

Patient Characteristics and Outcomes Following Swallowing Improvement Surgeries

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Abstract

Swallowing improvement surgeries (SISs) are performed to restore oral intake in patients with dysphagia, but evidence regarding combined surgical approaches remains limited. This retrospective single-center study investigated postoperative outcomes and factors associated with oral intake improvement, tracheostoma closure, and postoperative complications in 59 patients who underwent SIS between 2010 and 2025. Most patients had stroke or neurological diseases and exhibited substantial preoperative swallowing dysfunction. Cricopharyngeal myotomy and laryngeal suspension were performed in 74.6% and 71.2% of patients, respectively, and multiple procedures were performed in 66.1%. Postoperatively, swallowing function and oral intake significantly improved, with median Penetration–Aspiration Scale scores improving from 6 to 1 and Functional Oral Intake Scale (FOIS) scores improving from 1 to 5 (both $p < 0.001$). FOIS improvement of ≥ 2 points was observed in 55.9% of patients. Laryngeal suspension, multiple procedures, and lower preoperative FOIS scores were associated with postoperative oral intake improvement, whereas vocal cord medialization was associated with successful tracheostoma closure. Postoperative complications occurred in 33.9% of patients, most commonly surgical site infection. These findings suggest that individualized multilevel SIS procedures may effectively improve swallowing function and oral intake in patients with neurogenic dysphagia, although careful perioperative management remains important because of the relatively high complication rate.

Introduction

Dysphagia is a common and serious condition that can result from various neurological, muscular, or structural disorders. While rehabilitative and compensatory strategies form the mainstay of dysphagia management, surgical intervention is indicated in select patients to restore the swallowing mechanism or to prevent aspiration [1, 2]. Surgical management of dysphagia can be broadly categorized into swallowing improvement surgeries and aspiration prevention surgeries. The former aims to restore the physiological mechanisms of swallowing by correcting anatomical or functional abnormalities, while the latter focuses on airway protection by separating the respiratory and alimentary tracts [3, 4].

Swallowing improvement surgeries (SISs) seek to reestablish bolus transit by reconstructing or modifying the structures responsible for swallowing, such as the soft palate, larynx, and upper esophageal sphincter. For instance, pharyngeal flap surgery is performed for velopharyngeal insufficiency [5], laryngeal suspension for impaired laryngeal elevation [6, 7], and cricopharyngeal myotomy for upper esophageal sphincter dysfunction [8]. Medialization thyroplasty or injection laryngoplasty may also be indicated for glottic insufficiency [1]. However, the choice of SIS varies depending on the site and severity of the dysfunction, and it is often necessary to combine multiple procedures to achieve optimal functional recovery [9–12]. Therefore, a single standardized technique or predetermined combination of procedures may not be suitable for all patients. At our institution, detailed preoperative evaluations are routinely performed using videofluoroscopic swallowing study (VFSS), fiberoptic endoscopic evaluation of swallowing (FEES), and high-resolution manometry (HRM) to identify

the specific anatomical and functional abnormalities requiring surgical intervention. When indicated, multiple swallowing improvement procedures are actively combined according to each patient's individual pathophysiology.

Although SIS is increasingly recognized as an important treatment option for severe dysphagia, most previous studies have focused on single procedures. Patients with severe dysphagia often present with multilevel dysfunction, requiring pathophysiology-based combined surgical approaches to achieve functional recovery. Despite this clinical reality, evidence regarding combined SIS procedures remains limited, and predictors of postoperative outcomes—including oral intake improvement, tracheostoma closure, and postoperative complications—have not been fully clarified.

Accordingly, the present study retrospectively examined patients who underwent swallowing improvement surgery at our institution, focusing on postoperative changes in oral intake and swallowing function, tracheostoma outcomes, postoperative complications, and factors associated with these outcomes.

Methods

Study design and patients

We included patients who underwent SISs at the Department of Otolaryngology, the University of Tokyo Hospital, between January 2010 and March 2025. Patients with insufficient clinical data, follow-up of less than six months, or isolated vocal cord medialization primarily for the treatment of dysphonia were excluded. The study protocol was approved by the Human Ethics Committee of the University of Tokyo (No. 2487, 2022179NI) and complied with the tenets of the amended Declaration of Helsinki. Written informed consent was obtained from every patient, and patient anonymity was preserved.

