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## Spontaneous Swallowing Frequency [Has Potential to] Identify Dysphagia in Acute Stroke

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### Abstract

**Background and Purpose**—Spontaneous swallowing frequency has been described as an index of dysphagia in various health conditions. This study evaluated the potential of spontaneous swallow frequency analysis as a screening protocol for dysphagia in acute stroke.

**Methods**—In a cohort of 63 acute stroke cases swallow frequency rates (swallows per minute: SPM) were compared to stroke and swallow severity indices, age, time from stroke to assessment, and consciousness level. Mean differences in SPM were compared between patients with vs. without clinically significant dysphagia. ROC analysis was used to identify the optimal threshold in SPM which was compared to a validated clinical dysphagia examination for identification of dysphagia cases. Time series analysis was employed to identify the minimally adequate time period to complete spontaneous swallow frequency analysis.

**Results**—SPM correlated significantly with stroke and swallow severity indices but not with age, time from stroke onset, or consciousness level. Patients with dysphagia demonstrated significantly lower SPM rates. SPM differed by dysphagia severity. ROC analysis yielded a threshold of SPM 0.40 which identified dysphagia (per the criterion referent) with 0.96 sensitivity, 0.68 specificity, and 0.96 negative predictive value. Time series analysis indicated that a 5 to 10 minute sampling window was sufficient to calculate spontaneous swallow frequency to identify dysphagia cases in acute stroke.

**Conclusions**—Spontaneous swallowing frequency presents high potential to screen for dysphagia in acute stroke without the need for trained, available personnel.

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**Disclosures:** none

## Keywords

dysphagia; screening; acute stroke; dysphagia severity; spontaneous swallow; swallow frequency

Early identification of dysphagia in stroke survivors by post-admission screening has been shown to reduce morbidity and mortality [1,2,3]. [Dysphagia screening differs from the clinical assessment (e.g., bedside examination) of dysphagia in that screening does not entail diagnosis or detailed clinical description. Screening involves a brief, inexpensive, acceptable, and valid test of all members of a target population to identify those members at risk for a particular disease or condition[4, 5]. In acute stroke, dysphagia screening intends to identify those cases that require further professional evaluation (e.g., clinical bedside examination) vs. those who can safely take food, liquid, or medications by mouth [3].]Current methods proposed to screen for dysphagia in acute stroke cases typically incorporate some form of clinical examination plus or minus a 'test' swallow of one or more materials [6–8]. However, available evidence suggests that few published clinical screening protocols have adequate psychometric properties to function as effective dysphagia screening tools in stroke and no consensus exists regarding the optimal screening protocol [6,7,9]. Limitations in existing dysphagia screening tools may contribute to low compliance with dysphagia screening [3, 10] and exclusion of dysphagia screening as a performance measure by the Joint Commission in 2010 [3,7].

Spontaneous swallowing is viewed as one of a group of protective aerodigestive reflexes supporting airway protection [11–15]. Reduction in spontaneous swallowing frequency has been demonstrated as a sensitive index of dysphagia in clinical populations [16,17]. Moreover, reduced spontaneous swallow frequency has been associated with increased pharyngeal secretions which elevate the risk of chest infection in health-compromised individuals [16]. Evaluation of spontaneous swallowing frequency is anticipated to function as an effective screening of dysphagia in patients with acute stroke who are at risk for swallowing difficulty.

In the current study, a validated technique to calculate spontaneous swallow frequency was applied to a cohort of acute stroke patients. Acute stroke patients were categorized as presenting dysphagia or no dysphagia based on a validated clinical swallowing examination. Differences in spontaneous swallow frequency were compared across the two subgroups. In addition, receiver operator curve (ROC) analysis was used to identify a threshold in spontaneous swallow frequency that distinguished dysphagia status within the larger cohort. Finally, time series analysis was applied to identify the minimally adequate time period required for accurate calculation of spontaneous swallowing frequency.

## METHODS

### Subjects

Between May and July, 2012 consecutive stroke admissions were monitored and those meeting inclusion/exclusion criteria were recruited for inclusion in this study. Inclusion criteria incorporated age ≥ 21 years of age with confirmation of acute stroke by neurological examination and neuroimaging study. Exclusion criteria included trauma or anatomical alteration to the head neck region, pre-existing conditions contributing to dysphagia, pre-stroke dysphagia, intubation at the time of recruitment, and patient/proxy refusal to participate in this study. All participants received stroke and swallowing clinical evaluations in addition to assessment of spontaneous swallowing frequency. The local Institutional Review Board (IRB) approved the study and all patients or their approved proxy signed an IRB approved consent form.

## Stroke Assessments

The primary metric of stroke severity was the National Institutes of Health Stroke Scale (NIHSS) [18, 19]. The modified Rankin scale (mRS) [20, 21] was used as a metric of stroke impairment, and the modified Barthel Index (BI) [22, 23] was employed as a metric of functional impairment. Finally, the Glasgow Coma Scale (GCS) [24] was utilized as an index of consciousness. Obtained scores for each patient were presented as means and standard deviations for the dysphagia-specific subgroups.

## Dysphagia Assessments

The Mann Assessment of Swallowing Ability (MASA) [25] is a stroke-validated clinical assessment of swallowing. The MASA served as the criterion referent in this study. A MASA score of 178 (from a total of 200 possible points) indicates the presence of any dysphagia. In addition, MASA scores identify the severity of dysphagia (mild 168 – 178, moderate 139 – 167; severe 138). A second index of dysphagia, the Functional Oral Intake Scale (FOIS) [26] is a stroke-validated metric of functional oral intake of food and liquid. Higher scores on the FOIS indicate less severe dysphagia with greater ability for an expanded range of oral intake of food and liquid.

