ORIGINAL ARTICLE

Changes in Maximum Tongue Pressure and Postoperative Dysphagia in Mechanically Ventilated Patients after Cardiovascular Surgery

Toru Yamada[1], Ryoichi Ochiai[2], Yoshifumi Kotake[3]

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Background: There is no objective quantitative parameter for dysphagia, and the relationship between changes in maximum tongue pressure values and dysphagia is unknown. This study aimed to determine whether there is a difference in the change in maximal tongue pressure after extubating patients who were ventilated after cardiovascular surgery, with or without dysphagia.

Materials and methods: Adult patients who underwent mechanical ventilation *via* endotracheal intubation following cardiovascular surgery were included. Tongue pressure was measured before cardiovascular surgery and at 6 hours; 3 and 7 days after extubation. Dysphagia was confirmed by the functional oral intake scale (FOIS) on day 7 after extubation; an FOIS level above or equal to 6 was considered "dysphagia-negative."

Results: Of 68 patients, 15 (22.1%) were in the dysphagia-positive group, which significantly showed a history of diabetes mellitus, prolonged mechanical ventilation, and postextubation hospitalization. Additionally, the postoperative C-reactive protein level was significantly higher in the dysphagia-positive group than in the dysphagia-negative group. Maximum tongue pressure was significantly lower in the dysphagia-positive group at 3 and 7 days postextubation. Using a cutoff value of 27.6 kPa in a receiver operating characteristic curve (ROC) for maximum tongue pressure at 3 days after extubation, the area under the curve (AUC) was 0.82, sensitivity was 84.9%, and specificity was 84.2%.

Conclusion: Tongue pressure at 3 days after extubation is significantly lower in patients with dysphagia after cardiovascular surgery than in patients without dysphagia. If the maximum tongue pressure value is below 27.6 kPa on the third day following extubation, oral intake should be performed with caution.

Keywords: Cardiovascular surgery, Dysphagia, Mechanical ventilator, Postintensive care syndrome, Tongue pressure.

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This study examines changes in maximal tongue pressure after extubation in patients ventilated after cardiovascular surgery. The study shows that decreased tongue pressure was associated with dysphagia. Dysphagia is also associated with patient's prognosis. Muscle weakness and disuse atrophy due to fasting may be responsible for dysphagia after extubation.

The development of less invasive surgical techniques and advancements in anesthesia care have made surgery in elderly patients possible, which was not indicated in the past, thereby improving their quality of life. However, postoperative complications such as dysphagia can negatively affect the quality of life of these patients. Dysphagia renders patients incapable of oral intake, forces them to rely on parenteral nutrition, and requires them to undergo supportive therapy for several months until their swallowing function recovers.[1] Dysphagia that occurs after cardiovascular surgery is a serious problem that affects the patient's postoperative course, increases the risks of aspiration and pneumonia, prolongs hospitalization,[2–4] and leads to higher rates of in-hospital mortality.[4]

An observational study showed that postextubation dysphagia symptoms persisted after discharge in patients who were hospitalized for severe acute respiratory distress syndrome.[5] In critically ill patients, the onset of dysphagia has been indicated to be associated with the duration of endotracheal intubation.[6–9] Attention is also required regarding laryngeal injuries caused by the endotracheal intubation technique.[10] In addition, 60% of patients who developed dysphagia remained dysphagia-positive upon discharge.[8] Despite the effects of dysphagia on the course of critically ill patients, the continued use of enteral nutrition in many cases after extubation often causes dysphagia to be overlooked due to the absence of oral intake. Another conceivable reason for overlooking dysphagia is that dysphagia screening tools for critically ill patients have rarely been developed or used.[11,12]

[1]Department of Anesthesiology, Toho University Graduate School of Medicine, Ota-ku Omorinishi, Tokyo, Japan

[2]Professor emeritus, Toho University

[3]Department of Anesthesiology, Ohashi Medical Center, Toho University, Ohashi, Tokyo, Japan

Corresponding Author: Toru Yamada, Department of Anesthesiology, Toho University Graduate School of Medicine, Ota-ku Omorinishi, Tokyo, Japan, Phone: +81 337624151, e-mail: tooru-yamada@ns.toho-u.ac.jp

