Dysphagia (2018) 33:857–865
https://doi.org/10.1007/s00455-018-9920-9

ORIGINAL ARTICLE

Changes in Swallowing and Cough Functions Among Stroke Patients Before and After Tracheostomy Decannulation

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Received: 9 January 2018 / Accepted: 14 June 2018 / Published online: 18 June 2018

Abstract

We investigated the functional changes in swallowing and voluntary coughing before and after tracheostomy decannulation among stroke patients who had undergone a tracheostomy. We also compared these functions between stroke patients who underwent tracheostomy tube removal and those who did not within 6 months of their stroke. Seventy-seven stroke patients who had undergone a tracheostomy were enrolled. All patients were evaluated by videofluoroscopic swallowing studies and a peak flow meter through the oral cavity serially until 6 months after their stroke. During the intensive rehabilitation period, if a patient satisfied the criteria for tracheostomy tube removal, the tube was removed. The patients were divided into the 'decannulated' group and the 'non-decannulated' group according to their tracheostomy tube removal status. In the decannulated group, swallowing function did not change before and after tracheostomy decannulation; however, cough function was significantly improved after decannulation. Although both groups exhibited functional improvement in swallowing and coughing over time, the improvement in the decannulated group was more significant than the improvement in the non-decannulated group. Our results revealed that stroke patients who had better functional improvement in swallowing and coughing were more likely to be potential candidates for tracheostomy decannulation. Stroke patients who recovered from neurogenic dysphagia, they were no longer affected by the mechanical effect of the tracheostomy tube on swallowing function. This study suggests that if patients show improvement in swallowing and coughing after their stroke, a multidisciplinary approach to tracheostomy decannulation would be needed to achieve better rehabilitation outcomes.

Keywords Stroke · Tracheostomy · Deglutition · Cough · Decanulation · Function

Introduction

After a stroke, patients may lack the ability to protect their airway. When prolonged mechanical ventilation is required, a tracheostomy is frequently performed [1]. Although early tracheostomy in stroke patients may have several benefits [2, 3], decannulation of the tracheostomy tube is preferred if the underlying reason for tracheostomy tube placement has been resolved.

Although there is currently no protocol for the decannulation process, previous studies have proposed the following criteria for tracheal decannulation after traumatic brain injury [4, 5]: level of consciousness, tracheostomy tube capping, respiration, blue dye test, swallowing, and coughing. Other published guidelines have also revealed that patients should have efficient spontaneous coughing and subsequent swallowing function [6]. Therefore, according to the findings of previous studies, two important factors that are required prior to removal of a tracheostomy tube are swallowing and voluntary coughing, which is also referred to as expectoration [4–7].

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The effect of a tracheostomy tube on swallowing and cough functions has been investigated. Several suggested mechanisms for swallowing dysfunction after tracheostomy include a decrease in laryngeal elevation caused by tethering of the larynx by the tracheostomy tube [8–10], direct obstruction of the pharyngeal pathway by the tube cuff [11], and desensitization of the larynx due to chronic air diversion [12, 13]. A tracheostomy also affects cough function. Tracheostomized patients often have difficulty in initiating the compressive coughing phase, and cough flow is typically insufficient [14]. Another study demonstrated a significant increase in peak cough flow (PCF) after tracheostomy tube decannulation [15].

Recent studies have shown that the presence of a tracheostomy tube does not affect the biomechanics or kinematics of swallowing [16–18]. However, these studies were performed in patients who had sufficient swallowing and cough functions to safely remove the tracheostomy tube at the subacute stage or chronic stage. In addition, the enrolled patients in these studies had various etiologies that required tracheostomy tube placement, including stroke, vocal cord palsy, neuromuscular disorder, sepsis, and sleep apnea.

