The Relationships among Objective Measures of Tongue Strength and Risk of Aspiration

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ABSTRACT

Objective: The objective measures of tongue strength can predict the risk of aspiration. Isometric tongue pressure and endurance have been reported to be lower in patients who have premature spillage, penetration and/or aspiration on endoscopic evaluation. We aimed to study the relationships between the objective measures of tongue strength and risk of aspiration in our population.

Methods: Seventy-five participants were enrolled to the study. The mean age of the participants was 58.3 ±13.6 years old. They were divided into three groups (25 participants in each group). The first group was normal participants who have had no history of swallowing problem with normal flexible endoscopic evaluation of swallowing (FEES). The second group was symptomatic patients who have had history of dysphagia and/or aspiration but normal FEES. The third group was patients who have had history of dysphagia and/or aspiration with evidence of premature spillage or laryngeal penetration or aspiration by FEES. All participants underwent objective measurements of the tongue strength including maximal isometric pressure (MIP) and endurance by Iowa Oral Performance Instrument (IOPI). The quantitative data between groups were compared using ANOVA and chi-square test was used for qualitative data. The optimal cut-off points were determined by Receiver Operating Characteristic (ROC) curve.

Results: MIP and endurance were significantly lower in patients who have had premature spillage, penetration and/or aspiration on endoscopic evaluation. The appropriate cut-off points for high risk group are 35 and 25 kPa for the anterior and posterior tongue pressure respectively.

Conclusion: The tongue pressure can be used to screen patients who are at risk of aspiration, which will lead to early investigation and intervention for the management of these patients.

Keywords: Tongue pressure; Iowa Oral Performance Instrument (IOPI); flexible endoscopic evaluation of swallowing (FEES) (Siriraj Med J 2018;70: 302-309)

INTRODUCTION

The tongue is an important key structure for bolus formation and generating pressure for bolus propelling.[1-3] The impairment of lingual function exhibits reduction of bolus control, resulting in spillage or leakage of the food from the oral cavity into the pharynx before swallowing. The patients will ultimately have severe laryngeal penetration and aspiration. Aspiration can cause pneumonia, lung abscess, and fatal respiratory failure.[4-6] Patients at risk of severe premature spillage include elderly patients, patients with neuromuscular diseases such as stroke, Parkinson's disease, myasthenia gravis, or multiple sclerosis etcetera.[5] Leder found that patients who had incomplete lingual range of motion had 2.72 times higher risk of aspiration than a person without this problem.[7] Many clinicians use tongue-strength testing to determine potential risk of aspiration. Iowa Oral Performance Instrument (IOPI®) is a tool that is used to measure the strength of the tongue. This is a standard and reliable tool as has been shown in many researches.[1,3,8-12] The objective of this study was to

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Received 4 December 2017 Revised 16 February 2018 Accepted 25 April 2018
doi:10.14456/smj.2018.49

determine degree of tongue weakness with the risk of premature spillage which could lead to severe aspiration, and the tongue pressure in normal Thai population.

MATERIALS AND METHODS

This study was performed between August 2014 and April 2016 after being approved by the Human Investigation Committee. Measures of tongue strength were collected from three groups of individuals.

Population

1. **The first group** (normal participants group, n=25) had no history of swallowing problem and normal flexible endoscopic evaluation of swallowing (FEES)
2. **The second group** (symptomatic group, n=25) had history of dysphagia and aspiration that interfered with daily life and needed medical attention, but had normal FEES (no evidence of premature spillage or laryngeal penetration or aspiration).
3. **The third group** (diseased group, n=25) had history of dysphagia and aspiration with evidence of premature spillage or laryngeal penetration or aspiration on FEES.

Instrumentation & Intervention

Determining of aspiration status

The aspiration status of all participants was obtained by FEES. (Fig 1) The main findings of interest were premature spillage, laryngeal penetration, and aspiration.

1. **Premature spillage** is defined as inability to hold the food bolus within the oral cavity before initiating the pharyngeal phase of swallowing.
2. **Laryngeal** penetration is defined as passage of materials into the larynx, but not through the vocal folds.
3. **Aspiration** is defined as passage of materials through the vocal folds.

Fig 1. FEES instruments and FEES technique.

