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# The modified water swallowing test score is the best predictor of postoperative pneumonia following extubation in cardiovascular surgery

## A retrospective cohort study

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**Abstract**

No guidelines have been established for the evaluation of swallowing function following extubation. The factors of bedside swallowing evaluations (BSEs) that are associated with the development of pneumonia have not been fully elucidated. This study aimed to retrospectively investigate the most appropriate measurements of BSEs for predicting pneumonia.

The study subjects were 97 adults who underwent BSEs following cardiovascular surgery. Patients were divided into the pneumonia onset group (n = 21) and the non-onset group (n = 76). Patient characteristics, intraoperative characteristics, complications, BSE results, and postoperative progress were compared between the groups. BSEs were composed of consciousness level, modified water swallowing test (MWST) score, repetitive saliva swallowing test score, speech intelligibility score, and risk of dysphagia in the cardiac surgery score. Univariate and multivariate analyses with the BSE as the independent variable and pneumonia onset as the dependent variable were also performed to identify factors that predict pneumonia. For factors that became significant in univariate analysis, the incidence of pneumonia was shown using the Kaplan-Meier curve.

No significant differences were found in patient characteristics, intraoperative characteristics, and complications between the 2 groups. The postoperative progress was significantly different between the 2 groups, the pneumonia-onset group had a significantly longer time until the start of oral intake and a significantly lower median value of Food Intake Level Scale at the time of discharge. According to univariate and multivariate analyses, MWST score was a significant factor for predicting the onset of pneumonia even after adjusting for patient characteristics and surgical factors, and the incidence of pneumonia increased approximately 3 times when the MWST score was 3 points or less.

The MWST score after extubation in cardiovascular surgery was the strongest predictor of postoperative pneumonia in BSEs. Furthermore, the incidence of pneumonia increased approximately 3 times when the MWST score was 3 points or less. Predicting cases with a high risk of developing pneumonia allows nurses and attending physicians to monitor the progress carefully and take aggressive preventive measures.

**Abbreviations:** BSEs = bedside swallowing evaluations, FILS = Food Intake Level Scale, GCS = Glasgow Coma Scale, MWST = modified water swallowing test, RODICS = risk of dysphagia in cardiac surgery, RSST = repetitive saliva swallowing test, ST = speech therapist.

**Keywords:** bedside swallowing examinations, dysphagia, intensive care unit, nosocomial pneumonia, post-extubation swallowing function, the 3-milliliter water swallowing test

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*The datasets analyzed during the current study are not publicly available due to protect personal information but are available from the corresponding author on reasonable request.*

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*The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.*

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## 1. Introduction

The risk of dysphagia following prolonged intubation is high, with a reported incidence as high as 62%.[1] The prognosis for patients with post-extubation dysphagia is poor. Several studies reported that post-extubation dysphagia increased the prevalence of nosocomial pneumonia and reintubation, delayed the start of oral intake, prolonged hospitalization, and increased mortality.[2–5] Pneumonia is considered a serious complication of post-extubation dysphagia. Following cardiovascular surgery, patients with pneumonia have a higher rate of mortality during hospitalization (28% vs 6.2%) and lower long-term survival (62% vs 81%) than those without pneumonia.[6] Therefore, to prevent aspiration that contributes to pneumonia, it is very important to assess swallowing function following extubation.

Previous studies have reported that patients experienced dysphagia following cardiovascular surgery and developed a score to predict the onset of dysphagia after extubation.[7] However, this score does not include results of the swallowing screening test. Another study showed that factors contributing to development of postoperative pneumonia following major non-cardiovascular surgery are also scored for risk prediction[8]; however, measurements related to swallowing function have not been established.

Although several studies have focused on bedside swallowing examinations (BSEs), most studies analyzed stroke patients, and few studies have targeted post-extubation swallowing function. In addition, no guidelines have been established for the evaluation of swallowing function following extubation, and factors of BSEs that are associated with the development of pneumonia have not been fully elucidated.

With this background, this study aimed to clarify the characteristics of patients who developed pneumonia following extubation and retrospectively investigate the most appropriate measurements of BSEs for predicting pneumonia following cardiovascular surgery.

## 2. Methods

### 2.1. Study design and participants

This retrospective cohort study was conducted at the department of Rehabilitation Medicine of Shinshu University Hospital. All adult patients (aged ≥20 years) who underwent cardiovascular surgery between April 2010 and April 2016 and whose swallowing function was evaluated by speech therapists (STs) following extubation were included in the analysis.