Few studies have evaluated functional changes in stroke patients before and after tracheostomy tube removal. Current studies have suggested a pattern of recovery after stroke with the timing of specific intervention strategies, which include multidisciplinary rehabilitation therapy [19]. As stroke shows various clinical manifestations and recovery processes, swallowing and cough functions also change and improve after a stroke over time. In addition, the mechanical effect of a tracheostomy tube on swallowing and cough functions differ depending on the time after stroke onset, because neurogenic dysphagia after stroke recovers over time. If a patient is a potential candidate for tracheostomy tube removal, personalized, intensive approaches are needed for tracheostomy decannulation.

The aims of this study were to investigate the functional changes in swallowing and voluntary coughing before and after tracheostomy decannulation in stroke patients. We also compared these functional statuses between stroke patients who underwent tracheostomy tube removal and those who did not within 6 months of their stroke. In addition, we evaluated various functional statuses other than swallowing and cough function, such as cognition and activities of daily living.

Methods

Subjects

This study was designed as an observational prospective study and was conducted in the rehabilitation center of a university hospital, specifically a regional cerebrovascular center. Subacute stroke patients who had undergone a tracheostomy between March 2015 and December 2016 were enrolled. Patients who had previous strokes, a history of head or neck cancer, neuromuscular disease, or a poor general condition that would not permit the videofluoroscopic swallowing studies (VFSS) were excluded. All patients were in the subacute period of stroke and received personalized, intensive rehabilitation including physiotherapy, occupational therapy, swallowing therapy, and speech therapy.

The study protocol was approved by the institutional review board, and all participants provided written informed consent. (Dong-A University Hospital, IRB No: 15-156).

Tracheostomy Decannulation

The criteria for tracheostomy tube removal were adopted from previous studies [4, 5]: alert mental status, good respiratory function; anatomically intact upper airway as determined by laryngoscopy; including the ability to tolerate tracheostomy tube capping; reduced tracheal secretions; and intact swallowing and cough function. Patients who had undergone tracheostomy, had the ability to tolerate tube capping for 48 h and had the capacity to expectorate without assistance were eligible for tracheostomy tube removal. Tracheostomy decannulation was performed with consultation from the Department of Otorhinolaryngology. No patients required reinsertion of their tracheostomy tube after removal. The tracheostomy tubes were not downsized prior to tube decannulation.

Evaluation

All patients underwent VFSS and peak flow meter evaluations through the oral cavity to measure PCF every 2 or 4 weeks according to their medical and neurological condition. If patients satisfied the criteria for tracheostomy tube removal, the tracheostomy tube was removed. VFSS and PCF evaluations were performed within 7 days before and after tracheostomy decannulation. In patients who were not able to have their tracheostomy tube removed, these evaluations were serially performed within 6 months of their stroke. The patients were divided into a ‘decannulated’ group and a ‘non-decannulated’ group according to their tracheostomy removal status. All test procedures were recorded, and the findings were analyzed by three experienced physiatrists.

Functional Evaluations

Swallowing Function

Swallowing function was evaluated using the functional dysphagia scale (FDS) and penetration aspiration scale (PAS) based on the results of the VFSS. VFSS were performed with the patients in a sitting position to allow a lateral view. A modified version of the protocol from a study performed by Logemann was employed [20]. All patients received individualized feeding therapy based on the results of the VFSS.

The FDS was developed to quantify the severity of dysphagia; it correlates well with the American Speech-Language-Hearing Association national outcome measurement system criteria [21]. The FDS consists of 11 items with weighted values that represent 4 types of oral functions (lip closure, bolus formation, residues in oral cavity, and oral transit time) and 7 types of pharyngeal functions (triggering of pharyngeal swallow, laryngeal elevation and epiglottic closure, nasal penetration, residue in valleculae, residue in pyriformis sinus, coating of pharyngeal wall after swallowing, and pharyngeal transit time) that can be observed using VFSS. To determine the differences in the parameters related to a tracheostomy tube, the patients' FDS scores were divided into subsections and analyzed.