Measures of tongue strength

The tongue strength was objectively assessed by IOPI. (Fig 2) We placed the bulb on anterior tongue (just behind the alveolar ridge) and posterior tongue (midline of the tongue at sulcus terminalis) and then measured the following two values; (Fig 3)

1. **Maximum isometric pressure (MIP)** is the highest pressure that occurs when a patient's tongue is pushed against the palate. The MIP is reported in kilopascals (kPa).
2. **Endurance** is the period that a patient can maintain the pressure about 50% of the MIP, measured in seconds. This value represents the exhaustion of the tongue or tongue fatigability.

Fig 2. IOPI (Iowa oral performance instrument).

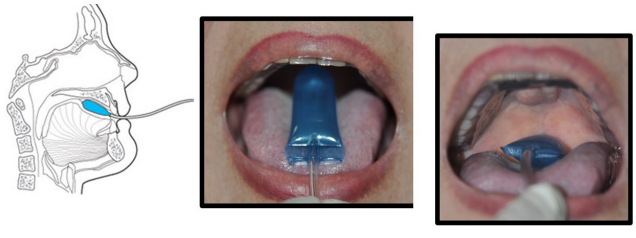

Fig 3. Position of tongue bulb.

Analysis

Statistical analyses have been conducted using SPSS version 19 (SPSS Inc). Descriptive statistics including the number & percentage of the categorical data and mean ± standard deviation of the continuous data with normal distribution were calculated to examine the distribution characteristics of group performance on tongue measures. All between-group comparisons were investigated using ANOVA for quantitative data (tongue measures, age) and chi-square test for qualitative data (sex). Pearson correlation was used to explore the relationship of tongue measure and bulb location. The

optimal cutoff points were determined using Receiver Operating Characteristic (ROC) curves and diagnostic values (sensitivity, specificity, positive and negative predictive values) were calculated. Significance level was set at 0.05 for all analyses.

RESULTS

Seventy-five adults were enrolled in this study. The mean age was 58.3 ±13.6 years (ranged 30-85), which did not differ between groups. Eleven of 50 patients (22%) with dysphagia had a history of aspiration pneumonia at least once in life. When compared with symptomatic group, the diseased group had more incidence of this event (40 vs. 4%). The most common underlying disease was cerebrovascular disease which was found 64% in the diseased group.

Descriptive statistics including age, gender, underlying disease, history of aspiration pneumonia, and duration of symptom are shown in Table 1.

Isometric tongue strength by objective measurement

The mean anterior isometric tongue strength in diseased group was 19.9±11.1 kPa (95% CI 15.3-24.5), which was significantly less than that of the normal participant group (59.5±13.3 kPa, 95% CI 54.0-65.0, $P < .001$) and the symptomatic group (46.4±10.4 kPa, 95% CI 42.1-50.7, $P < .001$). When comparing the mean posterior isometric tongue strength, we found the similar result that diseased group had lower posterior tongue strength than both normal participants (12.8±7.5, 95% CI 9.7-15.9 vs. 54.0±12.6, 95% CI 48.8-59.2, $P < .001$) and symptomatic group (12.8±7.5, 95% CI 9.7-15.9 vs. 39.4±12.7, 95% CI 34.1-44.6, $P < .001$). Moreover, the symptomatic group also had significantly lower isometric tongue strength than the normal participants on both anterior (46.4±10.4 vs. 59.5±13.3 kPa, $P < .001$) and posterior (39.4±12.7 vs. 54.0±12.6 kPa, $P < .001$) bulb location. (Table 2)

Correlation between anterior vs. posterior isometric tongue strength

Anterior isometric tongue strength was positively correlated with posterior isometric tongue strength (r= 0.915, $P < .001$), as shown in Fig 4.

From the ROC curve, the anterior and posterior isometric tongue strength cutoff values that were the best fit to identify aspiration in FEES were 35 and 25 kPa respectively. At this cutoff, the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were 92% (95% CI 75-98%), 96% (95% CI 87-99%), 92% (95% CI 75-98%) and 96% (95% CI 87-99%) respectively. The accuracy was 94.7% (95% CI 87-98%). By using the forward stepwise logistic regression analysis, we observed an increased risk for aspiration among who had anterior isometric tongue strength less than 35 kPa or posterior isometric tongue strength less than 25 kPa (Diagnostic Odd Ratio (DOR) 65.01; 95% CI 5.02-841.72) as shown in Fig 5.

TABLE 1. Demographics characteristic of 75 studied participants.

