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Original Article

Maximum Tongue Pressure as a Measure of Post-Extubation Swallowing Ability

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ABSTRACT

Background: Approximately half of all patients requiring mechanical ventilation with endotracheal intubation develop swallowing problems after extubation. Swallowing can be examined in several ways, but the preferred clinical methods are videofluoroscopic examination of swallowing or other imaging methods, which allow visual detection of abnormal swallowing patterns. Unfortunately, these imaging techniques do not allow quantitative analysis. If a device could provide numerical values in evaluating swallowing capability, research could then collect useful data to help determine when to reintroduce oral intake of food and liquids and whether aspiration is likely during such intake. Evidence suggests a relationship between maximum tongue pressure and the ability to swallow correctly. We therefore evaluated changes in tongue pressure over time in patients who had just been extubated and investigated whether significant pressure differences existed between patients who later aspirated and those who did not.

Methods: The participants were 36 patients who had received mechanical ventilation by means of endotracheal intubation. Maximum tongue pressure was measured repeatedly for 1 week after extubation. The values for participants who did and did not subsequently aspirate were then compared.

Results: Post-extubation tongue pressure values were lower than normal in all patients, but they increased over time. However, values for patients who aspirated were significantly lower than those for patients who could swallow normally.

Conclusion: The results suggest that tongue pressure is a useful test of post-extubation swallowing ability and that it can help determine when to restart oral intake of food and liquids and identify aspiration risk.

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KEYWORDS: dysphagia, tongue pressure, extubation, aspiration pneumonitis

Introduction

Approximately half of all patients receiving mechanical ventilation with endotracheal intubation experience post-extubation dysphagia, including transient dysphagia.[1–3] This increases the risk of aspiration and may lead to re-intubation.[4, 5] Careful evaluation of swallowing ability should therefore be performed as soon as possible after extubation.[6–8] However, no current tests can quantitatively evaluate post-extubation swallowing ability.[2, 9, 10] Swallow-

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Table 1 Baseline characteristics of patients

	total n = 62
Age (years)	62.7 ± 15.6
Sex (male/females) (n)	39/23
Tracheal intubation period (days)	7.2 ± 3.9
Steroid administration (n)	10
Internal use of antianxiety or psychotropic drugs (n)	25
False tooth (n)	16
Re-tracheal intubation (n)	3
Delirium development on or before 7th day after extubation (n)	17
Leaving hospital before 7th day (n)	5
Others (n)	1

disease (n)	total n = 62
CPA recovery	7
Acute drug intoxication	4
Acute myocardial infarction	4
Pneumonia	10
Heart failure	5
Ventricular fibrillation	2
Sepsis	5
External injury	12
Others	12

ing disorders are costly and clinically important in a large population of ICU patients.[11] Until now, such evaluation has usually involved videofluoroscopic (VF) examinations of swallowing.[12–14] However, because this procedure involves fluoroscopy, it is not simple; thus, it is unsuitable for simple screenings of post-extubation swallowing ability. At the bedside, screening recommendations include evaluations of tongue movement, proper velar and larynx position, swallowing reflex, and phlegm.[2] The Japanese 2009 Guidelines for Treatment of Stroke recommend a repetitive saliva swallowing test (RSST), a modified water swallowing test (MWST), and other tests for use in bedside evaluations.[15] These tests are certainly useful, but the results vary considerably among evaluators. In addition, because these tests involve actual swallowing, there is a danger of aspiration during testing.[12, 16, 17] Therefore, it would be much more useful to have a simple, precise, noninvasive quantitative test that poses no risk to patients during testing.

The tongue pressure test is a quantitative measure of swallowing ability that assigns a numerical value to tongue function.[18–20] Tongue pressure has been shown to be related to alimentation and swallowing disorders.[21–26] Patients with such disorders have significantly lower tongue pressure values than do controls, and tongue pressure is correlated with other well-known functional criteria used to evaluate swallowing ability.[25, 26] Most patients have at least some transient dysphagia after extubation, but the risk is greater for patients with low tongue pressure levels. Using data obtained from clinical records, we investigated changes over time in post-extubation tongue pressures in patients who required artificial respiration with endotracheal intubation and examined the relationship between tongue pressure and aspiration risk.