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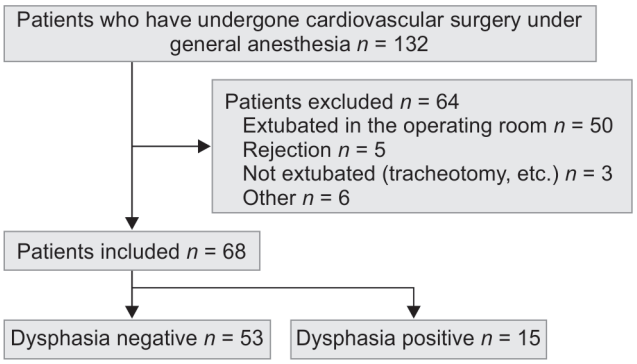
One of the screening tools for dysphagia is the measurement of tongue pressure. Low tongue pressure and dysphagia have also been studied in patients with stroke,[13] Parkinson's disease,[14] postoperative esophageal cancer,[15] postoperative head and neck cancer,[16] and emergency patients.[17] Ichibayashi et al. examined aspiration pneumonia resulting from postextubation dysphagia in patients who were receiving mechanical ventilation for at least 24 hours, at an emergency department.[17] Dysphagia was assessed based on the maximum tongue pressure at 6 and 24 hours; 3 and 7 days after extubation. Patients with postextubation aspiration pneumonia demonstrated significantly lower maximum tongue pressure at all the above points in time than patients who did not develop aspiration pneumonia. In addition, patients who developed postextubation aspiration pneumonia demonstrated reduced tongue pressure in all measurements from 24 hours onward. Furthermore, in a ROC curve drawn to predict aspiration pneumonia based on maximum tongue pressure, when a maximum tongue pressure of 13.8 kPa was used as the cutoff, sensitivity was 96.9%, specificity was 71.4%, positive predictive value was 93.3%, and negative predictive value was 83.3%; these results indicated that the maximum tongue pressure after extubation is a predictor of aspiration pneumonia. The usefulness of measuring tongue pressure in critically ill patients was suggested.

Although previous studies have reported that a lower tongue pressure after extubation is effective for predicting aspiration, they have not determined the changes over time in maximum tongue pressure after mechanical ventilation *via* endotracheal intubation. Therefore, we conducted this prospective study with patients who were mechanically ventilated *via* an endotracheal tube following cardiovascular surgery and were at a high risk of postextubation dysphagia to determine whether changes in maximum tongue pressure differ between patients who develop postextubation dysphagia and those who do not.

Flowchart 1: Flow diagram of patients undergoing cardiovascular surgery under general anesthesia



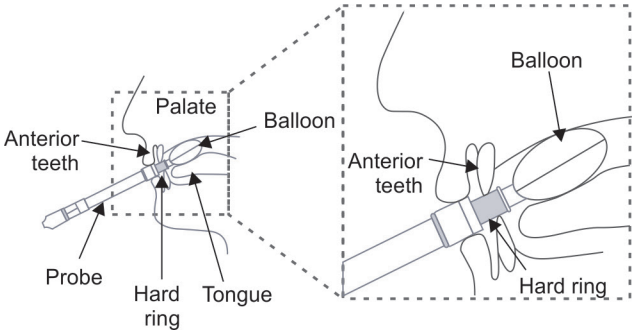


Fig. 1: Tongue pressure measurement. Insert the tongue probe into the patient's mouth, hold the hard ring between the front teeth or gums, and crush the balloon between the tongue and palate with maximum force for several seconds.[16]

Inclusion and Exclusion Criteria

The initial group of participants consisted of 132 adult patients (age ≥18 years) who were transferred to the intensive care unit (ICU) following cardiovascular surgery under general anesthesia at our hospital, between September 2018 and December 2019. None of the patients had reported dysphagia prior to surgery. Patients who did not provide consent prior to surgery (due to emergency surgery, refusal to participate, etc.), patients who underwent extubation in the operating room, patients who refused to undergo tongue pressure measurement after extubation, and patients who required postoperative tracheotomy were excluded from the study (Flowchart 1).

Tongue Pressure Measurement

Tongue pressure was measured with a JMS tongue pressure measurement device (TPM-01: JMS, Hiroshima, Japan). Each patient was asked to put a probe in their mouth and crush the balloon on the tip of the probe for several seconds by elevating their tongue with maximum force towards the palate (Fig. 1). Before the measurement, the patients were explained with the measurement procedure orally and in writing; the written explanation included an illustration that also showed points to keep in mind during measurement. Tongue pressure was measured before cardiovascular surgery and at 6 hours; 3 and 7 days after extubation. At each of these four time points, tongue pressure was measured three times, with the highest value used for analysis.