Methodology

We conducted a retrospective single-center study by reviewing medical records retrieved from the hospital database. We analyzed clinical and demographic data, including age, sex, primary diseases, surgical procedures performed, time from onset of dysphagia to surgery, patient ability to follow commands, performance status, oral intake status, and preoperative nutritional condition. In addition, preoperative swallowing function, presence of vocal cord paralysis, degree of laryngeal sensation, bacteria carriage, presence of tracheostomy, and history of hypertension or diabetes were assessed. Primary diseases were classified as stroke, brain tumor, other neurological diseases, respiratory diseases, head and neck malignancies, non-malignant head and neck tumors, infectious diseases, and others. Performance status was graded on a five-point scale (0–5), with grade 5 indicating the most severe condition [13](Supplemental Table 1). Oral intake status was evaluated using the Functional Oral Intake Scale (FOIS) [14]. This seven-point ordinal scale reflects the patient's level of functional oral intake, with higher scores indicating a more normal diet. Nutritional status was evaluated using

Onodera’s prognostic nutritional index (O-PNI) [15], calculated as follows: $10 \times \text{serum albumin (g/dL)} + 0.005 \times \text{total lymphocyte count (/mm}^3\text{)}$. O-PNI value of ≤ 40 is generally considered to indicate poor nutritional status, and in such cases, major resections or anastomoses are typically avoided. Swallowing function was evaluated using the Penetration–Aspiration Scale (PAS) based on VFSS. The PAS ranges from 1 (normal swallowing) to 8 (severe aspiration). Laryngeal sensation was categorized as normal, hypesthetic, or anesthetic based on endoscopic findings and was subsequently analyzed as normal versus reduced/absent sensation. Bacterial carriage was determined from the most recent pharyngeal or sputum culture obtained prior to surgery.

Postoperative outcomes included complications, tracheostoma status, swallowing function, and oral intake status. Complications included bleeding, surgical site infection, pneumonia, airway stenosis, and other adverse events. Tracheostoma outcomes were evaluated six months postoperatively, including tracheostoma closure and the use of speech cannulas or non-fenestrated cuffed tracheostomy tubes. Postoperative swallowing function was assessed using the best available PAS data obtained within six months after surgery, whereas postoperative oral intake status was evaluated using the FOIS score at six months postoperatively. FOIS improvement was defined as an increase of ≥ 2 points from the preoperative score to the score six months postoperatively.

Factors associated with postoperative FOIS improvement, tracheostoma closure, and postoperative complications were analyzed using clinical and demographic variables.

Statistical Analyses

We analyzed all data using BellCurve for Excel (version 4.03; Social Survey Research Information Co., Ltd.) and examined the relationship between clinical and demographic variables and postoperative outcomes, including FOIS improvement, tracheostoma closure, and postoperative complications. Continuous variables are presented as median and interquartile range (IQR) and were compared using the Mann–Whitney U test, whereas categorical variables are presented as numbers and percentages and were analyzed using Fisher’s exact test. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for variables that could be analyzed using 2×2 contingency tables. A p value < 0.05 was considered statistically significant.

Results

Demographics

Table 1 summarizes the demographic and clinical characteristics of the 59 patients included in this study. The median age was 67.5 years (IQR, 62.0–75.0), and 46 patients (78.0%) were male. Stroke was the most common primary disease (33 patients, 55.9%), followed by other neurological diseases (10, 16.9%). Head and neck malignancies and non-malignant head and neck tumors each accounted for 3 patients (5.1%). Cricopharyngeal myotomy and laryngeal suspension were performed in 45 patients

(76.2%) and 42 patients (71.2%), respectively, and multiple procedures were performed in 39 patients (66.1%). The median time from onset of dysphagia to surgery was 14.5 months (IQR, 7.0–38.8).

Table 1

Demographic and clinical characteristics of the patients no., number; IQR, interquartile range; FOIS, Functional Oral Intake Scale; PAS, Penetration–Aspiration Scale; O-PNI, Onodera's prognostic nutritional index.

Patients, no.	59
Age, years, median (IQR)	67.5 (62.0–75.0)
Sex (male), no. (%)	46 (78.0)
Primary diseases, no. (%)	
Stroke	33 (55.9)
Other neurological diseases	10 (16.9)
Head and neck malignancies	3 (5.1)
Non-malignant head and neck tumors	3 (5.1)
Brain tumors	2 (3.4)
Infectious diseases	2 (3.4)
Others	6 (10.2)
Surgical procedures, no. (%)	
Cricopharyngeal myotomy	45 (76.2)
Laryngeal suspension	42 (71.2)
Vocal cord medialization, no. (%)	14 (24)
Pharyngeal flap surgery	8 (13.6)
Cervical osteophytectomy	4 (6.8)
Hypopharyngoplasty	2 (3.4)
Single procedure, no. (%)	20 (33.9)
Multiple procedures, no. (%)	39 (66.1)
Time from onset to surgery, months, median (IQR)	14.5 (7.0–38.8)
Sufficient ability to follow commands, no. (%)	59 (100)
Performance status, median (IQR)	2 (1–3)
PAS score, median (IQR)	6 (3–8)
FOIS (preoperative), no. (%)	
1	34 (57.6)
2	9 (15.3)