Participants and Methods

We studied the records of 62 patients who had been brought to our Emergency Life Support Center, who had received mechanical ventilation with endotracheal intubation for 24 hours or longer, and whose primary condition had been successfully treated and resulted in extubation. Those for whom regular measurements were not possible during the full 7 days were excluded, as were those with neurologic and cerebrovascular disorders. The excluded patients included three patients who required re-intubation, 17 who developed delirium within 7 days after extubation, five who were discharged within 7 days, and one with missing data (Table 1). We analyzed data from

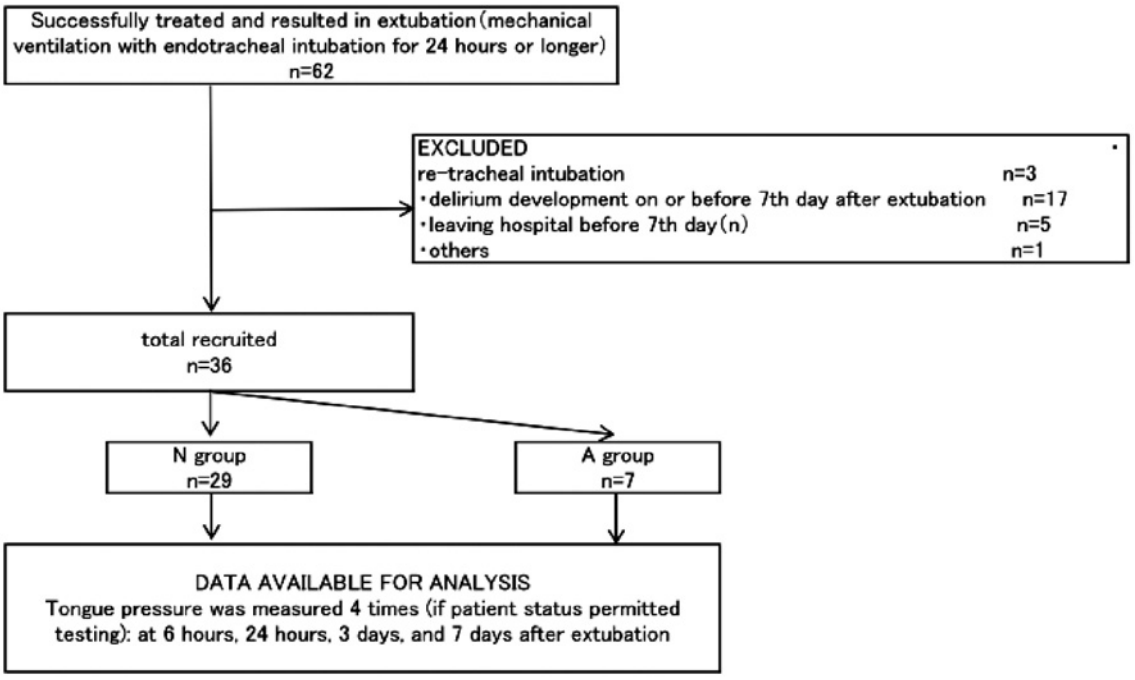

Fig. 1 Tongue pressure measurement of post-extubation flow diagram group N: normal; group A: aspiration

the remaining 36 patients who had undergone regular measurements of maximum tongue pressure over the full 7-day period. The 29 patients who did not develop aspiration after extubation were classified as the normal group (N), and the remaining seven patients who developed aspiration during the evaluation period, resulting in aspiration pneumonia, cessation of oral feedings, or postponement of oral feedings, were classified as the aspiration group (A). There were no cases in which oral intake was continued after aspiration in group A. In patients with aspiration and suspected aspiration, visible infiltrative shadows on recent radiographs were required for an aspiration diagnosis (Fig. 1).

A TPM-01 device (JMS, Hiroshima, Japan) was used to measure tongue pressure. The probe on the device was first inflated to a known initial pressure before the test. Patients inserted the probe into their mouths between the tongue and palate, and they were instructed to press the tip of the tongue as hard as possible against the palate, thereby providing a measure of maximum tongue pressure (Fig. 2, 3) Tongue pressure was measured four times (if patient status permitted testing): at 6 hours, 24 hours, 3 days, and 7 days after extubation. The four recorded values were the means of three individual measurements collected at each time point. The unit of measurement was kPa. The actual measurements were collected by a designated nurse in the Emergency and Critical Care Center or by members of a specially trained swallowing support team in the regular wards. All evaluators received specific instructions on tongue pressure measurement to ensure inter-observer reliability. Tongue pressure values were not used to determine whether patients were ready to start oral nutrition. Instead, existing standard methods were used to evaluate the likelihood of aspiration. To assess swallowing ability at our hospital, we use a five-item checklist designed to assess the safety of beginning oral intake of food and liquids. Patients are started on oral intake if the results of this checklist indicate that it is safe (Table 2).