Dysphagia Assessment

For the presence of dysphagia, the FOIS scores were assessed on day 7 after extubation.[18] A level of 6 or higher was considered "negative for dysphagia."

Airway and Mechanical Ventilator Management

All patients used the same endotracheal tube during ventilation. An anesthesiologist performed tracheal intubation using a videolaryngoscope. Postoperative ventilator management was performed by a cardiovascular surgeon. Once the patient's general condition has stable postoperatively, spontaneous awakened trial (SAT) and spontaneous breathing trial (SBT) were performed. Following passing the SAT and SBT, the patient was extubated by the cardiovascular surgeon.

Ethical Considerations

This study was conducted with the approval of the Ethics Committee of Toho University Omori Medical Center (Approval No. M19241 18009). After an explanation of the study from the investigators, written informed consent was obtained from every patient who participated as a subject of this study. The study protocol was also uploaded to the University hospital Medical Information Network (UMIN) Clinical Trials Registry before the study began (UMIN:000036794).

Statistical Analysis

Continuous data were compared between dysphagia-positive (D group) and dysphagia-negative (N group) participants using *t*-test for data with confirmed normality and Wilcoxon's rank-sum test for data with unconfirmed normality, and nominal data were compared using Chi-squared test. The relationship between the maximum tongue pressure value and the timing of measurement was examined by one-way analysis of variance (ANOVA) using Tukey's honestly significant difference test. The relationship between maximum tongue pressure and measurement timing in the D and N groups was examined with two-way ANOVA using Bonferroni method. For the cutoff value of dysphagia at maximum tongue pressure, ROC analysis was performed with the presence or absence of dysphagia as the objective variable and maximum tongue pressure as the explanatory variable. The AUC of the drawn ROC curve was determined. The Youden index was used to determine the cutoff value, which was calculated as (sensitivity + specificity – 1) and the highest value was adopted. Results showing $p < 0.05$ were considered statistically significant. Statistical analyses were performed with the program the name of statistical software (JMP) 11 (SAS Institute Inc., Cary, NC, USA).

A total of 68 patients were included in the analysis. Of these 68 patients, 15 (22.1%) were in the D Group, while 53 (77.9%) were in the N Group. Table 1 shows the basic characteristics of the patients in both groups. Diabetes mellitus was significantly more frequent in the D group than in the N group [Diabetes mellitus; 8/15 (53.3) % vs 13/53 (24.5) %, $p = 0.033$]. Median (interquartile range) operative time and anesthesia time were significantly longer in the D group than in the N group [operative time; 475 (420–636) minutes vs 430 (348–482) minutes, $p = 0.0255$ anesthesia time; 591 (527–772) minutes vs 534 (447–603) minutes, respectively, $p = 0.0214$]. Median postoperative mechanical ventilation time (interquartile range) was significantly longer in the D Group than in the N Group [3 (1–6) days vs 1 (0–1) days, respectively, $p < 0.0001$]. There was no significant difference in the presence or absence of postoperative delirium. For the maximum postoperative C-reactive protein (CRP) level, group D was significantly higher than group N [maximum postoperative CRP; 16.5 (10.5–23.6)mg/dL vs 9.3 (6.7–13.2) mg/dL, respectively, $p = 0.0032$]. Median time from extubation to discharge (interquartile range) was also significantly longer in the D group than in the N group [31 (25–36)days vs 17 (13–21.5) days, respectively, $p = 0.003$].