Patients, no.	59
3	5 (8.5)
4	2 (3.4)
5	4 (6.8)
6	1 (1.7)
7	4 (6.8)
Reduced or absent laryngeal sensation, no. (%)	42 (71.2)
Vocal cord paralysis, no. (%)	36 (61.0)
O-PNI, median (IQR)	39.0 (26.0–41.0)
Bacteria carriage, no. (%)	29 (49.2)
Presence of tracheostomy, no. (%)	22 (37.3)
Hypertension, no. (%)	30 (50.8)
Diabetes, no. (%)	12 (20.3)

Preoperatively, patients generally exhibited severe dysphagia. The median performance status was 2 (IQR, 1–3), the median PAS score was 6 (IQR, 3–8), and 34 patients (57.6%) had a FOIS score of 1. Reduced or absent laryngeal sensation was observed in 42 patients (71.2%), vocal cord paralysis in 36 (61.0%), bacterial carriage in 29 (49.2%), and tracheostomy in 22 (37.3%). The median O-PNI was 39.0 (IQR, 26.0–41.0). Hypertension and diabetes were present in 30 patients (50.8%) and 12 patients (20.3%), respectively.

Postoperative outcomes

As shown in Table 2, postoperative complications occurred in 20 patients (33.9%), including surgical site infection in 10 (50.0%), pneumonia in 3 (15.0%), bleeding in 2 (10.0%), and other complications in 5 (25.0%). A total of 43 patients (72.9%) required postoperative tracheostomy management, including 22 patients (51.2%) with pre-existing tracheostomy and 21 (48.8%) who underwent tracheostomy creation during surgery. At 6 months postoperatively, tracheostoma closure was achieved in 13 patients (30.2%), whereas 28 (65.1%) were managed with a speech cannula and 2 (4.7%) required a non-fenestrated cuffed tracheostomy tube (Fig. 1A).

Table 2
Postoperative outcomes. no., number; IQR, interquartile range.

Postoperative outcomes	
Complications, no. (%)	20 (33.9)
Bleeding, no. (%)	2 (10.0)
Surgical site infection, no. (%)	10 (50.0)
Pneumonia, no. (%)	3 (15.0)
Airway stenosis, no. (%)	1 (5.0)
Others, no. (%)	4 (20.0)
Patients requiring tracheostomy postoperatively, no. (%)	43 (72.9)
Pre-existing tracheostomy, no. (%)	22 (51.2)
Newly created tracheostomy at surgery, no. (%)	21 (48.8)
Status at 6 months postoperatively	
Tracheostoma status	
Closure, no. (%)	13 (30.2)
Using speech cannula, no. (%)	28 (65.1)
Using non-fenestrated cuffed tracheostomy tube, no. (%)	2 (4.7)
PAS (postoperative), median (IQR)	1 (1–1)
FOIS (postoperative), median (IQR)	5 (3–7)
Improvement ≥ 1 point, no. (%)	44 (74.6)
Improvement ≥ 2 points, no. (%)	33 (55.9)
Improvement ≥ 3 points, no. (%)	23 (39.0)
Improvement ≥ 4 points, no. (%)	22 (37.3)
Improvement ≥ 5 points, no. (%)	15 (25.4)
Improvement ≥ 6 points, no. (%)	8 (13.6)

Swallowing function and oral intake status significantly improved after surgery. The median PAS score improved from 6 (IQR, 3–8) preoperatively to 1 (IQR, 1–1) postoperatively ($p < 0.001$), whereas the median FOIS score increased from 1 (IQR, 1–3) to 5 (IQR, 3–7) ($p < 0.001$) (Fig. 1B, C). FOIS improvement of ≥ 2 points was observed in 33 patients (55.9%).

Associations between clinical factors and FOIS improvement

Clinical factors associated with postoperative FOIS improvement are summarized in Table 3. FOIS improvement of ≥ 2 points was significantly associated with laryngeal suspension (84.8% vs. 53.8%, OR 4.80, 95% CI 1.41–16.34, $p = 0.019$) and multiple procedures (78.8% vs. 50.0%, OR 3.71, 95% CI 1.19–11.55, $p = 0.0279$). In contrast, patients undergoing a single procedure were less likely to achieve significant FOIS improvement (21.2% vs. 50.0%, OR 0.27, 95% CI 0.09–0.84, $p = 0.0279$). Preoperative FOIS scores were significantly lower in the improvement group (median 1 [IQR, 1–1] vs. 3 [1.3–5.0], $p < 0.001$). Vocal cord paralysis tended to be more frequent in the improvement group, although the difference did not reach statistical significance (72.7% vs. 46.2%, $p = 0.0594$).