	Total (n=75)	Normal participant (n=25)	With dysphagia symptoms		*P* value**
			Normal FEES* (n=25)	Abnormal FEES* (n=25)	
Gender					
Male	45 (60%)	14 (56%)	14 (56%)	17 (68%)	0.607
Female	30 (40%)	11 (44%)	11 (44%)	8 (32%)	
Mean age (year) ± SD	58.3±13.6	53.8±13.8	59.9±12.7	61.2±13.6	0.117
Has history of aspiration pneumonia	11 (14.6%)	-	1 (4%)	10 (40%)	N/A
Mean duration of dysphagia (days)	206.2±166.2	-	205.0±158.8	207.4±176.5	N/A
Neurological diseases (e.g. CVA)	22 (29.3%)	0	6 (24%)	16 (64%)	N/A

*Normal FEES: defined as no evidence of premature spillage, laryngeal penetration and aspiration on FEES Abnormal FEES: defined as present of premature spillage or laryngeal penetration or aspiration on FEES

**The mean difference is significant at the 0.05 level.

Abbreviations: CVA = cerebrovascular accident, N/A = not applicable

TABLE 2. Mean anterior and posterior isometric tongue strength obtained on the IOPI.

	Normal Participant (n=25)	With dysphagia symptoms		*P* value ***
		Normal FEES * (n= 25)	Abnormal FEES * (n= 25)	
Anterior tongue strength (kPa)**	59.5±13.3 (35.0-86.0)	46.4±10.4 (23.0-69.0)	19.9±11.1 (4.0-48.0)	< .001[a]
Posterior tongue strength (kPa)**	54.0±12.6 (30.0-76.0)	39.4±12.7 (22.0-69.0)	12.8±7.5 (2.0-29.0)	< .001[a]

*Normal FEES: defined as no evidence of premature spillage, laryngeal penetration and aspiration on FEES Abnormal FEES: defined as present of premature spillage or laryngeal penetration or aspiration on FEES
** Mean±SD (minimum-maximum)
*** The mean difference is significant at the 0.05 level.
a: Using ANOVA and Bonferroni analysis methods, all pairwise comparisons had significantly differentiation (*P*< .05)

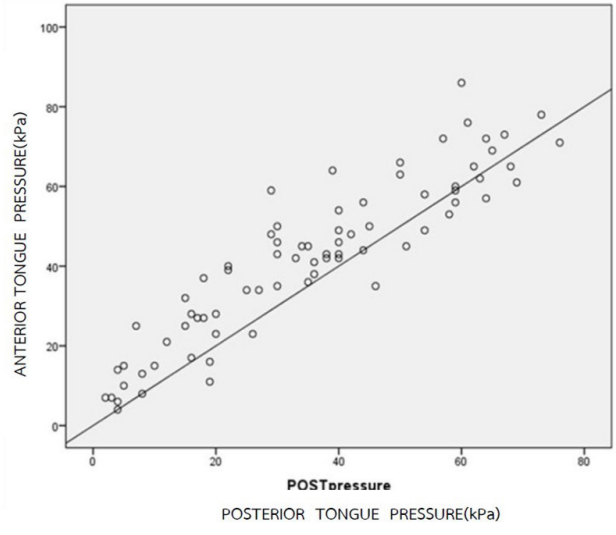

Fig 4. Correlation between anterior and posterior tongue pressure. Circle dots indicate individual data points.

Isometric Endurance

The mean isometric endurance in the diseased group was significantly less than the two other groups at both anterior (2.7±2.5; 95% CI 1.6-3.7 vs. 10.6±4.1; 95% CI 8.9-12.3, *P* < .001 and 2.7±2.5; 95% CI 1.6-3.7 vs. 7.9±4.7; 95% CI 5.9-9.8, *P* < .001) and posterior (1.7±1.9; 95% CI 0.9-2.5 vs. 9.8±4.8; 95% CI 7.8-11.7, *P* < .001 and 1.7±1.9; 95% CI 0.9-2.5 vs. 5.8±2.9; 95% CI 4.6-7.0, *P* < .001) bulb location. The same result was found when anterior and posterior endurances were compared between normal participants and symptomatic group (10.6±4.1 vs. 7.9±4.7, *P* = .048 and 9.8±4.8 vs. 5.8±2.9, *P* < .001). The mean anterior and posterior isometric endurances in all groups were illustrated in Table 3.