Cardiovascular surgery included great vessel graft replacement, valve replacement, valvuloplasty, coronary artery bypass grafting, and combined surgery. Patients who did not undergo open thoracotomy, patients who underwent tracheostomy without postoperative extubation, patients whose oral intake was delayed resulting from digestive tract disorders, such as postoperative ileus, and patients who were diagnosed with pneumonia before intervention by the STs (eg, ventilator-associated pneumonia) were excluded. Finally, a total of 97 patients were analyzed (Fig. 1).

This study was carried out in accordance with the ethical principles of the Declaration of Helsinki (2013 revised edition) and ethical guidelines for research. This study protocol was reviewed and approved by our ethics committee (approval number: 3357). As this was a non-invasive retrospective study, it was not possible to obtain informed consent from all discharged patients. Therefore, our ethics committee determined that individual patient consent was not required to collect data retrospectively. However, information about conducting the study was made public so that patients can opt out of the study.

### 2.2. Clinical characteristics

The STs reviewed

(1) patient characteristics,
(2) intraoperative characteristics,

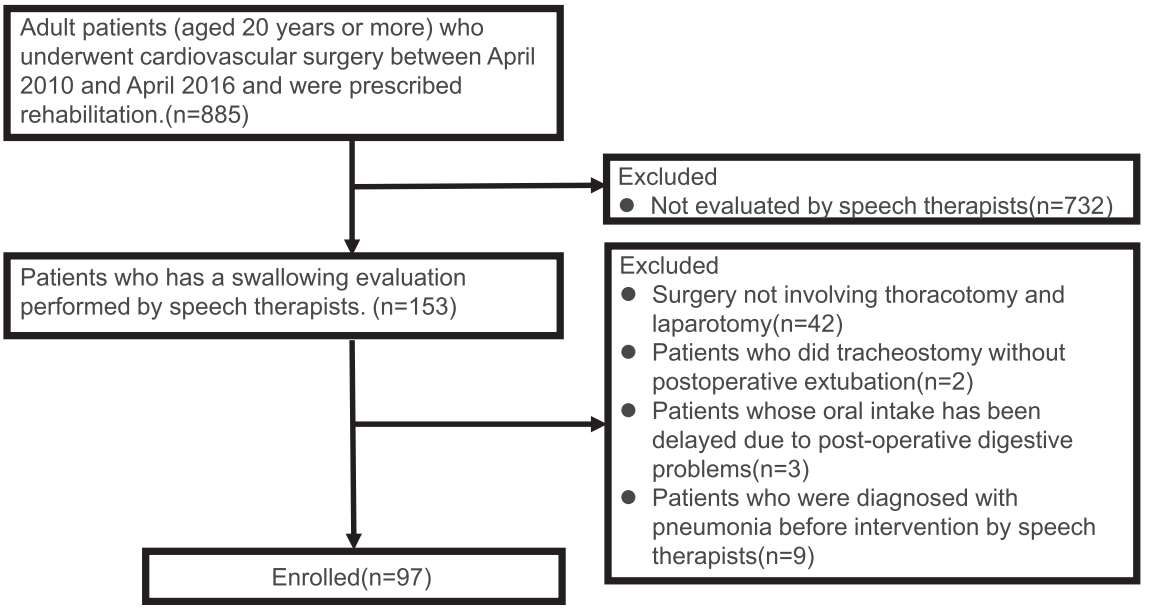


**Figure 1.** Flowchart of study subjects.

(3) postoperative complications,
(4) BSE results, and
(5) postoperative progress from the medical records.

Patient characteristics included age, sex, body mass index at the time of admission, and diagnosis and medical history (cerebrovascular disease, chronic kidney disease, dialysis, diabetes, and respiratory disease: chronic obstructive pulmonary disease, asthma, and bacterial pneumonia). Intraoperative characteristics included the need for emergency surgery, procedure type (great vessel graft replacement, valve replacement/valvuloplasty, coronary artery bypass grafting, combined surgery, or other surgery with laparotomy and thoracotomy), duration of surgery, and duration of tracheal intubation. Cerebrovascular disease , delirium, pleural effusion, hoarseness, and postoperative pneumonia were postoperative complications that were reviewed in the medical records.