Table 3

Associations between clinical factors and FOIS improvement no., number; IQR, interquartile range; OR, odds ratio; CI, confidence interval; FOIS, Functional Oral Intake Scale; PAS, Penetration–Aspiration Scale; O-PNI, Onodera's prognostic nutritional index; *, $p < 0.05$; ***, $p < 0.001$.

Patients, no.	Score improvement group	Minimal score improvement group	OR (95% CI)	p value
	33	26		
Age, years, median (IQR)	68.0 (62.0–74.0)	57.0 (62.3–76.5)		0.96
Sex (male), no. (%)	27 (81.8)	19 (73.1)	1.66 (1.48–5.72)	0.531
Primary diseases, no. (%)				
Stroke	20 (60.6)	13 (50.0)		0.303
Brain tumors	2 (6.1)	0	4.21 (0.19–91.53)	0.499
Other neurological diseases	5 (15.2)	5 (19.2)	0.75 (0.19–2.93)	0.737
Head and neck malignancies	2 (6.1)	1 (3.8)	1.61 (0.14–18.83)	1
Non-malignant head and neck tumors	0	3 (11.5)	0.10 (0.00–2.03)	0.08
Infectious diseases	2 (6.1)	0	4.21 (0.19–91.53)	0.499
Others	2 (6.1)	4 (15.4)	0.35 (0.06–2.11)	0.39
Surgical procedures performed, no. (%)				
Laryngeal suspension	28 (84.8)	14 (53.8)	4.80 (1.41–16.34)	0.019*
Cricopharyngeal myotomy	25 (75.8)	20 (76.9)	0.94 (0.28–3.15)	1
Vocal cord medialization	8 (24.2)	6 (23.1)	1.07 (0.32–3.58)	1

Patients, no.	Score improvement group	Minimal score improvement group	OR (95% CI)	p value
	33	26		
Pharyngeal flap surgery	6 (18.2)	2 (7.7)	2.67 (0.49–14.48)	0.446
Hypopharyngoplasty	2 (6.1)	0 (0)	4.21 (0.19–91.53)	0.499
Cervical osteophytectomy	3 (9.1)	0 (0)	6.08 (0.30–123.22)	0.248
Single procedure, no. (%)	7 (21.2)	13 (50.0)	0.27 (0.09–0.84)	0.0279*
Multiple procedures, no. (%)	26 (78.8)	13 (50)	3.71 (1.19–11.55)	0.0279*
Time from onset to surgery, months, median (IQR)	14.0 (9.9–35.0)	14.5 (7.0–45.8)		0.754
Sufficient ability to follow commands, no. (%)	31 (93.9)	24 (92.3)	1.29 (0.17–9.85)	1
Performance status, median (IQR)	2 (1–3)	2 (1–3)		0.843
PAS score, median (IQR)	7 (4–8)	6 (3–8)		0.322
FOIS (preoperative), median (IQR)	1 (1–1)	3 (1.3–5.0)		p < 0.001***
O-PNI, median (IQR)	39.0 (36.0–40.3)	39.0 (33.3–41.0)		0.827
Reduced or absent laryngeal sensation, no. (%)	24 (72.7)	18 (69.2)	1.19 (0.38–3.67)	0.781
Bacteria carriage, no. (%)	18 (54.5)	11 (42.3)		0.451
Vocal cord paralysis, no. (%)	24 (72.7)	12 (46.2)	3.11 (1.05–9.23)	0.0594
Presence of tracheostomy, no. (%)	14 (42.4)	8 (30.8)	1.66 (0.56–4.89)	0.423
Hypertension, no. (%)	17 (51.5)	13 (50)		0.022

Patients, no.	Score improvement group	Minimal score improvement group	OR (95% CI)	p value
	33	26		
Diabetes, no. (%)	6 (18.2)	6 (23.1)	0.74 (0.21–2.64)	0.749

Associations between clinical factors and tracheostoma closure

Clinical factors associated with tracheostoma closure are shown in Table 4. Vocal cord medialization was significantly associated with successful tracheostoma closure (46.2% vs. 13.3%, OR 5.57, 95% CI 1.22–25.36, $p = 0.044$). In contrast, stroke was significantly less frequent in the closure group than in the non-closure group (30.8% vs. 70.0%, OR 0.19, 95% CI 0.05–0.78, $p = 0.0225$). Hypertension was also less common among patients who achieved tracheostoma closure (30.8% vs. 66.7%, OR 0.22, 95% CI 0.05–0.90, $p = 0.0457$). Shorter duration from onset of dysphagia to surgery and lower preoperative FOIS scores tended to be associated with successful closure, although these differences did not reach statistical significance.