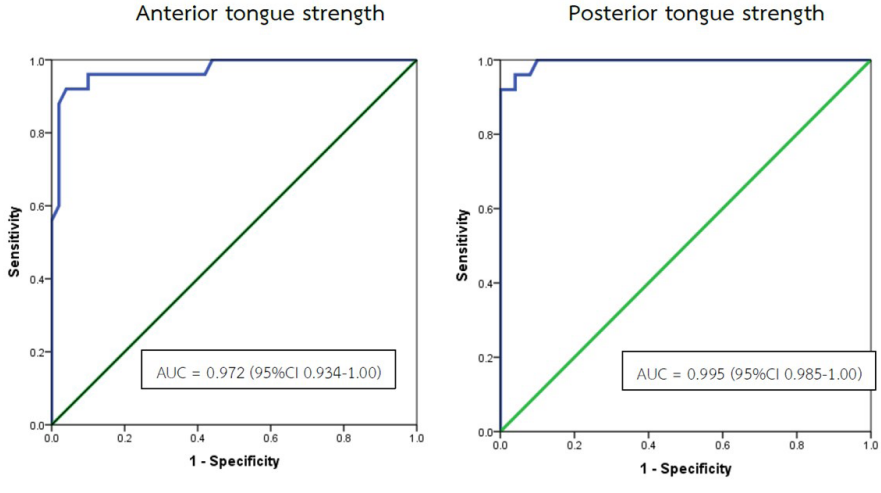

Fig 5. Receiver Operating Characteristic curves (ROC curve) of anterior and posterior isometric tongue strength to identify aspiration by FEES in all studied patients.

TABLE 3. Mean anterior and posterior endurance obtained on the IOPI.

	Normal	With dysphagia symptoms		
	Participant (n=25)	Normal FEES * (n= 25)	Abnormal FEES * (n= 25)	*P* value***
Anterior endurance (sec)**	10.6±4.1 (4.0-18.0)	7.9±4.7 (1.0-23.0)	2.7±2.5 (0-8.0)	< .001[a]
Posterior endurance (sec)**	9.8±4.8 (3.0-20.0)	5.8±2.9 (1.0-12.0)	1.7±1.9 (0-7.0)	< .001[a]

*Normal FEES: defined as no evidence of premature spillage, laryngeal penetration and aspiration on FEES Abnormal FEES: defined as present of premature spillage or laryngeal penetration or aspiration on FEES

** Mean ± SD (minimum-maximum)

*** The mean difference is significant at the 0.05 level.

a: Using ANOVA and Bonferroni analysis methods, all pairwise comparisons had significantly differentiation ($P < .05$)

Correlation between anterior vs. posterior endurance

There was a significant correlation between anterior endurance and posterior endurance (r= 0.830, $P < .001$), as shown in Fig 6.

The areas under the ROC curve to differentiate the aspiration-positive on FEES and aspiration-negative group using anterior and posterior endurances were 0.901 and 0.927 respectively. The cutoff point of 8 secs for anterior isometric endurance and 3 secs for posterior isometric endurance yielded the highest sensitivity and specificity. At this cutoff, the sensitivity, specificity, PPV, NPV, and accuracy of the anterior part were 96% (95% CI 80-99%), 66% (95% CI 52-77%), 58.5% (95% CI 43-72%), 97.1% (95% CI 85-99%), and 76% (95% CI 65-84%) respectively, and for the posterior part were 72% (95% CI 52-85%), 94% (95% CI 84-98%), 86% (95% CI 65-95%), 87% (95% CI 76-94%), and 86% (95% CI 77-92%) respectively, as shown in Fig 7.

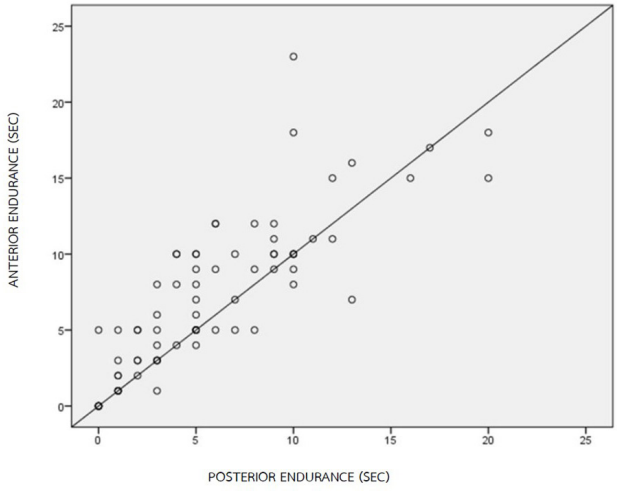

Fig 6. Correlation between anterior and posterior endurance.