Regarding BSEs, the level of consciousness at the time of the initial ST evaluation, Glasgow Coma Scale score, Modified Water Swallowing Test (MWST) score, Repetitive Saliva Swallowing Test (RSST) score, speech intelligibility score, and Risk of Dysphagia in Cardiac Surgery (RODICS) score were evaluated. Postoperatively, the number of days until the patient began eating meals, length of hospital stays, and Food Intake Level Scale (FILS) score at discharge were analyzed.

In this study, pneumonia was defined as postoperative pneumonia based on previous literature.[8] Patients were diagnosed with postoperative pneumonia if they met one of the following 2 criteria postoperatively.

(1) Rales or dullness to percussion on physical examination of chest, and any of the following: New onset of purulent sputum or change in character of the sputum, or Isolation of organism from blood culture, or Isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy.
(2) Chest radiography showing new or progressive infiltrate, consolidation, cavitation, or pleural effusion and any of the following: New onset of purulent sputum or change in character of sputum, or Isolation of organism from blood culture, or Isolation of pathogen from specimen obtained by transtracheal aspirate, bronchial brushing, or biopsy, or Isolation of virus or detection of viral antigen in respiratory secretions, or Diagnostic single antibody titer (IgM) or fourfold increase in paired serum samples (IgG) for pathogen, or Histopathologic evidence of pneumonia. Criterion 2 may involve a computed tomography examination of the chest, if necessary, which was read by a radiologist in addition to the attending physician.

The diagnosis was comprehensively made by the attending physician based on the above criteria.

### 2.3. BSEs

The attending physician requested the STs to perform BSEs when nurses suspect swallowing dysfunction in the intensive care unit following extubation or when the attending physician suspected that the swallowing function had declined because of medical history, complications, and intubation time. When BSEs are requested by the attending physician, the STs perform the BSEs on the requested day or on the next day. The STs confirm the medical records of the patient and perform BSEs. The level of consciousness, motor function of the mouth and tongue, articulation function and voice quality, oral hygiene, cough strength, and saliva swallowing were all assessed. If these tests indicate that it is possible to swallow water directly, the MWST is performed. If oral hygiene is not good, the evaluation of swallowing function is performed after oral care. The outline of BSEs is shown below:

- MWST: Patients are instructed to swallow 3 ml of water, which is injected into the oral floor with a syringe. The conditions of swallowing are scored in five stages. The sensitivity and specificity of MWST for differentiating between aspirators and non-aspirators with a cutoff level of 3 are 70% and 88%, respectively[9,13] (Table 1).
- RSST: Patients are instructed to swallow saliva as many times as possible within 30 seconds. An RSST count of less than 3 times within 30 seconds indicates suspected dysphagia. The sensitivity and specificity of RSST to predict aspiration, according to video fluorographic examinations, are reported to be 0.98 and 0.66, respectively.[10,13]
- Speech Intelligibility[11]: This index indicates the degree of verbal communication transmission ability and determines the overall severity of speech function in the following 5 levels.
  (1) Everything is understood.
  (2) Occasionally, some words cannot be heard.
  (3) Words are apparently understood when the listener knows the content.
  (4) There is a word which is understood occasionally.
  (5) All words are incomprehensible.
- RODICS score[7]: This scoring system identifies patients at risk for post-cardiac dysphagia. The highest possible score is 38 points, with a total score of $<4$ indicating low risk, a score between 4 and 9 suggesting moderate risk, and score of $>9$ indicating high risk. The middle and high risk groups have significant risks of developing dysphagia after cardiovascular surgery.
- FILS: A 10-point observer-rating scale that measures the severity of dysphagia.[12]

### 2.4. Statistical analyses

First, patients were divided into the pneumonia-onset group and the non-onset group, according to the occurrence of pneumonia

**Table 1**

**modified water swallowing test (MWST)[9,13].**

[Procedure]

The patient is given 3 ml of cold water in the oral floor, and then instructed to swallow the water. If possible, the patient is asked to perform 2 dry (saliva) swallows. If the patient meets score 4, a maximum of 2 additional attempts (a total of 3 attempts) should be made, and the worst assessment will be recorded as the final result.