Table 4

Associations between clinical factors and tracheostoma closure no., number; IQR, interquartile range; OR, odds ratio; CI, confidence interval; FOIS, Functional Oral Intake Scale; PAS, Penetration–Aspiration Scale; O-PNI, Onodera's prognostic nutritional index; *, $p < 0.05$.

Patients, no.	Closure group	Non-Closure group	OR (95% CI)	p value
	13	30		
Age, years, median (IQR)	68.0 (67.0–73.0)	65.5 (62.0–73.0)		0.354
Sex (male), no. (%)	12 (92.3)	25 (83.3)	2.40 (0.25–22.88)	0.649
Primary diseases, no. (%)				
Stroke	4 (30.8)	21 (70.0)	0.19 (0.05–0.78)	0.0225*
Brain tumors	2 (15.4)	0 (0)	13.26 (0.59–297.69)	0.086
Other neurological diseases	2 (15.4)	3 (10.0)	1.64 (0.24–11.18)	0.63
Head and neck malignancies	2 (15.4)	1 (3.3)	5.27 (0.43–64.16)	0.213
Non-malignant head and neck tumors	1 (7.7)	2 (6.7)	1.17 (0.10–14.13)	1
Infectious diseases	1 (7.7)	1 (3.3)	2.42 (0.14–41.88)	0.518
Others	1 (7.7)	2 (6.7)	1.17 (0.10–14.13)	1
Surgical procedures performed, no. (%)				
Laryngeal suspension	11 (84.6)	29 (96.7)	0.19 (0.02–2.31)	0.213
Cricopharyngeal myotomy	9 (69.2)	23 (76.7)	0.68 (0.16–2.92)	0.709
Vocal cord medialization	6 (46.2)	4 (13.3)	5.57 (1.22–25.36)	0.044*
Pharyngeal flap surgery	1 (7.70)	2 (6.67)	1.17 (0.10–14.13)	1
Hypopharyngoplasty	2 (15.4)	4 (13.3)	1.18 (0.19–7.43)	1

Patients, no.	Closure group	Non-Closure group	OR (95% CI)	p value
	13	30		
Cervical osteophylectomy	2 (15.4)	0 (0)	13.26 (0.59–297.69)	0.086
Single procedure, no. (%)	3 (23.1)	5 (16.7)	1.50 (0.30–7.49)	0.681
Multiple procedures, no. (%)	10 (76.9)	25 (83.3)	0.67 (0.13–3.33)	0.681
Time from onset to surgery, months, median (IQR)	10 (7–26)	21.5 (11.3–38.8)		0.085
Sufficient ability to follow commands, no. (%)	12 (92.3)	28 (93.3)	0.86 (0.07–10.38)	1
Performance status, median (IQR)	2 (1–2)	2 (1–3)		0.517
PAS score, median (IQR)	6 (3–7)	8 (4.3–8)		0.126
FOIS (preoperative), no. (%)	2 (1–2)	1 (1–1)		0.074
O-PNI, median (IQR)	39.0 (37.0–40.0)	38.0 (34.0–40.0)		0.245
Reduced or absent laryngeal sensation, no. (%)	9 (69.2)	22 (73.3)	0.82 (0.20–3.42)	1
Bacteria carriage, no. (%)	7 (53.8)	17 (56.7)	0.89 (0.24–3.30)	1
Vocal cord paralysis, no. (%)	9 (69.2)	21 (70.0)	0.96 (0.23–3.96)	1
Presence of tracheostomy before surgery, no. (%)	5	17	0.48 (0.13–1.81)	0.332
Hypertension, no. (%)	4 (30.8)	20 (66.7)	0.22 (0.05–0.90)	0.0457*
Diabetes, no. (%)	2 (15.4)	8 (26.7)	0.50 (0.09–2.77)	0.696

Factors associated with postoperative complications

Factors associated with postoperative complications are summarized in Table 5. No significant associations were identified between postoperative complications and clinical or demographic variables, although laryngeal suspension and multiple procedures tended to be more frequent in patients with complications.

Table 5

Factors associated with postoperative complications no., number; IQR, interquartile range; OR, odds ratio; CI, confidence interval; FOIS, Functional Oral Intake Scale; PAS, Penetration–Aspiration Scale; O-PNI, Onodera's prognostic nutritional index.

