such as the feeding condition, and the frequency of pneumonia.

Consistent with previous studies, neurological disease was the most common comorbidity in patients who underwent aspiration prevention surgery [2, 4, 10, 21]. The underlying neurological disorders were different between patients aged < 30 years and ≥ 30 years. In the < 30 age group, disorders from infancy, such as hypoxic brain damage and congenital disease were common. In the ≥ 30 years age group, disorders that occurred after adulthood, such as degenerative disease and cerebrovascular disease were common. In

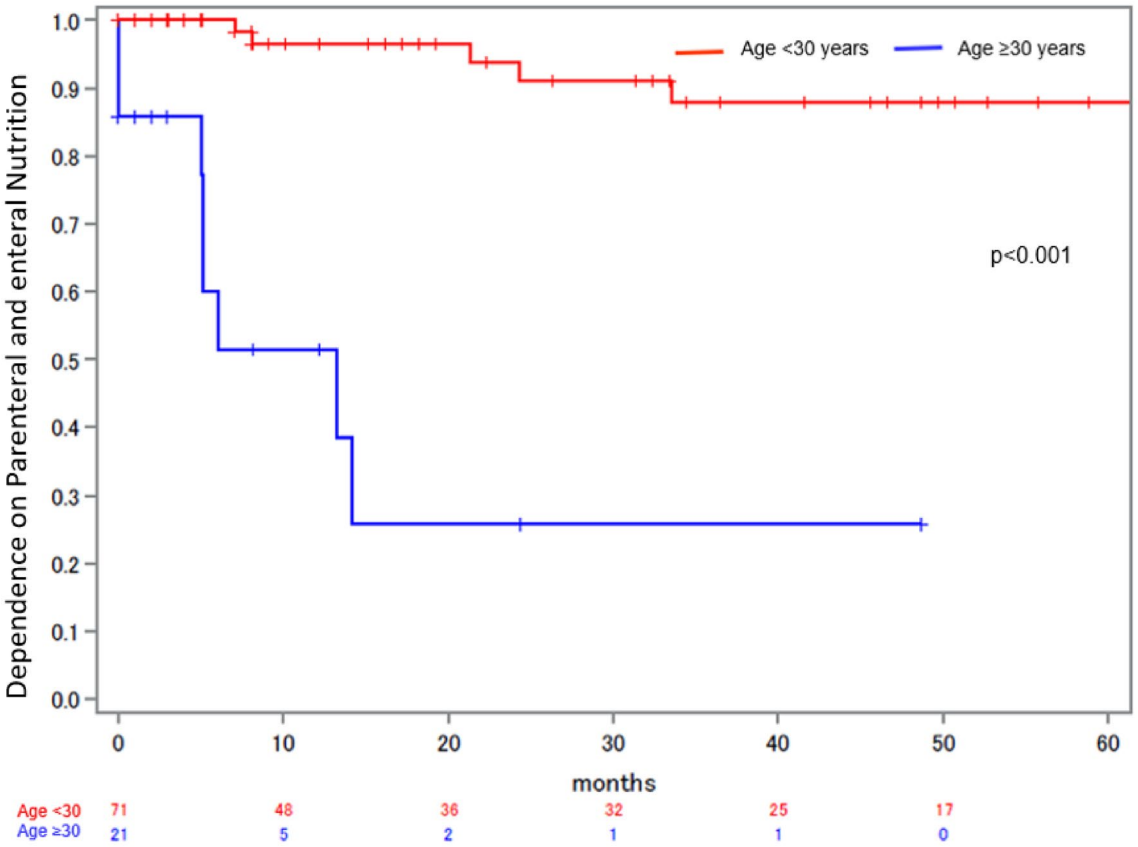

Fig. 2 Kaplan–Meier curves of postoperative dependence on parenteral and enteral nutrition in the < 30 years group and the ≥ 30 years group ($n = 92$). The numbers at the bottom of the figure shows the number of patients at risk

the population under 75 years of age, aspiration prevention surgeries in Japan were often performed at less than 30 years of age. LTS was more likely to be performed than TL in the < 30 years age group than in the ≥ 30 years age group. This may be due to the fact that reversible procedures that preserve the larynx in young patients are preferred by their families and doctors [22].

Aspiration prevention surgeries, which completely separate the digestive and respiratory tracts, are effective in reducing aspiration pneumonia. In this study, the frequency of pneumonia was significantly decreased after aspiration prevention surgery, as seen in previous studies on patients who underwent LTS, TL, tracheoesophageal diversion, and subglottic laryngeal closure [3, 7, 10–12, 14, 15]. In our study, the rate of decrease in the annual number of pneumonia episodes before and after surgery was 53.6%, and the rate was relatively low compared to the other two studies that evaluated episodes of aspiration pneumonia (90–96%) [14, 15]. These previous studies are reports from a single institution, each of which may have involved a relatively large number of aspiration prevention surgeries. On the other hands, we used an insurance claims database, which is likely to have included facilities with large number of aspiration prevention surgeries and those with small number of surgeries. Institutional factors such as the number of surgeries may have influenced the results of pneumonia episodes. Publication bias should be considered as studies with good outcomes have been more likely to be reported. Our study might have underestimated the efficacy of surgery, because we included only pneumonia episodes that required hospitalization and antibiotic infusions, which can include episodes other than aspiration pneumonia. After aspiration prevention surgery that completely separates the digestive and respiratory tracts, there is no salivary flow into the trachea. However, a loss of the nasal functions such as cleaning, heating, and moisturizing effects on inhaled air can cause respiratory problems and pulmonary infections [23]. The remaining studies could not be compared to the results of our study because they calculated the number of pneumonia episodes in different ways [3, 7, 10–12].