The PAS evaluates airway invasions [22] and has a maximum score of 8 points. Scores are determined primarily based on the depth to which material passes into the airway and whether material entering the airway can be expelled. The penetration category corresponds to level 5 on the scale, and levels 6–8 correspond to laryngo-tracheal aspiration. A PAS score of 8 indicates that material enters the airway, passes below the vocal folds, and no effort is made to eject the material.

Voluntary Cough Function

PCF was used to measure voluntary coughing ability, which was assessed by having patients cough as forcefully as possible through a peak flow meter. Prior to testing, patients were allowed to use the peak flow meter several times to become accustomed to the test. For PCF testing, the opening of the tracheostomy tube was temporarily occluded during expiration, and the patient's lips were placed tightly around a mouthpiece. A maximum of three attempts were used for the analysis. PCF is the primary parameter in assessing voluntary coughing efficacy; numerous studies have employed this parameter as a voluntary cough measurement tool [23–25].

Parameters that can affect functional outcomes, including initial stroke characteristics, Korean version of Mini-Mental State Examination (K-MMSE) scores, Korean version of the modified Barthel Index (K-MBI) scores, and the presence of aphasia and neglect, were also evaluated.

Statistical Analysis

SPSS 21.0 for Windows was used for statistical analysis. Student's t test and the Chi-square test were performed to compare the two groups, namely, the group of patients who were eligible for tracheostomy tube removal within 6 months after their stroke and the group of patients who were not. A paired t-test or repeated-measure analysis of variance (ANOVA) was used to compare data obtained serially in each group. A p value of less than 0.05 was considered statistically significant. Post hoc analysis was performed using the Tukey honestly significant difference test if there was a significant effect using the repeated-measures ANOVA.

Results

One hundred and one patients with a tracheostomy tube were enrolled from March 2015 to December 2016. Among these patients, 13 were excluded, and 11 were lost to follow-up. Seventy-seven patients satisfied the inclusion criteria and were analyzed in this study. Most patients (63 patients, 81.8%) were transferred from the Department of Neurosurgery due to a large amount of intracerebral hemorrhage (ICH), intravenous hemorrhage (IVH), malignant ischemic infarction with hemorrhage transformation, or malignant ischemic infarction with severe brain edema that showed midline shifting and required a craniectomy. Tracheostomy was performed 10.9 ± 6.1 days after the onset of stroke. The most common cause of tracheostomy was failure of ventilator weaning. Of the included patients, 35 were eligible for tracheostomy tube removal within 6 months of their stroke.

Table 1 lists the baseline demographic characteristics of the tracheostomized patients. At the onset of stroke, the patients in the decannulated group were significantly younger than the patients in the non-decannulated group (the patients who were ineligible for tracheostomy tube removal within 6 months of their stroke). The initial stroke characteristics, including ischemic or hemorrhagic stroke and supratentorial or infratentorial stroke, and the initial National Institutes of Health Stroke Scale (NIHSS) scores, were not significantly different between these two groups. In addition, the initial functional evaluations, including

Table 1 Baseline demographic characteristics of tracheostomy patients

	Decannulated group (n = 35)	Non-decannulated group (n = 42)	p value
Age	50.6 ± 11.0	63.7 ± 10.1	0.03*
Gender (male/female)	20/15	23/19	0.087
Days from stroke onset	27.4 ± 5.9	31.8 ± 11.4	0.158
Duration from stroke onset to tracheostomy (days)	10.1 ± 5.0	12.6 ± 5.5	0.113
Stroke character			
Ischemic/hemorrhagic	11/24	14/28	0.071
Operation (craniectomy, craniotomy)	7/19	20/17	0.416
Supratentorial/infratentorial	22/13	19/23	0.57
Rt/Lt/bilateral	8/12/15	15/12/15	
Initial NIHSS	21.4 ± 6.2	23.2 ± 4.4	0.471
Initial mRS	4.7 ± 2.4	4.8 ± 2.1	0.128
Neglect (yes/no)	11/24	20/22	0.081
Aphasia (yes/no)	13/22	16/26	0.283
FDS total (0–100)	48.2 ± 35.1	52.9 ± 28.7	0.352
FDS oral (0–38)	10.2 ± 7.3	15.1 ± 8.2	0.087
FDS pharyngeal (0–62)	34.7 ± 15.3	46.5 ± 20.2	0.139
PAS	7.1 ± 3.4	7.8 ± 2.9	0.661
PCF (L/min)	57.1 ± 29.8‡	51.5 ± 32.7§	0.597
K-MBI (0–100)	11.8 ± 10.5	5.7 ± 10.7	0.073
K-MMSE (0–30)	4.6 ± 12.1	1.9 ± 9.3	0.258