Patients, no.	With complications	Without complications	OR (95% CI)	p value
	20 (34)	39 (66)		
Age, years, median (IQR)	64.5 (58.5–73.0)	68.0 (63.5–76.5)		0.45
Sex (male), no. (%)	17 (85)	29 (74)	1.95 (0.47–8.10)	0.511
Primary diseases, no. (%)				
Stroke	12 (60.0)	21 (53.8)	1.29 (0.43–3.84)	0.784
Brain tumors	0 (0.0)	2 (5.1)	0.37 (0.92–7.99)	0.544
Other neurological diseases	2 (10.0)	8 (20.5)	0.43 (0.08–2.25)	0.469
Head and neck malignancies	2 (10.0)	1 (2.6)	4.22 (0.36–49.68)	0.263
Non-malignant head and neck tumors	1 (5.0)	2 (5.1)	0.97 (0.08–11.44)	1
Infectious diseases	2 (10.0)	0 (0)	10.68 (0.49–233.73)	0.111
Others	1 (5.0)	5 (12.8)	0.36 (0.04–3.29)	0.653
Surgical procedures				
Laryngeal suspension, no. (%)	17	25	3.17 (0.79–12.75)	0.1318
Cricopharyngeal myotomy, no. (%)	14	31	0.60 (0.18–2.07)	0.5213
Vocal cord medialization, no. (%)	6	8	1.66 (0.48–5.70)	0.5213
Pharyngeal flap surgery, no. (%)	4	4	2.19 (0.48–9.87)	0.4245
Hypopharyngoplasty, no. (%)	0	2	0.37 (0.02–7.99)	0.5441
Cervical osteophytectomy, no. (%)	2	2	2.06 (0.27–15.80)	0.5984

Patients, no.	With complications	Without complications	OR (95% CI)	p value
	20 (34)	39 (66)		
Single procedure, no. (%)	4 (20)	16 (41.0)	0.36 (0.10–1.28)	0.149
Multiple procedures, no. (%)	16 (80)	23 (59.0)	2.78 (0.78–9.89)	0.149
Time from onset to surgery, months, median (IQR)	12.5 (8.8–29.3)	21 (7–44.5)		0.149
Sufficient ability to follow commands, no. (%)	20 (100)	35 (90.0)	5.20 (0.27–101.5)	0.289
Performance status, median (IQR)	2 (1–2.5)	2 (1–3)		0.678
PAS score, median (IQR)	7 (3–8)	7 (3–8)		0.088
FOIS (preoperative), no. (IQR)	1 (1–2)	1 (1–3)		0.678
O-PNI, median (IQR)	39.0 (37.0–42.0)	39.0 (33.5–40.5)		0.63
Reduced or absent laryngeal sensation, no. (%)	14 (70)	28 (71.8)		0.987
Bacteria carriage, no. (%)	10 (50)	19 (48.7)	1.05 (0.36–3.09)	1
Vocal cord paralysis, no. (%)	14 (70)	22 (56.4)	1.80 (0.57–5.68)	0.402
Presence of tracheostomy, no. (%)	16 (80)	27	1.78 (0.49–6.46)	0.538
Hypertension, no. (%)	8 (40)	22 (56.4)	0.52 (0.17–1.54)	0.279
Diabetes, no. (%)	5 (25)	7 (17.9)	1.52 (0.41–5.60)	0.518

Discussion

In the present study, swallowing improvement surgeries resulted in significant improvements in swallowing function and oral intake status in patients with substantial swallowing dysfunction. In particular, combined pathophysiology-based procedures, including laryngeal suspension and cricopharyngeal myotomy, were frequently performed and were associated with favorable postoperative outcomes. Clinically meaningful FOIS improvement was achieved in more than half of the patients, despite marked preoperative swallowing impairment. Furthermore, laryngeal suspension, multiple

procedures, and lower preoperative FOIS scores were associated with postoperative oral intake improvement. In addition, vocal cord medialization was associated with successful tracheostoma closure.