[Assessment criteria]

1. Inability to swallow with choking and/or breathing changes
2. Swallow occurred, but with breathing changes
3. Swallow occurred, but with choking and/or wet hoarseness
4. Swallow successfully
5. Swallow successfully with ability of additional dry swallowing twice in 30s

after extubation. Patient characteristics, intraoperative characteristics, postoperative complications, BSE results, and postoperative progress were compared between the groups. The unpaired t-test was used to compare continuous variables, and the Mann-Whitney *U* test was used for ordinal and continuous variables that are not normally distributed, while the chi-square test was used for nominal variables. Then, univariate and multivariate analyses with a Cox proportional hazards model were conducted to investigate the most appropriate tests of the BSE for predicting pneumonia. In the analysis, the dependent variable was the occurrence of pneumonia, and the independent variables were the five tests included in the BSEs. In the multivariate analysis, the propensity score was used to adjust many confounders to 1 to avoid overestimating the model. That is, covariates were adjusted for patient characteristics, intraoperative characteristics, and postoperative complications by converting them to propensity scores. In addition, for MWST and RSST, data were converted to binary dummy variables above or below the cutoff value based on the reported cutoff values[10,13] for aspiration. Furthermore, in cases where MWST could not be implemented at the time of the initial evaluation, we responded to it as evaluation criteria of 3 or less. For tests that became significant in the univariate analysis, the incidence of pneumonia was drawn using the Kaplan-Meier curve. $P < .05$ was considered statistically significant. All analyses were performed using SPSS (22.0J for Macintosh).

## 3. Results

Of the 97 patients, 21 were classified into the pneumonia-onset group and 76 into the non-onset group. The median (interquartile range) diagnosis time of pneumonia was 11.00 (5.50–24.00) days following surgery among the pneumonia-onset group. No patients needed a gastrostomy or tube feeding as preoperative nutrition measures. After surgery, almost all patients underwent rehabilitation. Regarding the timing of pneumonia diagnosis, the rate of diagnosis during non-food swallowing training after intervention by the ST was 57.14%, and the rate of diagnosis after starting meals was 19.05%. Table 2 shows comparisons between the pneumonia-onset group and the non-onset group. The percentage of speech intelligibility at each point was significantly different between the two groups ($P = .030$), and the rate of MWST score of 3 or less was significantly higher in the pneumonia-onset group than in the non-onset group ($P = .014$). The pneumonia-onset group had a significantly longer time until the start of oral intake ($P < .001$) and a significantly lower median value of FILS at the time of discharge ($P = .001$).

According to the univariate analyses, the MWST score (HR: 2.922, 95% CI: 1.066–8.012, $P = .037$) was a significant factor for predicting the onset of pneumonia (Table 3). Figure 2 shows the incidence of pneumonia using the Kaplan-Meier curve during the observation period when dichotomized by the MWST score. Table 3 also shows the results of multivariate analysis adjusted for the propensity score. As there were 21 cases with the pneumonia-onset group, two factors were used as independent variables in the multivariate analysis model to avoid overestimation of the model. Models 1 to 5 show the hazard ratio (HR) and 95% confidence interval (CI) for each of the BSE tests and the propensity score, respectively. In the multivariate analysis, the MWST score (HR 3.161, 95% CI 1.052–9.500, $P = .040$) was also identified as a significant factor.

## 4. Discussion

The results of this study indicated that the most predictable measurement of BSEs for subsequent pneumonia onset was the MWST score after extubation following cardiovascular surgery. When the MWST score was 3 points or less, the incidence rate of pneumonia increased about 3 times.

The incidence rate of pneumonia was approximately 3% during the observation period; this rate included nine cases that had already been diagnosed with pneumonia at the time of ST intervention. In a previous study on dysphagia after cardiovascular surgery, the incidence of pneumonia was reported to be approximately 3%, and the incidence in this study was similar to that reported in previous studies.[7] In a systematic review of water swallowing test results, the sensitivity of the test of swallowing a small volume of water (1–5 ml) with 1 sip to identify aspiration was 71% (95% CI: 63%–78%) and the specificity was 90% (95% CI: 86%–93%).[14] Furthermore, when both the airway response and voice quality change were deemed to be signs of aspiration, they were considered useful and improved the diagnostic accuracy of aspiration detection.[14] The sensitivity and specificity of the MWST for aspiration were 70% and 88%, respectively.[13] Moreover, the MWST incorporated airway responses, such as coughing, respiratory distress, and wet voice quality in the evaluation criteria; thus, it accuracy appears to be not inferior to the accuracy of the water swallowing test as reported in previous research.[14] Although MWST after extubation is not patient-specific, it is likely to be useful for evaluating swallowing after extubation.