Values are the number or mean ± SD

NIHSS National Institute of Health Stroke scale, *MRS* modified Rankin Scale, *FDS* functional dysphagia scale, *PAS* penetration aspiration scale, *PCF* peak cough flow, *K-MBI* Korean-version of the modified Barthel index, *K-MMSE* Korean-version of the mini-mental state examination

*$p < 0.05$ by the Student t-test

‡Only in 14 patients

§Only in 17 patients

swallowing, coughing, cognition, and activities of daily living, showed no statistically significant between-group differences.

Figure 1 shows the changes in swallowing functions among patients who were eligible for tracheostomy tube removal (decannulated group) at initial evaluation and before and after tracheostomy decannulation, according to the time. Patients in the decannulated group demonstrated significant improvements in swallowing function over time. Post hoc analysis showed that based on the FDS scores, significant improvement in swallowing function was achieved from baseline to before tracheostomy tube removal, and from baseline to after tracheostomy tube removal; however, no significant changes were observed when comparing swallowing function between before and after tracheostomy decannulation (Fig. 1a). However, based on the PAS scores, significant improvement was observed between before and after the tracheostomy decannulation (Fig. 1b). Cough function also showed significant improvement over time, and the post hoc test revealed that cough function was significantly improved after tracheostomy tube removal (Fig. 2).

In the decannulated group, the shortest duration of tracheostomy time was 37 days, which was achieved by a 31-year-old man with a hypertensive ICH in the basal ganglia and IVH. The lowest PCF score before tracheostomy tube removal of 112 L/min was observed in a 56-year-old male patient with malignant middle cerebral artery (MCA) infarction who had undergone a craniectomy. Among the decannulated patients, 31.4% required a limited diet consisting of soft blended diet and fluid with a thickener (viscosity range 351–1750 cP) [26] due to the risk of aspiration immediately prior to tracheostomy decannulation.

Table 2 shows the various functional changes in each group from the baseline evaluation to immediately before tracheostomy tube removal in the decannulated group and 6 months after tracheostomy tube removal in the non-decannulated group. In the non-decannulated group, which included patients who could not undergo tracheostomy tube removal, functional evaluations at baseline and at 6 months after the onset of stroke were compared. Both groups showed improvement in most functional measurements, including swallowing, coughing, cognitive function,