Table 1: Patients' characteristics

	Dysphagia-positive n = 15	*Dysphagia-negative n = 53*	*p-value*
Age (years)[a]	67 (59–72)	71 (56.5–77.5)	n.s.
Sex (male/female)[b]	13/2	38/15	n.s.
Body mass index[a]	23.7 (22.2–25.1)	22.7 (20.4–24.7)	n.s.
Cardiovascular surgical risk			
Congestive heart failure (%)	3 (20.0)	10 (18.9)	n.s.
Hypertension (%)	10 (66.7)	37 (69.8)	n.s.
Diabetes mellitus (%)	8 (53.3)	13 (24.5)	0.033
Cerebral infraction (%)	1 (6.7)	13 (24.5)	n.s.
Atrial fibrillation (%)	6 (40.0)	14 (26.4)	n.s.
Atrial fibrillation (%)	2 (13.3)	10 (18.9)	n.s.
COPD[c] (%)	3 (20.0)	3 (5.7)	n.s.
Single procedure[b]			
CABG[d] (%)	3 (20.0)	8 (15.1)	n.s.
Valve replacement/repair (%)	5 (33.3)	23 (43.4)	n.s.
Ascending aortic graft replacement (%)	3 (20.0)	3 (5.7)	n.s.
TAR[e] (%)	2 (13.3)	7 (13.2)	n.s.
Other (%)	0 (0)	4 (7.6)	n.s.
Combined procedure[b]			
Valve replacement + CABG[d] (%)	1 (6.7)	5 (9.4)	n.s.
TAR[e] + CABG[d] (%)	1 (6.7)	3 (5.7)	n.s.
Preoperation EF[f] (%)	60.9 (58.9–75.3)	66.1 (57.6–74.6)	n.s.
Operation time (minutes)[a]	475 (420–636)	430 (348–482)	0.0255
Anesthesia time (minutes)[a]	591 (527–772)	534 (447–603)	0.0214
Extracorporeal circulation time (minutes)[a]	226 (204–303)	224 (180–263)	n.s.
Mechanical ventilation days[a]	3 (1–6)	1 (0–1)	<0.0001
Postoperative delirium[b]	8/7	13/40	n.s.
Maximum CRP (mg/dL)[a]	16.5 (10.5–23.6)	9.3 (6.7–13.2)	0.0032
Days from extubation to discharge[a]	35 (28–37)	18 (14–25.5)	<0.0001

[a]Median (interquartile range) data for continuous variables that are not normally distributed, The Mann–Whitney test was used for the analysis, [b]Number (percentage) and *p* value (Chi-squared test), [c]COPD, chronic obstructive pulmonary disease, CABG[d], Coronary artery bypass grafting, [e]Total arch replacement, [f]EF, ejection fraction. n.s., non-significant

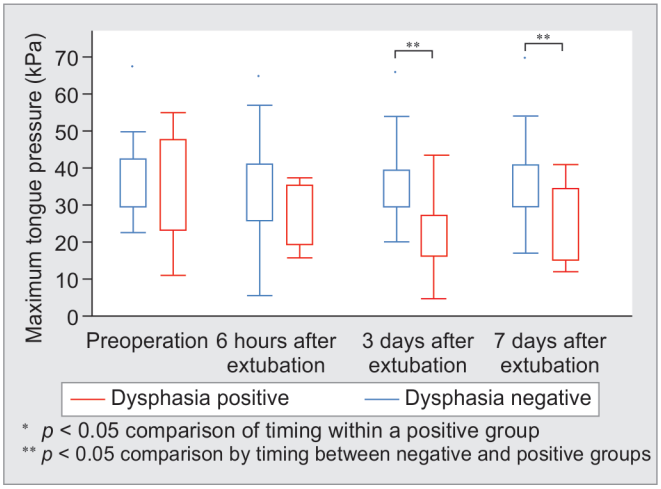


Fig. 2: Two-way ANOVA and multiple comparisons of tongue pressure. Data show median and interquartile range. The whiskers extend to 1.5 times interquartile range, and the outliers are values outside the whiskers' range. Bonferroni method as a *post hoc* test for two-way ANOVA. *$p < 0.05$ comparison by timing between negative and positive groups

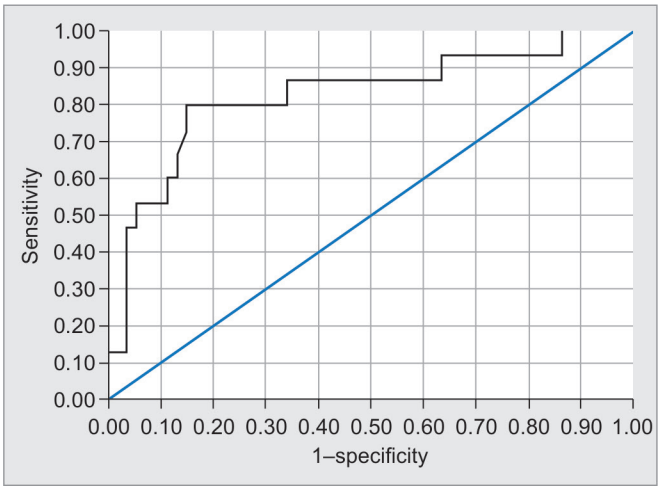


Fig. 3: Receiver operating characteristic curve to predict dysphagia. AUC = 0.82; maximum tongue pressure = 27.6 kPa; sensitivity = 84.9%; and specificity = 84.2%

The change in the maximum tongue pressure value at each time point of the study in all patients was evaluated. The mean values ± standard deviation (SD) for each time point are as follows. Preoperatively, 36 ± 9.4 kPa; 6 hours after extubation, 32.1 ± 11.2 kPa; 3 days after extubation, 32.2 ± 11.1 kPa; and 7 days after extubation, 34.2 ± 10.4 kPa. No significant difference was observed in these four timings.