Many studies have reported the usefulness and efficacy of BSEs.[15–17] A previous systematic review classified BSEs into 4 categories: subjective bedside examination, questionnaire-based tools, protocolized multi-item evaluations, and single-item exam maneuvers.[15] The BSEs used in this study included a combination of single-item examination maneuvers. However, there was a limit to using only the single-item examination alone[16]; another study reported that comprehensive evaluation is more useful than the single-item examination.[18] Many protocolized multi-item evaluations often include medical history, level of consciousness, facial/oral/lingual movement function, articulation, voice function, coughing ability, and water swallowing test.[15] In this study, the items examined were Glasgow Coma Scale (GCS) total score, MWST score, RSST score, speech intelligibility score, and RODICS score; on the contrary, facial/oral/lingual movement function, voice function, and coughing ability were not evaluated directly. However, it may be possible to infer facial/oral/lingual movement function and speech function from the speech intelligibility score. Therefore, we believe that the items examined in this study contain items similar to those found in protocolized multi-item evaluations.

Hamazaki et al.[16] and Christensen et al[17] indicate that the evaluation consists of 2 or more stages for swallowing assessment specialized for extubation. In the first stage, evaluations are performed to determine whether or not a water swallowing test can be carried out, and if passed, a water swallowing test is performed. Evaluation items in the first stage include saliva swallowing, voice quality, and level of consciousness. In our study, MWST had a direct risk of aspiration, so we decided against it if implementation was deemed difficult. Therefore, MWST was performed based on the GCS score, RSST score, speech intelligibility score, and RODICS score. The results of this study showed that the GCS score, RSST score, speech intelligibility score, and RODICS score were not direct factors for predicting the onset of pneumonia;

**Table 2**

**Comparison of patient characteristics, Intraoperative characteristics, postoperative complications, bedside swallowing examinations, and postoperative progress in both groups.**

| | the pneumonia onset group (n = 21) | the non-onset group (n = 76) | *P* value |
|---|---|---|---|
| age (yr) | 77.62 ± 8.18 | 73.55 ± 11.16 | .123 |
| sex (male) (%) | 61.90 | 63.16 | 1.000 |
| BMI (kg/m$^2$) | 22.07 ± 2.98 | 24.20 ± 3.88 | .569 |
| Diagnosis (GVD) (%) | 71.43 | 69.74 | 1.000 |
| medical history | | | |
| CVD (%) | 42.86 | 27.63 | .193 |
| CKD (%) | 33.33 | 19.74 | .239 |
| dialysis (%) | 9.52 | 9.72 | .978 |
| respiratory disease (%) | 19.05 | 11.84 | .470 |
| COPD (%) | 9.52 | 4.17 | .338 |
| Asthma (%) | 0 | 5.56 | .270 |
| bacterial pneumonia (%) | 9.52 | 5.56 | .515 |
| diabetes (%) | 9.52 | 13.89 | .600 |
| emergency surgery (%) | 52.38 | 57.89 | .804 |
| procedure type | | | |
| great vessel graft replacement (%) | 66.67 | 55.26 | .456 |
| VR/VP (%) | 0 | 13.16 | .112 |
| CABG (%) | 4.76 | 6.58 | 1.000 |
| combined surgery (%) | 23.81 | 26.32 | 1.000 |
| other surgery (%) | 4.76 | 1.32 | .388 |
| Duration of surgery (min) | 457.95 ± 164.39 | 468.64 ± 162.88 | .791 |
| Duration of tracheal intubation (min) | 6313.62 ± 7654.20 | 3509.18 ± 3919.54 | .119 |
| Postoperative complication | | | |
| CVD (%) | 14.29 | 27.63 | .263 |
| Delirium (%) | 57.14 | 44.44 | .331 |
| Hoarseness (%) | 90.48 | 84.21 | .470 |
| pleural fluid (%) | 80.95 | 61.84 | .102 |
| Number of days until postoperative ST intervention (d) | 5 (3.0–11.5) | 5 (3.0–8.0) | .318 |
| Consciousness level (%) | | | |
| GCS13 | 38.10 | 18.42 | .150 |
| GCS14 | 38.10 | 44.74 | |
| GCS15 | 23.81 | 36.84 | |
| Speech Intelligibility (%) | | | |
| 1 | 38.10 | 51.32 | .030 |
| 2 | 38.10 | 35.53 | |
| 3 | 23.81 | 9.21 | |
| 4 | 0 | 2.63 | |
| 5 | 0 | 1.32 | |
| RSST* 1(%) | 61.90 | 53.95 | .622 |
| MWST† 2(%) | 76.19 | 44.74 | .014 |
| RODICS (%) | | | |
| Low | 4.76 | 6.58 | .772 |
| Intermediate | 19.05 | 13.16 | |
| High | 76.19 | 80.26 | |
| Number of days until meal start (d) | 22 (13.5–33.0) | 6.5 (4.0–10.0) | .000 |
| Postoperative length of hospital stays (d) | 44 (24.5–73.5) | 31 (24.0–42.0) | .087 |
| FILS (at discharge) | 7 (3.5–8.0) | 8 (7.0–9.0) | .001 |

* 1 RSST:Percentage of patients who were less than 3 times / 30 seconds.