The present study received approval from the Toho University Medical Center Omori Hospital Ethics Committee, and informed consent was received from all participants or their family members before study enrollment and after receiving a written explanation of the study goals and procedures (Approval No. 24-132). The statistical software used was Excel Statistics 2012 (Social Survey Research Information Co., Ltd., Tokyo, Japan). All values obtained were expressed as mean ± SD. The Mann-Whitney U-test was used to analyze differences in age and intubation time, and the chi-square test was used to analyze dif-

ferences in the male-female ratio, steroid use, and psychotropic drug use. The association of maximum tongue pressure with post-intubation time was analyzed with one-way analysis of variance and Tukey's multiple comparison test. Associations of maximum tongue pressure with post-intubation time in groups N and A were evaluated with two-way factorial analysis of variance and Bonferroni's multiple comparison test. Statistical significance was set at $p < 0.05$.

Fig. 2 Tongue pressure measuring device (TPM-01, JMS, Hiroshima)
This was the first Japanese study to use this device, which was approved for manufacture, sale, and clinical use in August 2010.

Results

Table 3 shows the background characteristics of groups N and A. No statistically significant differences were observed for any characteristic. Most patients resumed oral feeding within 24 hours after extubation, but the mean interval between extubation and start of oral feeding was 2.2 ± 2.5 days.

Maximum tongue pressure was 19.1 ± 10.4 kPa at 6 hours after extubation, 20.8 ± 9.2 kPa at 24 hours, 21.9 ± 11.5 kPa at 3 days, and 24.4 ± 10.2 kPa at 7 days after extubation. Tongue pressure at 6 hours and 7 days post-extubation significantly differed ($p < 0.05$) (Fig. 4). Two-way factorial analysis of variance was used for multiple comparisons of values between groups. In group N, maximum tongue pressure significantly increased over time, from 21.6 ± 10.4 kPa at 6 hours post-extubation to 25.5 ± 9.7 kPa at 3 days and 28.0 ± 10.2 kPa at 7 days ($p < 0.05$). In contrast, maximum tongue pressure in group A did not significantly increase; it was 8.5 ± 5.6 kPa at 6 hours after extubation and 9.7 ± 4.9 kPa at 7 days. Maximum tongue pressure values in groups N and A were 21.6 ± 10.4 kPa and 8.5 ± 5.6 kPa, respectively, at 6 hours; 22.2 ± 8.5 kPa and 15.9 ± 11.1 kPa, respectively, at 24 hours; 25.5 ± 9.7 kPa and 6.9 ± 3.7 kPa, respectively, at 3 days; and 28.0 ± 10.2 kPa and 9.7 ± 5.0 kPa, respectively, at the end of the 7-day study period. At each time point, the value for group A was significantly lower than that for group N ($p < 0.05$) (Fig. 5). The maximal tongue pressure immediately before

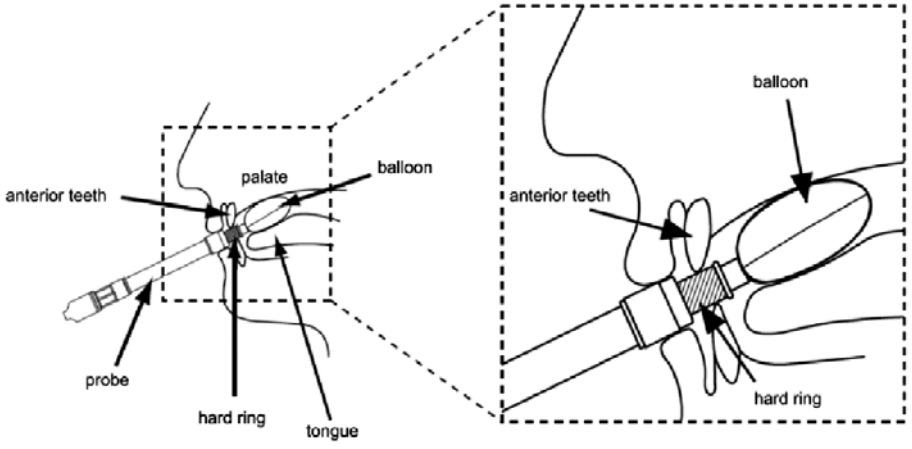

Fig. 3 Tongue pressure measurement method
The internal pressure of the balloon is first adjusted to a predetermined pressure, after which it is positioned in the oral cavity as shown. Tongue pressure is measured by having patients lift the tongue toward the palate with as much force as possible, as if to crush the balloon.