The feeding route after surgery may depend on the general condition of the patient [4]. A case series of 15 pediatric patients with severe motor and intellectual disability who underwent LTS or TED reported that no patient could tolerate an oral diet postoperatively [15]. In contrast, a single-institute retrospective study of 44 patients who underwent

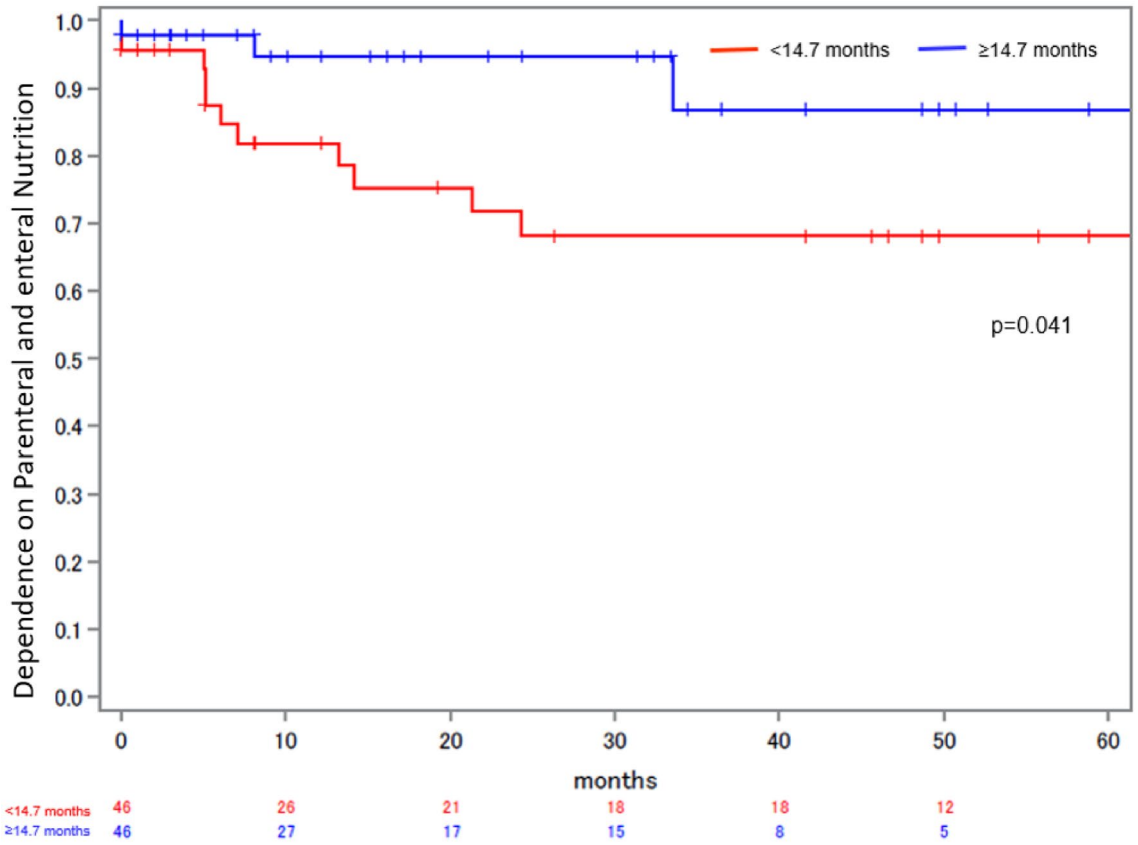

Fig. 3 Kaplan–Meier curves of postoperative dependence on parenteral and enteral nutrition in the shorter duration of preoperative parenteral and enteral nutrition group (< 14.7 months) and in the longer duration group (≥ 14.7 months) ($n = 92$). The numbers at the bottom of the figure shows the number of patients at risk

Table 3 Multivariable Cox proportional analysis for postoperative oral intake without dependence on parenteral and enteral nutrition according to underlying neurological diseases

	Adjusted HR (95% CI)	*p* value
Neurological diseases		
Hypoxic brain damage	1 [reference]	
Congenital	1.17 (0.20–7.01)	0.86
Degenerative disease	9.06 (2.14–38.3)	0.0024
Cerebrovascular disease	10.51 (2.30–47.98)	0.0027