† 2 MWST: Percentage of patients who were below the criteria 3.

BMI, body mass index; CABG, coronary artery bypass grafting; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CVD, cerebrovascular disease; FILS, Food Intake Level Scale; GCS, Glasgow coma scale; GVD, great vessel disease; MWST, Modified Water Swallowing Test; RODICS, Risk of Dysphagia in Cardiac Surgery; RSST, Repetitive Saliva Swallowing Test; VR/VP, valve replacement/valvuloplasty.

however, they are considered essential elements for determining whether the MWST should be performed. Therefore, the MWST should not be implemented as a stand-alone tool, but rather in combination with other BSEs. Therefore, the MWST should be used in conjunction with the other BSEs and not as a single tool.

Regarding the time of pneumonia diagnosis, only 19% of patients were diagnosed after the start of dietary intake; most patients were diagnosed when little or no oral intake was given. If the MWST score is 3 points or less, meals are not usually resumed. Predicting the incidence of pneumonia is important for preventing it; however, many patients who did not start oral intake were diagnosed with pneumonia afterwards. There is no point in predicting the incidence of pneumonia if it cannot be prevented. Many factors may contribute to patients not being

**Table 3**

**univariate analysis and multivariate analysis with COX proportional hazards model.**

| | Univariate analysis | | Multivariate analysis | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Model 1 | | Model 2 | | Model 3 | | Model 4 | | Model 5 | |
| Factors | HR | (95%CI) | HR | (95%CI) | HR | (95%CI) | HR | (95%CI) | HR | (95%CI) | HR | (95%CI) |
| GCS score | 0.720 | (0.398–1.304) | 1.211 | (0.347–4.234) | | | | | | | | |
| MWST[†1] | 2.922[*] | (1.066–8.012) | | | 3.161[*] | (1.052–9.500) | | | | | | |
| RSST[†2] | 1.116 | (0.457–2.724) | | | | | 1.258 | (0.444–3.566) | | | | |
| Speech intelligibility | 1.260 | (0.778–2.040) | | | | | | | 0.855 | (0.244–2.990) | | |
| RODICS score | 1.053 | (0.975–1.137) | | | | | | | | | 0.147 | (0.012–1.728) |

[*] $P < .05$.

[†] 1 MWST, binary variable with criteria below 3 or above 4; [†]2 RSST:, binary variable that is less than 3 times or more than 3 times in 30 seconds.

95%CI, 95% confidence interval; GCS, Glasgow Coma Scale; HR, hazard ratio; MWST, Modified Water Swallowing Test; RODICS, risk of dysphagia in cardiac surgery; RSST, Repetitive Saliva Swallowing Test; propensity score; including age, sex, body mass index, history of cerebrovascular disease, history of chronic kidney disease, history of chronic respiratory disease, great vessel disease, surgical procedure, emergency surgery, postoperative delirium, postoperative cerebrovascular disease, postoperative hoarseness, and postoperative pleural effusion.

able to consume even 3 ml of water safely. For example, they cannot pump out airway secretion, or they may have a poor swallowing reflex, laryngeal elevation failure, vocal cord paralysis, insensitivity to instructions, and poor respiratory condition. The results of the MWST are reflective of these functional declines. It is important to analyze underlying mechanisms for an MWST score of 3 points or less to consider the measures to avoid the onset of pneumonia. If necessary, care such as improving the level of arousal, swallowing function training, expectoration assistance, airway aspiration, positional drainage, and oral cleanliness are important for preventing pneumonia.