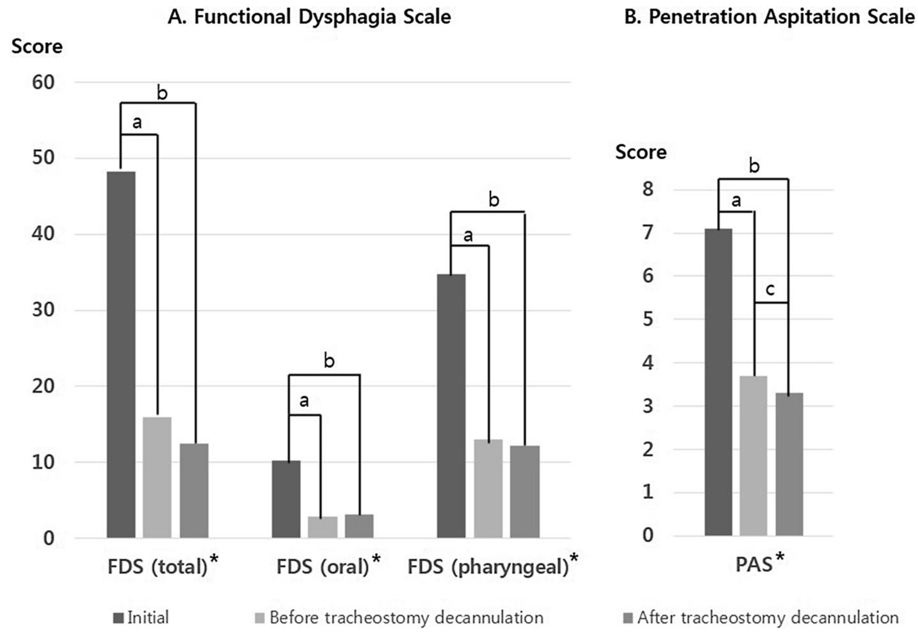

Fig. 1 Changes in swallowing function over time among patients who were eligible for tracheostomy tube removal. Patients in the decannulated group demonstrated significant improvements in swallowing function over time. Post hoc analysis showed that based on the FDS scores, significant improvement in swallowing function was achieved from baseline to before tracheostomy tube removal, and from baseline to after tracheostomy tube removal; however, no significant changes were observed between before and after tracheostomy decannulation (**a**). Based on the PAS scores, significant improvement was observed between before and after the tracheostomy decannulation (**b**). *$p < 0.05$ by ANOVA. Post hoc *t*-test: *a* $p < 0.017$ indicating a significant difference between initial and before tracheostomy decannulation. *b* $p < 0.017$ indicating a significant difference between initial and after tracheostomy decannulation. *c* $p < 0.017$ indicating a significant difference between before and after tracheostomy decannulation

and activities of daily living. However, patients in the non-decannulated group showed no improvements in the PCF and PAS scores.

The initial functional evaluations for both groups showed no significant differences. When we compared these two groups immediately prior to tracheostomy decannulation in the decannulated group and 6 months after the onset of stroke in the non-decannulated group, the patients in the decannulated group achieved significantly higher FDS, PAS, PCF, MBI and MMSE scores. In the decannulated group, all patients could tolerate an oral diet (24 received a normal regular diet and 11 received a limited diet). However, 38.1% ($n = 16$) of patients in the non-decannulated group could not consume their diet orally.

When comparing the changes between the two groups (Table 3), the decannulated group had significantly higher scores than the non-decannulated group for swallowing and coughing functions. The decannulated group also achieved higher activities of daily living (ADL) scores and showed greater cognitive function improvements than the non-decannulated group.

Complications related to tracheostomy decannulation, including arterial desaturation, tracheal stenosis, granuloma, and pneumonia, did not occur in this population. None of the patients required reinsertion of a tracheostomy tube after removal. The reasons for failure to remove a tracheostomy tube in the non-decannulated group ($n = 42$) included uncooperative mental status ($n = 20$, 47.6%), lack of coughing ability resulting in failure to expectorate sputum or post-swallowing residue ($n = 14$, 33.3%), large amounts of secretion, and failure to deflate the tracheostomy tube cuff ($n = 18$, 42.9%). Of the patients in the non-decannulated group, 16 (38.1%) could not restore oral swallowing function; thus, a percutaneous endoscopic gastrostomy tube was inserted. In addition, 7 patients had a recurrent stroke.

Discussion

This study aimed to demonstrate functional changes in swallowing and voluntary coughing among stroke patients before and after tracheostomy decannulation. When these functions were compared before and after tracheostomy decannulation, our results revealed that swallowing function did not change at tracheostomy tube removal, whereas cough function was significantly increased after tracheostomy decannulation.