$N = 89$

HR hazard ratio; *CI* confidence interval

TED reported that the percentage of patients whose main nutritional route was oral intake significantly increased from 21 to 56% within one month after surgery, and patients who maintained their mobility and communication ability were more likely to be able to consume food orally after surgery [2]. In our study, postoperative dependence on parenteral and enteral nutrition was lower in the ≥ 30 years group than in the < 30 years group. The result might be affected by the difference in the severity of motor and intellectual disability between the two groups, because the underlying neurological disorders were different between patients aged < 30 years and those aged ≥ 30 years. The HRs for postoperative oral intake in patients with degenerative disease and cerebrovascular disease were significantly higher than the HRs for patients with hypoxic brain damage. Degenerative disease and cerebrovascular disease were found to be common underlying neurological conditions in those aged ≥ 30 years. However, patients with degenerative disease, which is common in patients aged ≥ 30 years, may gradually lose their ability of oral intake as the degenerative disease progresses, even if oral intake is once possible after surgery.

Postoperative dependence on parenteral and enteral nutrition was lower in the shorter duration of preoperative parenteral and enteral nutrition group than in the longer duration group based on the Kaplan–Meier analysis. However, there was no significant difference in the multivariable analysis or sensitivity analysis. A greater number of patients and more confounding factors such as the severity of motor and intellectual disability should be examined to establish the association between the duration of preoperative parenteral and

enteral nutrition and postoperative feeding conditions. With regard to the "use it or lose it" paradigm, myoarchitectural changes are known to rapidly occur with disuse. Over time, disuse atrophy manifests as a reduction in muscle strength, increased fatigability, and aberrant motor control [24]. Greater use of the swallowing mechanism is likely to result in better postoperative feeding conditions. A study using an ovine model suggested that the swallowing outcomes after TL were superior to those after LTS [25]. In this study, there was no statistical difference in postoperative dependence on parenteral and enteral nutrition between patients who underwent TL and those who underwent non-TL, including other modified procedures such as TED and subglottic laryngeal closure. The association between surgical procedures and postoperative feeding conditions in actual clinical situations has not been reported. In the analyses among patients aged ≥ 18 years the outcomes of postoperative feeding condition were similar to the outcomes of the analyses among patients of all ages between patients who underwent non-TL and TL, and between patients who received preoperative parenteral and enteral nutrition for ≥ 14.7 months and those who received it for < 14.7 months.

Limitation

The present study has several limitations. First, the insurance claims database used in this study was primarily collected for billing purposes, and detailed clinical information was not obtained in certain conditions. We could not evaluate the impact of aspiration prevention surgery on quality of life as information on swallowing function, phonatory function, and mobility could not be obtained from the database. We could not distinguish between patients who were fed only with enteral nutrition and those who were fed both enterally and orally. We could not detect anastomotic leakage or fistula formation, which are postoperative complications of aspiration prevention surgery. We were unable to identify the cause of intractable aspiration accurately from the disease name of the database, but we estimated comorbidities that might have affected the indications for aspiration prevention surgery. The cause of death also could not be identified from the database. Second, people aged 75 years and older were not included in the database. This should be considered when interpreting the results of this study. No previous studies investigated the differences in postoperative feeding outcomes between young adults and older patients, but it might be possible that patients aged 75 years and older have poorer postoperative feeding outcomes. Third, the study patients were limited to those living in Japan who were primarily of Asian ethnicity. Therefore, the generalizability of our study results to patients of other countries and other ethnicities may be limited.

Conclusion

This retrospective cohort study used a nationwide insurance claims database in the population aged < 75 years and demonstrated that aspiration prevention surgeries were performed in patients with neurological disease and that postoperative oral intake was achieved more frequently in patients aged ≤ 30 years than in those aged > 30 years. This is the first multi-institutional analysis of patients who underwent surgery for intractable aspiration. This study supports the effectiveness of aspiration prevention surgery in reducing aspiration pneumonia. Further research is necessary to investigate the factors related to postoperative oral intake, such as the timing of surgery and surgical procedures.

Author Contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by KM, MT and YK. The first draft of the manuscript was written by KM and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declarations

Conflict of interest Koji Kawakami has received research funds from Eisai Co. Ltd.; Kyowa Kirin Co. Ltd.; Sumitomo Dainippon Pharma Co. Ltd.; Pfizer Inc.; Stella Pharma Corporation; CMIC Co. Ltd.; Suntory Beverage & Food Ltd.; Mitsubishi Corporation, and Real World Data Co. Ltd.; consulting fees from LEBER Inc.; JMDC Inc.; Shin Nippon Biomedical Laboratories Ltd.; Kaken Pharmaceutical Co. Ltd.; and Advanced Medical Care Inc.; executive compensation from Cancer Intelligence Care Systems; Inc.; honorarium from Mitsubishi Chemical Holdings Corporation, Mitsubishi Corporation, and Pharma Business Academy; and holds stock in Real World Data Co. Ltd.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent The requirement for informed patient consent was waived because this study was a secondary analysis of anonymous patient data.

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