Table 2 Swallowing evaluation sheet

Swallowing evaluation
A doctor's in charge permission yes or no
1. When was it choked?
Under ingestion
After ingestion
Time should pass for a while after ingestion
It is not made to take in
2. Pa・ta・ka・ra Was each sound pronounced normally?
pa normal or abnormal
ta normal or abnormal
ka normal or abnormal
ra normal or abnormal
3. Oral hygiene state
False tooth yes or no
Oral hygiene state good or defect
There is generation of heat by pneumonia within 1 month these days. yes or no
4. RSST /30 seconds
5. Food test
jelly possible or impossible
thickness – water possible or impossible
water possible or impossible
After 1 ～ 5 enforcement, conference is carried out by the doctor in charge and a nurse, and a meal start is considered.

Before the patient is started on oral intake, we evaluate swallowing ability by asking the above five questions, in sequence.
＊RSST: repetitive saliva swallowing test

Table 3 Background characteristics of groups N and A

	group N (n = 29)	group A (n = 7)	P value
Age (year)	60.0 ± 17.5	68.4 ± 12.0	N.S.
Sex (male) (n)	16	5	N.S.
Intubation period (day)	7.5 ± 3.4	9.0 ± 0.3	N.S.
Steroid administration (n)	6	2	N.S.
Use of psychotropic drug (n)	15	5	N.S.

There were no significant differences between groups N and A in age, sex, duration of intubation or steroid, anxiolytic, or psychotropic drug use.

the onset of aspiration in group A was 13.5 ± 4.9 kPa. In addition, Receiver operating characteristic curve (ROC) analysis was performed on the maximal tongue pressure as the aspiration predictive index for all the cases; the diagnostic cut-off for maximal tongue pressure was 13.8 kPa, the sensitivity was 96.6%, and the specificity was 71.4%. The positive predictive value was 93.3%, and the negative predictive value was 83.3% (Fig. 6).

In group A, aspiration was diagnosed within 24 hours after extubation in five of the seven patients and within 3 days after extubation in the other two patients. At 1 week after extubation, maximum tongue pressure had increased in group N. In group A, maximum tongue pressure was low at 6 hours post-intubation and at 1 week.

Discussion

Although dysphagia related to intubation has been frequently reported, the relationship between post-extubation tongue pressure and swallowing ability is not well understood. Tongue pressure is important in eating and proper swallowing, particularly in moving boluses of food down into the esophagus. The tongue is used to send

roughly masticated lumps of food to the pharynx. Not surprisingly, studies have reported a correlation between tongue strength and the time required for food boluses to be swallowed and reach the esophagus.[21, 24, 25] A few studies found that loss of tongue strength can be used to evaluate dysphagia risk.[18, 21, 24–26]

As mentioned above, in patients requiring mechanical ventilation with endotracheal intubation, tongue strength tends to increase after extubation. Immediately after extubation, the tongue tends to be weaker than usual, and swallowing ability is below normal. However, recovery is usually complete after 1 week. Tongue pressure varies with age and sex and between individuals, and there is a clear tendency toward weaker pressures in elderly adults. Utanohara et al.[19] found that the standard value for maximum tongue pressure was 31.9 ± 8.9 kPa for adults older than 70 years and 41.7 ± 9.7 kPa for those aged 20-29 years, a difference of almost 10 kPa. Furthermore, maximum tongue pressure is higher among men than among women during the third through fifth decades of life, but it does not differ between sexes after the age of 60. With advancing age, it becomes increasingly difficult to use tongue pressure values to predict swallowing ability.[19]

Changes over time in tongue pressure differed greatly in groups N and A. At 6 hours post-extubation, group N already had tongue pressures greater than 20 kPa, and the pressures significantly increased at 1 week. In group A, tongue pressure values were under 10 kPa 6 hours after extubation, and they only slightly increased from these values at 1 week. When maximum tongue pressure values in groups N and A were compared at each time point (6