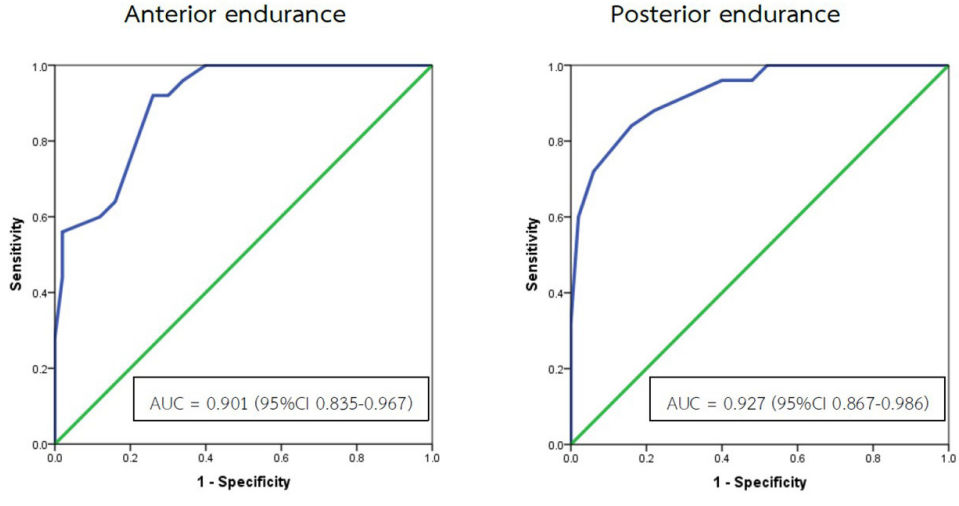

Fig 7. Receiver Operating Characteristic curves (ROC curve) of anterior and posterior endurance to identify aspiration in FEES in all studied patients.

Tongue strength and endurance in normal population

The mean and SD of anterior and posterior isometric tongue pressures obtained from the 25 control participants were 59.5±13.3 (95% CI 54.0-65.0) and 54.0±12.6 (95% CI 48.8-59.2) kPa respectively, whilst the anterior and posterior endurances were 10.6±4.1 (95% CI 8.9-12.3) and 9.8±4.8 (95% CI 7.8-11.7) secs respectively.

Effect of age and sex on the isometric tongue strength and endurance

Men were more likely to have higher isometric tongue strength than women with both anterior (63.8 vs. 54.1) and posterior (58.6 vs. 48.1) bulb location, but only the difference of posterior tongue strength was significant (P = .035). As well as the endurance, men tended to have longer endurances at both anterior (11.4 vs. 9.5) and posterior (11.0 vs. 8.2) bulb locations, but the difference was not significant (P >.05). To compare between two age groups: <60 years and ≥60 years, the result revealed that younger group had stronger tongue strength and higher endurance than the elder, but this was not statistically significant. This study revealed no correlation between age and isometric tongue strength or age and endurance in healthy participants. (Table 4)

DISCUSSION

Dysphagia accounts for approximately 24% to 80% of patients which depends on the concomitant medical disorders and the population studied.[6,13] Dysphagia is practically classified into two categories; oropharyngeal and esophageal dysphagia. Tongue weakness implies one of the common etiologies of oropharyngeal dysphagia, which leads to chronic aspiration.[2,6,14-16] In our study, 22% of patients with clinical dysphagia had a meaningful aspiration resulting in aspiration pneumonia at least once in life. Leder found that patients with impaired lingual function would have a 2.72 times higher risk of aspiration than a person without this problem.[7] Our result shows that patients who have had laryngeal penetration-aspiration had lower isometric tongue strength at both anterior and posterior bulb locations compared with normal participants. These support findings of previous studies that lower isometric tongue strength represented diminished functional reserve, which increased risk for dysphagia and aspiration.[1,3,17] The impairment of lingual function reduces ability to maintain the bolus during the oral phase and leads to spillage or leakage of the food from the oral cavity into the pharynx before airway protection reflex occurs. The suitable tongue strength is essential for safe swallowing and the exercises designed to strengthen the tongue may be one of the most useful therapies.[18] Common assessment is based on subjective judgment of the force being applied by tongue against resistance provided by tongue depressor. Disadvantages of subjective method are assessors' bias and inconsistent grading by multiple assessors.[9] Isometric endurance is another interesting value that represents fatigability of tongue. During the oral phase, the tongue creates the pressure against the palate to seal the posterior exit. If a patient can hold the pressure only shortly, this will increase the likelihood of leakage leading to premature spillage and penetration-aspiration. While the relationship