Most stroke patients with a tracheostomy tube showed various functional improvements (including not only

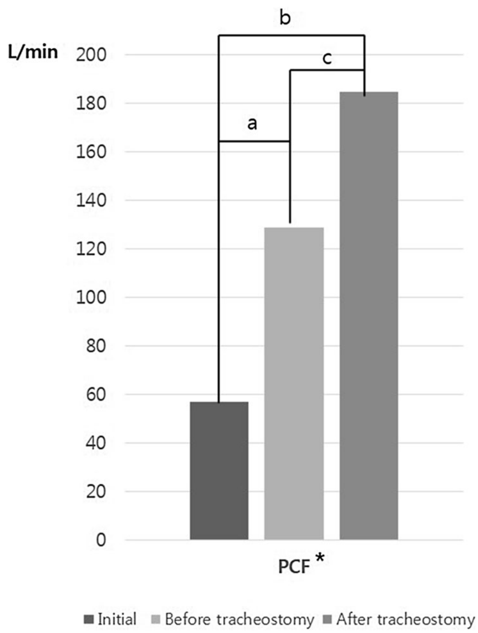

Fig. 2 Changes in cough function over time among patients in the decannulated group. The PCF scores showed significant improvement in cough function over time, and post hoc tests revealed that cough function was significantly improved after tracheostomy tube removal. *$p < 0.05$ by ANOVA. Post hoc *t*-test; *a* $p < 0.017$ indicating a significant difference between initial and before tracheostomy decannulation. *b* $p < 0.017$ indicating a significant difference between initial and after tracheostomy decannulation. *c* $p < 0.017$ indicating a significant difference between before and after tracheostomy decannulation

swallowing and coughing but also cognitive function and ADLs) over time regardless of whether she/he satisfied the criteria for tracheostomy tube removal. However, the functional improvement in patients who were eligible for tracheostomy tube removal (decannulated group) was significantly higher than the improvement among patients in the non-decannulated group. Patients who were younger at the onset of stroke and had better functional improvement and were more likely to be considered as a potential candidate for tracheostomy decannulation. The initial stroke characteristics were not related to the ability to perform tracheostomy decannulation.

Functional Changes in Swallowing and Coughing According to the Evaluation Time

Swallowing functions before and after tracheostomy decannulation did not significantly differ in this study. Previous studies have demonstrated that tracheostomy tubes do not affect the biomechanics and kinematics of swallowing function [16–18]. However, other studies have revealed the interference of tracheostomy on swallowing function due to a decrease in laryngeal elevation as a result of tethering of the larynx by the tracheostomy tube [8, 9], direct obstruction of the pharyngeal pathway by the tube cuff [11], and desensitization of the larynx.

The swallowing evaluation time after stroke onset was an important factor in the different effect from a tracheostomy tube on swallowing function. The acute phase of stroke patients involved neurogenic dysphagia and pharyngeal weakness; thus, the mechanical effects of a tracheostomy tube may negatively affect swallowing function. However, it appeared that stroke patients who had recovered from neurogenic dysphagia or displayed improvements in pharyngeal weakness were not affected by the mechanical effects of the tracheostomy tube on swallowing function. In previous studies [16–18], enrolled patients were in the chronic stages of their dysphagia symptoms or have recovered from neurogenic dysphagia; thus, swallowing function was not changed before and after tracheostomy tube removal.

In contrast, cough function after tracheostomy decannulation significantly increased, which is consistent with a previous study [14, 15]. It appears that the mechanical effect of a tracheostomy tube inhibits maximal cough function regardless of whether a patient's swallowing function has recovered. Because the tracheostomy tube is positioned in the way of cough output, thus, it acts as a barrier and can generate airway resistance against maximal cough function.

Relation Between Swallowing and Cough for Removal of the Tracheostomy Tube

Several studies reported that swallowing and coughing are important criteria for tracheal decannulation and are closely connected [4–6, 27]. However, safe decannulation was achieved in stroke patients who did not achieve normal functional status for both swallowing and coughing. Our previous study also indicated a discrepancy between swallowing and coughing in stroke patients based on their stroke lesion [28].

In this study, 31.4% of patients required a restricted dietary formula due to the risk of aspiration prior to tracheostomy decannulation. Even though patient's swallowing function was not completely recovered, if the patient's cough function was appropriate, with expectoration of post-swallowing residue, the patient was able to undergo their tracheostomy tube removal.