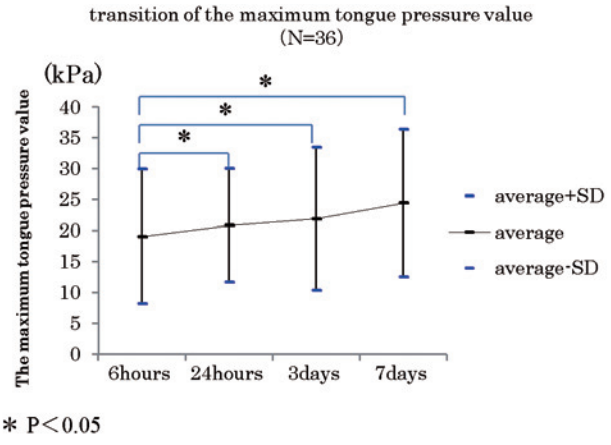

Fig. 4 Change in maximum tongue pressure (n = 36)
Maximum tongue pressure increased over time. At 1 week, maximum tongue pressure had increased to greater than 20 kPa.

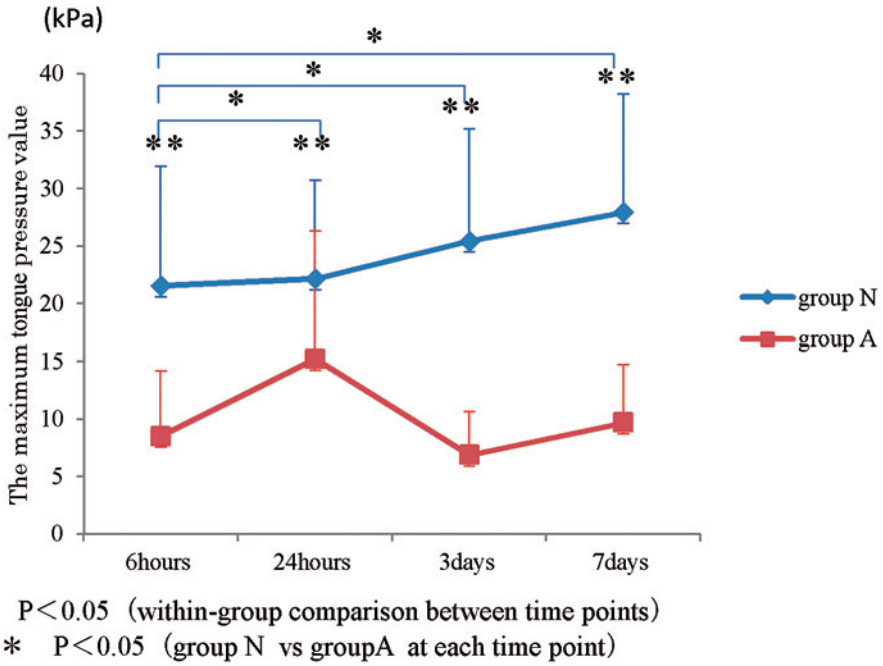

Fig. 5 Maximum tongue pressure in groups N and A
At 1 week, maximum tongue pressure had significantly increased in group N but not in group A. Furthermore, the values for group N were significantly higher than those for group A at all time points.