Figure 2 shows the changes in the maximum tongue pressure in groups D and N. The mean values ± SD for each timing are as follows: Group D was 34.7 ± 12.8 kPa preoperatively, 27.5 ± 7.9 kPa 6 hours after extubation, 22.5 ± 10.2 kPa 3 days after extubation, and 26.8 ± 10.1 kPa 7 days after extubation. Group N was 36.4 ± 8.3 kPa preoperatively, 33.3 ± 11.7 kPa 6 hours after extubation, 34.9 ± 9.8 kPa 3 days after extubation, and 36.3 ± 9.6 kPa 7 days after extubation. There was no significant difference in the maximum tongue pressure before surgery between groups D and N. On 3 and 7 days after extubation, group D was significantly lower than group *N* ($p < 0.005$). In both groups, there was no significant difference between preoperative and the other three timings, but in group D, the maximum tongue pressure value on the third day after extubation was the lowest among the maximum tongue pressure values measured.

The ROC curve presents the maximum tongue pressure at 3 days after extubation when a significant difference first emerged between the D and N groups (Fig. 3). When 27.6 kPa was used as the cutoff value for maximum tongue pressure to predict dysphagia, the AUC was 0.82, sensitivity was 84.9%, and specificity was 84.2%.

The physical disabilities, cognitive impairment, and psychological impairment that occur in critically ill patients following intensive care have been termed as postintensive care syndrome (PICS).[19,20] Physical hypofunction in PICS is believed to arise from factors such as ICU-acquired weakness (ICU-AW), a neuromuscular disorder associated with disuse atrophy and critical illness.[21] This systemic muscle weakness is not limited to specific muscles. In critical illness, skeletal muscle is progressively catabolized, leading to skeletal muscle atrophies and the weakening of the muscles. This muscle weakness is thought to result from simultaneously increased protein catabolism and decreased protein synthesis.[22] In addition, this muscle weakness progresses over time.[23] Dysphagia that occurs after mechanical ventilation is referred to as postextubation dysphagia and ICU-acquired swallowing disorder,[24,25] and has been the focus of much attention in recent years. It has been reported that these swallowing disorders are associated with a worse prognosis for patients,[4] and although it is known that the severity of the disease and the duration of mechanical ventilation are related to the risk of swallowing disorders, the mechanisms and diagnostic methods are not clear.[26] One of the reasons why dysphagia is not yet clearly understood is the lack of an objective quantitative parameter for dysphagia. Therefore, tongue pressure, an objective quantitative parameter that requires the cooperation of the patient, is beginning to be used as an objective parameter of dysphagia. However, muscle weakness related to swallowing was reported to be associated with dysphagia,[27] and in this study, we also examined dysphagia and changes in maximum tongue pressure values.

Dysphagia is also a complication in critically ill postoperative cardiovascular surgery patients, and prolonged postoperative ventilation is considered as a risk factor for postextubation dysphagia.[3,28] With respect to the relationship between frailty and dysphagia in patients who undergo mechanical ventilation for 12 hours or more following cardiovascular surgery, one study that assessed frailty in terms of handgrip strength found that a majority of patients with low handgrip strength exhibited dysphagia.[29] In a long-term follow-up study of postextubation dysphagia in critically ill patients,[8] patients with postextubation dysphagia were more critically ill, spent more time on mechanical ventilation, and often experienced muscle weakness upon ICU/hospital discharge. In this regard, our study showed similar results. Patients who became dysphagic had a longer ventilation period and a higher severity of illness than those who did not have dysphagia.

We considered the relationship between changes in maximum tongue pressure values and dysphagia. In this study, there was no significant difference between the maximum tongue pressure preoperatively and at 6 hours after extubation and the presence

of dysphagia, but the maximum tongue pressure values were significantly lower in patients with dysphagia at 3 and 7 days after extubation. In another study that compared tongue pressure between outpatients and critically ill patients who were extubated following ≥48 hours of mechanical ventilation,[30] tongue pressure in critically ill patients gradually recovered over time but was lower than the maximum tongue pressure among outpatients even at 2 weeks after extubation. Oral sarcopenia, which is considered to be related to dysphagia, has been shown to be associated with generalized sarcopenia, even in patients who are not critically ill.[31] In this study, maximum tongue pressure was reduced in patients with dysphagia throughout the study period (until 7 days after extubation).