This study has some limitations that should be addressed. First, although this study aimed to detect evaluation items of BSEs that predict postoperative pneumonia, postoperative pneumonia after extubation is not necessarily just a result of aspiration. Additionally, aspiration does not immediately lead to pneumonia. Making a clear diagnosis of aspiration pneumonia is difficult.[16] Therefore, it may be somewhat difficult to predict the onset of pneumonia based on patients' scores on RSST or MWST, which are tests to detect dysphagia or aspiration. In addition, this study did not analyze the information on the surgical technique that could affect pulmonary complications (thoracotomy or sternotomy), so we could not take into account the effect of different techniques. However, the incidence rate of postoperative pneumonia is higher in cases with an MWST score of less than 3 points. Paradoxically, poor swallowing function may be one of the causes of postoperative pneumonia. Second, patients are limited to ST intervention cases. Therefore, the swallowing function of 732 patients without ST intervention is unknown, and there is a limit to generalizing this result because of selection bias. The referral to the STs was requested by the attending physician when dysphagia was suspected, cerebrovascular disease develops following surgery, or when hoarseness was strong. Extraction using this criterion indicated that the high incidence of pneumonia in ST intervention cases resulted in appropriate selection of high-risk cases. Although this study is limited to ST intervention cases, predicting the risk of pneumonia in those subjects is clinically relevant. Third. This study is a single-center clinical trial and the sample size is relatively small, which may affect the power of the study. In addition, the patient

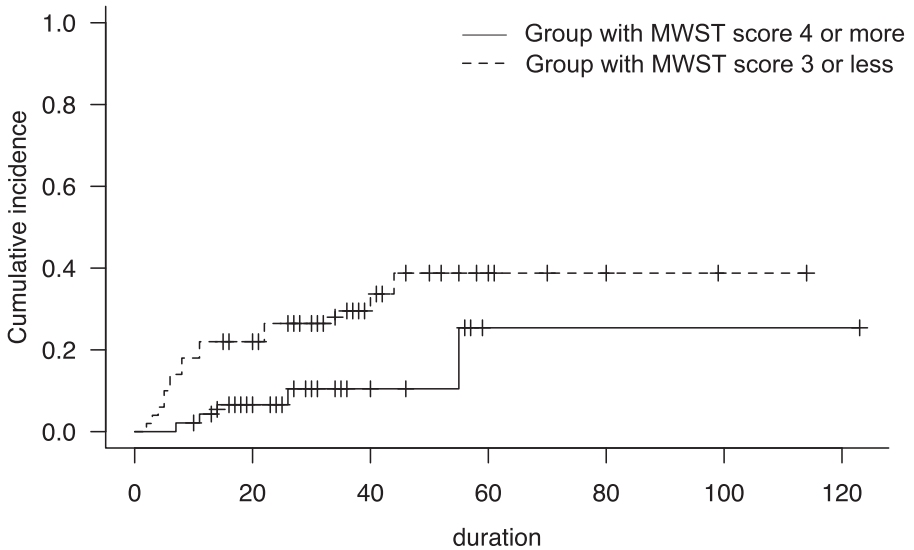


**Figure 2.** Postoperative pneumonia incidence rate when grouped by modified water swallowing test (MWST) cutoff value (3 or less and 4 or more). The incidence rate of pneumonia during the observation period was calculated by the Kaplan-Meier method. The result indicated that the incidence of pneumonia in the group with MWST scores of 3 or less was significantly higher than that in the group with scores of 4 or more.

characteristics are not homogeneous. Therefore, the results may not apply to all ages and types of surgery. Fourth, BSE items included assessments of cough ability, oral hygiene, and voice quality, but were not included in this analysis. Regarding cough ability, it was often impossible to sufficiently cough voluntarily because of wound pain, and there were many missing values. The oral hygiene status could not be adopted as a study item because the numerical evaluation was not performed. It is necessary to digitize in future investigations. Hoarseness was determined if any of the following types of hoarseness were present: rough hoarseness, breathy hoarseness, asthenic hoarseness, and strained hoarseness. Hoarseness was indicated by the presence or absence of hoarseness, regardless of severity. Therefore, some cases very mild, and most cases had hoarseness, so hoarseness was not analyzed as a BSE item.

Finally, since this study excluded patients who were diagnosed with pneumonia before the first ST evaluation, the results are limited to patients who had not been diagnosed with pneumonia at the time of the initial evaluation. Even when considering these limitations, this study is highly novel because it uses multivariate analysis that identifies factors predicting the onset of pneumonia after extubation.