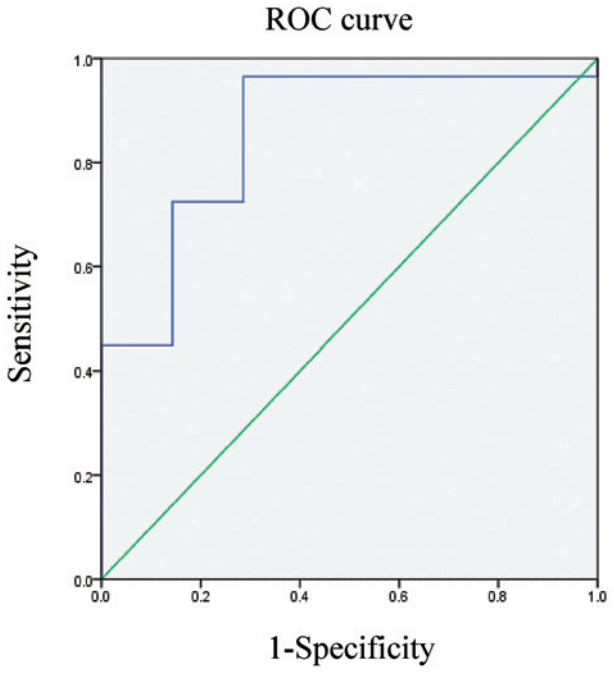

Fig. 6 ROC analysis

hours, 24 hours, 3 days, and 7 days after extubation), the values in group A were significantly lower than those in group N at all time points. Maximum tongue pressure reflects the ability to swallow, and values were low in patients who developed aspiration. In addition, because maximum tongue pressure did not increase even after 1 week in patients who later aspirated, careful evaluation of swallowing ability should continue for at least 1 week in addition to indirect swallowing training and the intervention of a swallowing support team. Such management should reduce the incidence of aspiration-related problems.

As noted above, normal tongue pressure differs by age and sex and between individuals.[27] Unfortunately, we did not analyze age and sex differences in the present study, so these differences should be evaluated in future studies. In patients who underwent intubation, potential problems with swallowing function could be inferred from tongue pressure values, and our findings did indicate that poor values were associated with a high risk of aspiration. However, there was no statistical correlation between duration of intubation and risk of aspiration after extubation. In addition, previous studies do not show a relationship between duration of intubation and decreased swallowing ability.[28, 29]

Normally, elevation of the soft palate seals off the oral and nasal cavities. When the tongue comes into direct contact with the soft palate, the hyoid bone is raised and the epiglottis seals off the entrance to the trachea. Once this intraoral configuration has been achieved, food boluses may be swallowed with no risk of aspiration. Therefore, the correct functioning of the soft palate, epiglottis, and hyoid each depends on the strength of tongue muscles during swallowing. Maximum tongue pressure in group A might have been diminished by edema development caused by friction from the intubation tube, which decreases the motility of the soft palate, epiglottis, and hyoid. This decreases tongue muscle tone and markedly reduces maximum tongue pressure. However, even in patients with relatively high maximum tongue pressures after extubation, the tongue muscle may fatigue with time because of the need to move the less-motile soft palate, epiglottis, and hyoid. This increasing fatigue could progressively reduce tongue pressures, thereby leading to aspiration. Alternatively, patients with excess sputum immediately after extubation would need to repeatedly expel and then swallow multiple times. This could increase the workload of the soft palate, epiglottis, and hyoid and reduce maximum tongue pressure. The intubation period was generally longer in group A. Future studies with a greater number of subjects and a larger variety of respiratory conditions might help clarify the relationship between intubation time and tongue pressure.

In group N, tongue pressure values significantly increased at 1 week after extubation, and the highest values (>20 kPa) were seen in patients who did not subsequently aspirate. However, even some patients who did not aspirate had pressures less than 10 kPa at 6 hours after extubation. Thus, although tongue pressure is useful in evaluating decreased ability to swallow, it might not be sufficient for predicting dysphagia. However, tongue pressure measurement is noninvasive and easy, and it yields reproducible quantitative values, making it a good bedside instrument. The patients in this study reported no discomfort, and the test was noninvasive. Because the results obtained are quantitative, the data are suitable for objective evaluation by a third party. This test may eventually replace videofluoroscopy as the standard testing instrument. The results of this study suggest that tongue pressure measurement could increase the objectivity of evaluating potential dysphagia when used in conjunction with RSST or MWST.[18]

Conclusion

Tongue pressure measurement is a simple, noninvasive method of evaluating post-extubation swallowing ability. Post-extubation tongue pressures are low in patients requiring mechanical ventilation, but they normally return to healthy levels over time. In addition, tongue pressure values of patients who developed post-extubation swallowing disorders were significantly lower than those of patients without such disorders. Patients with such disorders seemed to require more than 1 week to recover their swallowing ability. Although tongue pressure alone should not be used to diagnose reduced post-extubation swallowing ability, it might be useful in combination with other tests. Future studies should enroll a larger number of participants and the results should be compared with other scales to better assess the value of tongue pressure measurements. The current findings suggest that tongue pressure measurement could become a useful device for screening potential aspiration cases and for determining the appropriate time to start oral intake of food and liquids.

Conflicts of interest: The authors have no conflicts of interest to disclose.

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