TABLE 4. Mean anterior & posterior tongue strength and anterior & posterior endurance as a function of age and gender in normal participant (n=25)

	Anterior tongue strength (kPa)*	Posterior tongue strength (kPa)*	Anterior endurance (sec)*	Posterior endurance (sec)*
Gender				
Men	63.8±13.2	58.6±11.2	11.4±1.0	11.0±5.3
Women	54.1±11.8	48.1±12.2	9.5±4.2	8.2±3.6
P Value **	.069	.035	.268	.145
Age				
<60	61.8±12.9	55.8±12.1	11.3±3.7	10.6±4.8
≥60	52.3±12.9	48.3±13.5	8.5±5.0	7.0±3.7
P Value **	.132	.214	.159	.104

* Mean±SD

** The mean difference is significant at the 0.05 level.

of strength of tongue and swallowing function are well documented, the study of endurance is limited and the results about this issue are inconsistent. The systematic review of Valerie A et al in 2013 revealed that when compared with healthy control groups, the populations with disorders such as Parkinson's disease, head and neck cancer, multiple sclerosis, traumatic brain injury, or cerebrovascular accident had significantly lower tongue endurance, but they did not identify the aspiration status among patients.[9] Our study revealed that patients who have had laryngeal penetration-aspiration had lower isometric endurance at both anterior and posterior bulb locations compared with normal participants. The IOPI is one of the objective methods that has been used successfully to evaluate tongue strength in several studies.[9,19] Up to date, the cutoff points to identify risk of aspiration on endoscopic evaluation has not been reported. From our study, the most appropriated cutoff points for the anterior and posterior tongue pressures to the presence of aspiration are 35 and 25 kPa, respectively. These scores offer high sensitivity, specificity, positive and negative predictive value and accuracy. Additionally, a patient who has anterior isometric tongue strength less than 35 kPa or posterior isometric tongue strength less than 25 kPa would have 65.01 times higher risk for aspiration than a person who has more tongue strength. These cutoff scores are suitable in screening and grading patients into high or low risk of aspiration. This will allow physicians to better identify those who will benefit from aspiration precautions20 and can help them choose a better treatment plan such as dietary modification, postural adjustment, and/or tongue strengthening rehabilitation. We observed that 6 patients in the diseased group who had received tongue strengthening training exercise developed better isometric tongue strength and ultimately decreased the degree of penetration-aspiration on FEES.

According to tongue strength measures in normal swallowing, mean values of tongue strength is ranged from 43 to 78 kPa in healthy adults[9,21] and the difference of maximal tongue strength and endurance in healthy normal population was reported depending on race and age.[9,22,23] The normal score in Thai population has not previously been studied. Our study demonstrated means of anterior and posterior tongue strengths in healthy Thai people are 59.5±13.3 kPa and 54.0±12.6 kPa respectively. The mean of anterior and posterior endurances are 10.6±4.1 and 9.8±4.8 secs respectively. No statistically significant difference of the tongue strength and endurance between adult men and women was found in this study. Previous literatures mentioned the effect of aging on tongue strength and reported that maximum tongue strength would decrease with increasing age in healthy adults.[9,22,24] They hypothesized that the result was related to an overall decline in skeletal muscle mass and central nervous system change in the elderly.[17] However, this will require further investigation for the tongue pressure and endurance in each gender of varying age groups and races.[25,26] Finally, the positions of the IOPI bulb applied in the mouth may have differed between studies.[27] In this study we recorded the tongue strength and endurance both anteriorly and posteriorly and obtained the similar result that the tongue strength and endurance measured in the anterior position was typically higher than in the posterior part.[9] Nevertheless, there were the positive correlations of both tongue strength and endurance values obtained from the anterior and posterior portions of tongue, so clinicians can measure the tongue pressure only at the anterior part because of the ease of application.

CONCLUSION

Our data suggests that objective measures of tongue strength can predict the risk of aspiration. Isometric tongue strength and endurance were lower in patient who had had premature spillage, penetration and/or aspiration on endoscopic evaluation. Tongue strength measured by IOPI may help identify patients at risk of aspiration and the appropriate cutoff points for high risk group are 35 and 25 kPa for the anterior and posterior tongue pressures respectively. According to its simple techniques, the tongue pressure can be used to screen aging or neurological deficit population which will lead to early investigation and also early intervention especially in the high risk for aspiration group.

ACKNOWLEDGMENTS

This research project was supported by Faculty of Medicine Siriraj Hospital, Mahidol University, Grant Number (IO) R015831057.

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