## 5. Conclusions

The MWST score after extubation in cardiovascular surgery most strongly predicts the onset of postoperative pneumonia. Furthermore, the incidence of pneumonia increased approximately 3 times when the MWST score was 3 points or less. This result suggests that when starting oral ingestion, it is possible to extract cases with a high risk of subsequent postoperative pneumonia. This result is helpful for nurses who are continuously observing postoperative vital fluctuations and for attending physicians who issue instructions to start eating. In addition, by predicting cases with a high risk of developing pneumonia, the prevention of pneumonia, such as giving priority to expectoration care, requesting early intervention by swallowing specialists, and selecting appropriate nutritional measures becomes possible.

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## Author contributions

Natsuko Oguchi designed the study with support from Shuhei Yamamoto and wrote the initial draft of main manuscript. Shuhei Yamamoto, Shota Ikegami, and Masaaki Sato contributed to statistical analysis and interpretation of data, and Shuhei Yamamoto and Shota Ikegami assisted in the preparation of the manuscript. Shuhei Yamamoto also prepared Figure 2. Satsuki Terashima and Ruka Arai have contributed to data collection and interpretation, and Hiroshi Horiuchi critically reviewed the manuscript. Shuhei Yamamoto, Shota Ikegami, Hiroshi Horiuchi, and all other authors provided critical comments on the draft and agreed on the submitted version of the manuscript.

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## References

[1] Skoretz SA, Flowers HL, Martino R. The incidence of dysphagia following endotracheal intubation: a systematic review. Chest 2010; 137:665–73.
[2] Macht M, King CJ, Wimbish T, et al. Post-extubation dysphagia is associated with longer hospitalization in survivors of critical illness with neurologic impairment. Crit Care 2013;17:R119.
[3] Macht M, Wimbish T, Bodine C, et al. ICU-acquired swallowing disorders. Crit Care Med 2013;41:2396–405.
[4] Macht M, Wimbish T, Clark BJ, et al. Postextubation dysphagia is persistent and associated with poor outcomes in survivors of critical illness. Crit Care 2011;15:R231.
[5] Barker J, Martino R, Reichardt B, et al. Incidence and impact of dysphagia in patients receiving prolonged endotracheal intubation after cardiac surgery. Can J Surg 2009;52:119–24.
[6] Ibañez J, Riera M, Amezaga R, et al. Long-term mortality after pneumonia in cardiac surgery patients: a propensity-matched analysis. J Intensive Care Med 2016;31:34–40.
[7] Grimm JC, Magruder JT, Ohkuma R, et al. A novel risk score to predict dysphagia after cardiac surgery procedures. Ann Thorac Surg 2015; 100:568–74.
[8] Arozullah AM, Khuri SF, Henderson WG, et al. Development and validation of a multifactorial risk index for predicting postoperative pneumonia after major noncardiac surgery. Ann Intern Med 2001; 135:847–57.
[9] Tohara H, Saitoh E, Mays KA, et al. Three tests for predicting aspiration without videofluorography. Dysphagia 2003;18:126–34.
[10] Oguchi K, Saitoh E, Mizuno M, et al. The repetitive saliva swallowing test (RSST) as a screening test of functional dysphagia (1) normal values of RSST. JJRM 2000;37:375–82.
[11] Itoh M. The sensitivity of single-word intelligibility test. Jpn J Logop Phoniatr 1993;34:237–43.
[12] Kunieda K, Ohno T, Fujishima I, et al. Reliability and validity of a tool to measure the severity of dysphagia: the Food Intake LEVEL Scale. J Pain Symptom Manage 2013;46:201–6.
[13] Yagi N, Oku Y, Nagami S, et al. Inappropriate timing of swallow in the respiratory cycle causes breathing–swallowing discoordination. Front Physiol 2017;8:676.
[14] Brodsky MB, Suiter DM, González-Fernández M, et al. Screening accuracy for aspiration using bedside water swallow tests: a systematic review and meta-analysis. Chest 2016;150:148–63.
[15] O'Horo JC, Rogus-Pulia N, Garcia-Arguello L, et al. Bedside diagnosis of dysphagia: a systematic review. J Hosp Med 2015;10:256–65.
[16] Hamazaki M, Hiramatsu Y, Akiyama N. Development of a questionnaire for assessing dysphagia at ICU. J Jpn Acad Crit Care Nurs 2011;7:26–34.
[17] Christensen M, Trapl M. Development of a modified swallowing screening tool to manage post-extubation dysphagia. Nurs Crit Care 2018;23:102–7.
[18] Matsuo T, Matsuyama M, Watanabe A, et al. The comparative study of dysphagia screening tests. The Japanese Journal of Dysphagia Rehabilitation 2016;20:3–10.