A characteristic feature of the present cohort was that more than 70% of the patients had stroke or neurological diseases, whereas head and neck diseases accounted for only approximately 10% of cases. Dysphagia after head and neck cancer treatment is often caused by structural defects, fibrosis, and sensory impairment associated with surgery, radiotherapy, or chemotherapy [16]. In contrast, patients with stroke or neurological diseases generally do not have structural abnormalities in the cervical region, and dysphagia mainly results from impaired neuromuscular coordination and multilevel functional impairment. Therefore, the underlying pathophysiology differs substantially between these patient populations. In neurological diseases, both single SIS [2, 17, 18] and combined pathophysiology-based SIS procedures [1, 7, 9, 11] have been performed according to the site and severity of dysfunction. In contrast, reports regarding dysphagia after head and neck disease treatment have mainly described single SIS procedures [19, 20], and the limitations of SIS have also been recognized in this population [16, 21]. In the present study, postoperative FOIS and PAS scores improved significantly, and laryngeal suspension as well as multiple procedures were associated with postoperative FOIS improvement. These findings may reflect the characteristics of the present cohort, in which multilevel functional impairment was common. Because pharyngeal-phase dysphagia can involve complex dysfunction at multiple anatomical and physiological levels, surgical strategies tailored to the underlying pathophysiology may provide greater functional benefit than a single standardized procedure. In the present cohort, multiple procedures were frequently combined according to each patient's functional impairment. Therefore, the favorable outcomes observed in this study may reflect not only the use of multiple procedures but also careful procedure selection based on detailed preoperative pathophysiological assessment. At our institution, VFSS, FEES, and HRM are routinely used to identify the specific mechanisms of dysphagia, allowing individualized surgical planning tailored to each patient's functional impairment. Among the procedures performed, laryngeal suspension was significantly associated with postoperative FOIS improvement. This finding is also physiologically plausible. Laryngeal suspension mechanically elevates and advances the larynx, thereby facilitating bolus passage through widening of the esophageal inlet. In addition, anterior-superior laryngeal displacement promotes epiglottic retroflexion and anterior displacement of the arytenoid region, thereby narrowing the laryngeal vestibule and reducing aspiration risk [1]. These structural modifications may contribute to improved postoperative oral intake.

In the present study, vocal cord medialization was identified as a significant positive factor associated with tracheostoma closure. Successful tracheostoma closure requires not only improvement in swallowing function but also maintenance of safe airway management (28649385). This finding appears physiologically reasonable, as medialization of the vocal cord improves glottic closure during phonation and swallowing, thereby reducing aspiration risk while improving cough effectiveness and airway clearance [22, 23]. In contrast, stroke was identified as a negative factor associated with tracheostoma closure. Patients with stroke are more likely to exhibit persistent pharyngolaryngeal sensory impairment

and reduced spontaneous expectoration ability as neurological sequelae [24, 25]. Therefore, even when postoperative oral intake improved, maintenance of the tracheostoma may have been considered necessary to ensure airway safety and secretion management. Hypertension was also negatively associated with tracheostoma closure. This association may have been influenced by the high proportion of stroke patients in the present cohort, because hypertension is a major risk factor for stroke [26]. Further validation using multivariable analyses in larger cohorts is warranted.

Postoperative complications occurred in 34% of patients following SIS, with surgical site infection accounting for approximately half of these complications. In the present study, no significant risk factors for postoperative complications were identified; however, this may have been influenced by the limited sample size. Laryngeal suspension has been reported to be associated with complications such as wound infection, cervical abscess, airway edema, and thyroid cartilage injury. In particular, foreign materials such as sutures or tapes used for laryngeal elevation may serve as a nidus for infection [6, 7]. In addition, poor oral hygiene and oropharyngeal bacterial colonization may contribute to postoperative infectious complications, including pneumonia [27]. Cricopharyngeal myotomy also requires careful attention to complications including pharyngeal fistula, esophageal perforation, and deep cervical or mediastinal infection [28]. Despite the relatively high complication rate observed in this cohort, clinically meaningful improvements in swallowing function and oral intake were achieved in many patients. Therefore, careful perioperative management and appropriate patient selection remain essential when performing combined SIS procedures.

This study has several limitations. First, this was a retrospective single-center study with a relatively small sample size, which may have limited the statistical power to identify significant factors associated with postoperative outcomes. In particular, multivariable analyses could not be performed because of the limited number of outcome events. Second, the study population was heterogeneous with respect to underlying diseases and surgical procedures, reflecting the individualized and pathophysiology-based nature of SIS. Third, because most patients had stroke or neurological diseases, the findings may primarily reflect the characteristics of neurogenic dysphagia. Finally, longer-term postoperative outcomes were not fully assessed. Further prospective multicenter studies with larger cohorts are warranted to validate the present findings.

Conclusion

In conclusion, SIS significantly improved swallowing function and oral intake status in patients with substantial swallowing dysfunction. Combined pathophysiology-based SIS procedures, particularly laryngeal suspension, were associated with favorable postoperative outcomes, suggesting the importance of individualized multilevel surgical strategies for neurogenic dysphagia. Vocal cord medialization may contribute to successful tracheostoma closure by improving airway safety and cough effectiveness. Although postoperative complications were relatively common, careful perioperative management and appropriate patient selection may help maximize the functional benefits of SIS.