Mckim [15] and Winck [29] reported that PCF values greater than 160 L/min indicate successful decannulation. However, the mean PCF values prior to tracheostomy tube removal were 129.1 ± 28.1 L/min in our study, and 78% of patients obtained PCF values lower than 160 L/min. These patients showed no post-swallowing residue and had a low risk of pharyngeal aspiration; thus, they were able to have their tracheostomy tubes removed despite low PCF

Table 2 Functional changes between groups

	Decannulated group (n = 35)		p value	Non-decannulated group (n = 42)		p value	p value
	Initial	Before tracheostomy removal		Initial	6 months after onset		
Days from stroke onset	27.4 ± 5.9	82.6 ± 13.2	–	31.8 ± 11.4	183.7 ± 21.8	–	–
Tracheostomized period (days)	12.5 ± 4.8	67.7 ± 22.7	–	15.8 ± 8.1	173.6 ± 33.8	–	–
mRS	4.7 ± 2.4	2.8 ± 1.7	0.003*	4.8 ± 2.1	3.7 ± 2.5	0.02*	0.072†
FDS total (0–100)	48.2 ± 35.1	15.9 ± 8.5	0.001*	52.9 ± 28.7	33.3 ± 12.4	0.04*	0.001†
FDS oral (0–38)	10.2 ± 7.3	2.9 ± 4.3	0.001*	15.1 ± 8.2	10.1 ± 5.5	0.001*	0.001†
FDS pharyngeal (0–62)	34.7 ± 15.3	13.0 ± 10.1	0.02*	46.5 ± 20.2	32.4 ± 13.1	0.031*	0.001†
PAS	7.1 ± 3.4	3.7 ± 2.9	0.001*	7.8 ± 2.9	6.4 ± 3.1	0.06	0.002†
PCF (L/min)	57.1 ± 29.8‡	129.1 ± 28.1	0.001*	51.5 ± 32.7§	60.8 ± 11.8‖	0.184	0.001†
Diet (NRD/LD/nonoral)	0/0/35	24/11/0	–	0/0/42	0/26/16	–	
K-MBI (0–100)	11.8 ± 10.5	56.4 ± 30.1	0.001*	5.7 ± 10.7	34.9 ± 18.2	0.037*	0.001†
K-MMSE (0-30)	4.6 ± 12.1	21.8 ± 12.8	0.001*	1.9 ± 9.3	7.8 ± 5.1	0.001*	0.001†

Values are the number or mean ± SD

FDS functional dysphagia scale, *PAS* penetration aspiration scale, *PCF* peak cough flow, *NRD* normal regular diet, *LD* limited diet, *K-MBI* Korean-version of the modified Barthel index, *K-MMSE* Korean-version of the mini-mental state examination

*$p < 0.05$ by the Pared t-test in each group

†$p < 0.05$ by Student t-test, the two groups were compared immediately before tracheostomy decannulation in "decannulated" group patients and 6 months after the onset of stroke in "non-decannulated" group

‡Only in 14 patients

§Only in 17 patients

‖Only in 28 patients

Table 3 Comparison of functional changes between groups before tracheostomy removal

Changes	Decannulated group (n = 35) Changes between initial evaluation and before tracheostomy remoal	Non-decannulated group (n = 42) Changes between initial evaluation and 6 months after onset	p value
ΔFDS total	30.2 ± 17.5	23.3 ± 15.8	0.001*
ΔFDS oral	7.1 ± 5.5	5.4 ± 2.8	0.07
ΔFDS pharyngeal	24.7 ± 11.5	16.3 ± 12.7	0.01*
ΔPAS	3.6 ± 2.9	1.4 ± 1.9	0.002*
ΔPCF	80.9 ± 32.4	26.1 ± 11.7	0.02*
ΔK-MBI	52.1 ± 26.3	31.8 ± 11.9	0.03*
ΔK-MMSE	18.5 ± 12.7	7.1 ± 5.4	0.001*

Values are the number or mean ± SD

FDS functional dysphagia scale, *PAS* penetration aspiration scale, *PCF* peak cough flow, *K-MBI* Korean-version of the modified Barthel index, K-*MMSE* Korean-version of mini-mental status exam

*$p < 0.05$ by Student's t-test

values. In contrast, patients who had PCF values above 160 L/min but showed silent aspiration on VFSS were not able to have their tracheostomy tubes removed, particularly those with infratentorial lesions.