Long-term mechanical ventilation following cardiovascular surgery is considered a risk factor for postextubation dysphagia. In our assessment of the relationship between preoperative tongue pressure and postextubation dysphagia, no significant difference was observed.

The invasiveness of cardiovascular surgery combined with the longer duration of mechanical ventilation necessitated by critical illness resulted in ICU-AW. This can be inferred from the significantly higher postoperative CRP levels in patients who developed dysphagia. In addition, sedation and tracheal intubation greatly inhibit tongue movement, resulting in disuse atrophy and hypofunction of the tongue; recovery from these conditions can take a great deal of time. Dysphagia must therefore be detected quickly to prevent aspiration pneumonia. Another problem is the postextubation route of nutrition. After extubation, patients with dysphagia typically undergo enteral nutrition *via* a nasogastric tube. Long-term nasogastric intubation is reported to be a risk factor for dysphagia in patients after cardiovascular surgery.[32] In addition, nasogastric tubes are reported to inhibit swallowing function.[33] Furthermore, long-term intubation prevents patients from progressing with oral intake, which diminishes swallowing function, reduces maximum tongue pressure, and could also lead to aspiration. Therefore, swallowing function must be monitored using approaches such as tongue pressure measurement until 3 days after extubation, and patients with reduced tongue pressure or those diagnosed with dysphagia must continue to perform swallowing exercises and undergo rehabilitation.

The reduction in maximal tongue pressure, which lasted up to 7 days after extubation, may be due to the effects of the above-mentioned ICU-AW and discontinuation of oral intake after extubation and the associated nasogastric tube feeding. However, there was no significant difference in preoperative maximum tongue pressure between patients with and without postoperative dysphagia. In a study that compared tongue pressure before and 2 weeks after esophagectomy in patients with esophageal cancer,[15] higher preoperative tongue pressure was associated with greater postoperative reductions in tongue pressure. A history of heart failure and preoperative reduced cardiac function are risk factors for dysphagia after cardiovascular surgery.[4,34] Therefore, we considered the hypothesis that in patients who develop postoperative dysphagia, the maximum tongue pressure is already decreased preoperatively due to heart failure. However, according to our results, preoperative maximum tongue pressure was not associated with the presence of dysphagia.

In a study that examined the association between aspiration pneumonia and maximum tongue pressure after extubation in patients at an emergency department,[17] an ROC curve was drawn for maximum tongue pressure to predict aspiration pneumonia, with a cutoff point of 13.8 kPa, as mentioned previously. In this study, maximum tongue pressure best predicted dysphagia when the cutoff point was 27.6 kPa. This difference in cutoff points conceivably occurred because the previous study cited above used aspiration as an outcome,[17] whereas this study used a swallowing assessment sheet and the Modified Water Swallowing Test results as an indicator. Patients with more severe dysphagia demonstrate higher incidences of pneumonia and reintubation as well as higher mortality than patients without dysphagia.[9] The results of this study, which investigated dysphagia before it led to aspiration pneumonia, suggest that assessment of tongue pressure should be used as an indicator for early dysphagia intervention to prevent aspiration pneumonia.

Among patients who required ventilatory support after cardiovascular surgery, those who developed dysphagia after extubation had significantly lower maximum tongue pressure 3 and 7 days after extubation, although there was no significant difference between the two groups in maximum tongue pressure values preoperatively and 6 hours after extubation compared to those who did not develop dysphagia. In patients who developed dysphagia, we speculated that it was related to disuse atrophy caused by ICU-AW due to intraoperative and postoperative invasive procedures such as cardiovascular surgery and subsequent ventilatory management, and discontinuation of oral intake during ventilation and after extubation. In addition, if the maximum tongue pressure value is less than 27.6 kPa on the third day after extubation, oral intake should be carefully implemented. It is clinically useful to be able to track the progress of dysphagia after extubation using objective parameters such as tongue pressure rather than subjective observations made by the evaluator.

Toru Yamada https://orcid.org/0000-0002-5178-9377
Ryoichi Ochiai https://orcid.org/0000-0003-3039-3979
Yoshifumi Kotake https://orcid.org/0000-0001-5597-7132

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