Declarations

Author Contributions

R.T.: performed patients' care, collected and analyzed the data, and wrote the draft of the manuscript. R.U.: developed the concept, designed the study, performed patients' care, collected and analyzed the data, and wrote the draft of the manuscript. T.G.: performed patients' care, collected the data, and reviewed the manuscript. R.I.: performed patients' care, collected the data, and reviewed the manuscript. C.C.: performed patients' care and performed English editing of the manuscript. M.K.: performed patients' care and reviewed the manuscript. T.S.: performed patients' care and reviewed the manuscript. A.M.: performed patients' care, collected the data, and reviewed the manuscript. K.K.: developed the concept and reviewed the manuscript.

All authors: interpreted the data and contributed to the writing of the manuscript.

All authors have read and agreed to the published version of the manuscript.

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None

Ethical Statement

The study protocol was approved by the Human Ethics Committee of the University of Tokyo (No. 2487, 2022179NI) and complied with the tenets of the amended Declaration of Helsinki.

Data Availability Statement

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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Figures

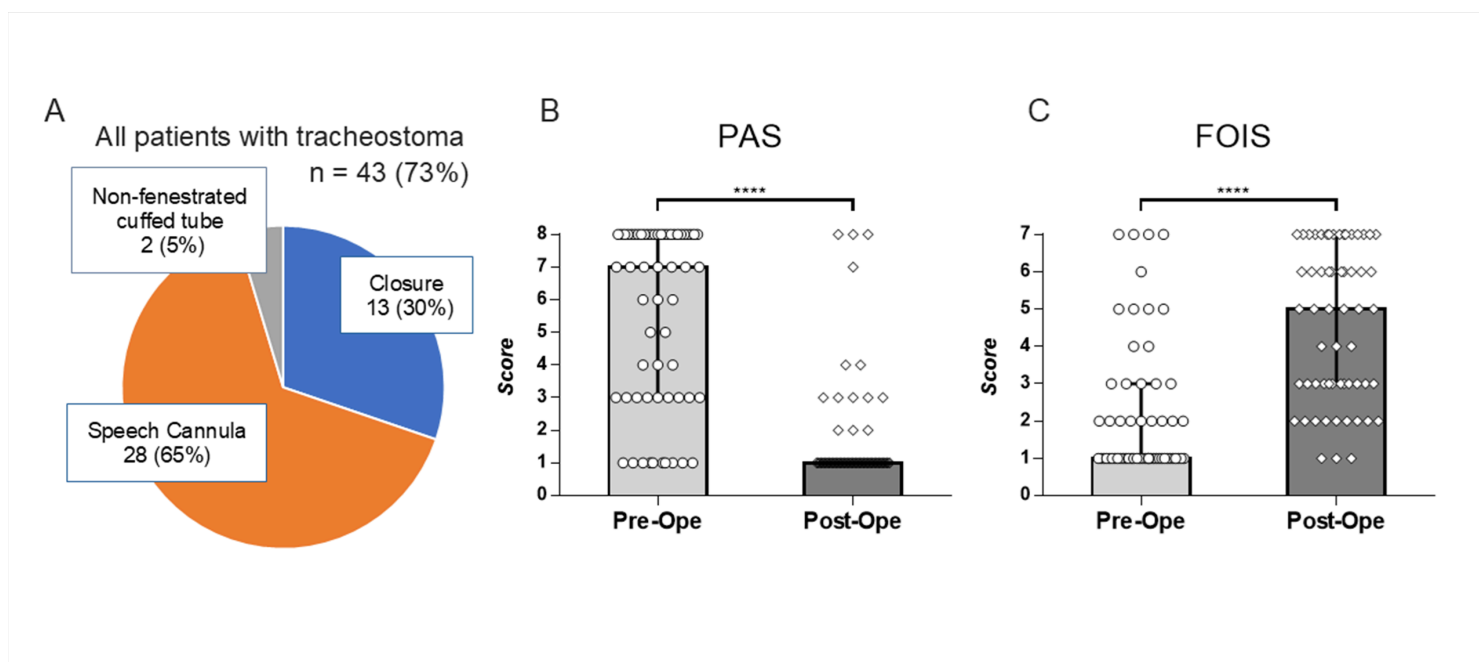


Figure 1

(A) Tracheostoma status at 6 months postoperatively. (B,C) Comparison of preoperative and postoperative PAS (B) and FOIS (C) scores. PAS, Penetration–Aspiration Scale; FOIS, Functional Oral Intake Scale. ****, $p < 0.0001$.

Supplementary Files

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- [SupplementalTable1.docx](#)