Thus, we would like to suggest that fully intact cough and swallowing function are not indications for tracheostomy tube removal. As previously described, various functions appear to be related to the ability to remove a patient's tracheostomy tube, and a multidisciplinary individual approach is needed to determine the earliest possible time at which the tube can be removed in stroke patients.

Multidisciplinary Approach to Tracheostomy Decannulation After a Stroke

In this study, when comparing the functional changes between two groups, the decannulated group had significantly higher scores than the non-decannulated group for swallowing, coughing, cognition, and ADL functions. Previous studies have emphasized that a multidisciplinary approach to post-tracheostomy care is important for the safe removal of a tracheostomy tube [6, 15, 27, 30]. Decannulation is a complex and multidisciplinary process that is affected by various factors. Our results indicated that various functions could affect tracheostomy tube removal in stroke patients. In this study, the functional status of the patient, including not only swallowing and cough functions but also ADL and cognitive functions, was evaluated; these functions could affect the safety of tracheostomy tube removal. This study was the first to evaluate the generalized functional status in stroke patients with tracheostomy after decannulation.

The removal of a tracheostomy tube is an important rehabilitation goal but cannot always be performed [31]. Only a few studies have focused on post-tracheostomy care and functional evaluations; thus, post-tracheostomy care is often neglected in an otherwise thorough evaluation of individual tracheostomy decannulation [30, 32]. Because most functions including swallowing and coughing, are shown to rapidly recover within 6 months after stroke, our results suggest that if a patient shows improvement in swallowing and cough functions after stroke in this period, a multidisciplinary approach to achieve the earliest possible time of tracheostomy decannulation is required for better rehabilitation outcomes. [19, 33].

Strengths and Limitations

To our knowledge, this study was the first to demonstrate various functional relationships before and after tracheostomy tube removal in patients with stroke. Only patients with subacute stage stroke who had undergone tracheostomy tube placement were enrolled.

However, this study has several limitations, particularly the low number of enrolled patients, and low number of subjects who completed the baseline PCF evaluation, particularly in the non-decannulated group, as after stroke, patients with aphasia, apraxia or cognitive impairment could not conduct PCF test according to the examiner's command. Although we attempted to classify the patients according to their stroke lesions, most patients had a malignant MCA infarction or large ICH, including IVH, and had both supratentorial and infratentorial lesions. As a result, we were unable to divide the groups by distinct stroke lesions. Furthermore, the times at which both groups were compared differed; the decannulated group was evaluated before tracheostomy removal, whereas the non-decannulated group was evaluated 6 months after stroke. However, maximal recovery from stroke occurs within 6 months, which explains why we evaluated functional measures at 6 months in the decannulated group. We did not perform the blue dye test, which was one of the important factors of tracheostomy tube removal.

Conclusion

Our results revealed that swallowing function did not change before and after tracheostomy decannulation; however, cough function was significantly improved after decannulation. Stroke patients who recovered from neurogenic dysphagia, they were no longer affected by the mechanical effect of the tracheostomy tube on swallowing function. In addition, stroke patients who had better functional improvement in swallowing and coughing were more likely to be potential candidates for tracheostomy decannulation. Thus, we suggest that if patients show improvement in swallowing and cough functions after their stroke, a multidisciplinary approach to tracheostomy decannulation will be needed to achieve better rehabilitation outcomes.

Funding This study was partially supported by the Dong-A University research fund.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval This article does not contain any studies with human participants performed by any of the authors.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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