## Spontaneous Swallow Frequency Assessment

Spontaneous swallow frequency was measured with an acoustic recording obtained via a miniature microphone (VT506, Voice Technologies Switzerland) connected to a digital voice recorder (Olympus DS-40). The microphone was adhered to the skin of the anterolateral neck just below the lateral cricoid cartilage in the area identified by Takahashi [27, 28] as optimal to record swallow sounds. Rycote was used to affix the microphone over the recording area (Rycote Microphone Windshields LTD, Gloucestershire, UK). Recordings were obtained over a 30 minute interval with all patients resting quietly in bed. All recordings were analyzed off line using an acoustic software program (TF 32, P. Milenkovic, Madison, WI, 2001) which displayed a visual trace of the recording simultaneous with the auditory signal. Two independent judges reviewed all recordings in one minute segments to identify the presence or absence of swallow activity. Judges were blinded to the clinical status of stroke cases. Spontaneous swallowing frequency rate was calculated as swallows per minute (SPM) for each 30 minute recording. In prior work, this technique was validated and demonstrated high interjudge reliability [29].

## Statistical Analyses

Sample demographics were evaluated using descriptive statistics. Raw values for each subject were examined using correlations to note significant relationships between swallow frequency, stroke, and dysphagia indices. Based on MASA threshold, dysphagia subgroups (+/–) were identified and SPM was compared between subgroups. MASA severity categories were analyzed for significant differences in SPM across severity of dysphagia and compared using independent t tests.

Accuracy of the screening measure SPM to identify patients with dysphagia was identified by comparison to the clinical evaluation method (MASA) and analyzed in terms of sensitivity (Se), specificity (Sp), and positive and negative predictive values (PPV, NPV). The 95% confidence intervals (CI) of these measures were calculated using standard methods. To identify the optimal SPM cut point discriminating between patients with and without dysphagia, receiver operator characteristic curves (ROC) were constructed [30]. Area under the curve (AUC) was calculated using the method of Hanley and McNeil [31]. Overall concordance between the SPM measure and the standard clinical examination (MASA) was

expressed as classification accuracy and computed from 2×2 tables. Reliability between and within raters was evaluated using ICC statistics.

To identify the minimally adequate time sampling window, time series analysis was conducted using the 30-minute recording window for all subjects. Initially, recordings were segmented and collapsed into 5-minute windows. Graphic examination of the data series was conducted using a plot of observed values against time. Time series forecasting (naïve model) was employed to evaluate change in swallow frequency over successive time periods. Correlations between values of swallow frequency at different points in time, as a function of the time difference, were evaluated using autocorrelation. Once stationarity was confirmed parameter estimates were evaluated using a Box-Jenkins ARIMA method. A best-fit ARIMA model then statistically identified the optimum time window. ANOVA was used to evaluate and compare forecasted error rates between dysphagia and non-dysphagia subgroups. All statistical analyses were conducted using SPSS 21.0 and Medcalc 2.0.

## Results

### Subjects

63 patients were enrolled during the study recruitment period. Mean age (SD) was 59.2 years (15.2) and 33 were male. Both ischemic (N = 39) and hemorrhagic (N = 24) strokes were included. The mean (SD) interval between onset of stroke symptoms and dysphagia screening was 4.6 days (4.1) with a mode of 48 hours. The prevalence of dysphagia based on the MASA was 41% (N = 26). No significant differences were identified in the onset-screening interval between dysphagia subgroups. NIHSS mean scores were significantly higher for the dysphagia subgroup ( $t = -4.87$ ,  $p < 0.0001$ ) as were Rankin scores ( $t = -6.71$ ,  $p < 0.0001$ ). Barthel ( $t = 7.53$ ,  $p < 0.0001$ ) and GCS ( $t = 2.52$ ,  $p = 0.016$ ) scores were significantly lower in the dysphagia subgroup. Both dysphagia indices (MASA:  $t = 10.09$ ,  $p < 0.0001$ ; FOIS:  $t = 8.98$ ,  $p < 0.0001$ ) were significantly lower in the dysphagia subgroup (Table 1).

### Relations between Spontaneous Swallow Frequency and Stroke, Dysphagia

The mean (SD) swallow frequency rate (SPM) for the combined stroke cohort was 0.42 (0.07) SPM. This rate did not correlate significantly with time from stroke onset to dysphagia evaluation, GCS, or age. SPM significantly correlated with all stroke measures: NIHSS ( $r = -0.39$ ;  $p < 0.005$ ), mRS ( $r = -0.51$ ,  $p < 0.0001$ ). BI ( $r = 0.44$ ,  $p < 0.0001$ ). SPM also correlated significantly with both dysphagia measures: MASA ( $r = 0.52$ ,  $p < 0.0001$ ), FOIS ( $r = 0.51$ ,  $p < 0.0001$ ).

### Swallow Frequency Rate (SPM) and Dysphagia

The mean (SD) SPM for the subgroup of patients with dysphagia was 0.23 (0.15) vs. 0.56 (0.31) for the subgroup without dysphagia ( $t = 5.0$ ,  $p < 0.0001$ ) (Figure 1). SPM and MASA severity levels depicted a nearly linear relationship (Figure 2). SPM for severe and moderate dysphagia severity cases differed significantly from cases without dysphagia (severe vs. no dysphagia  $t = 5.74$ ,  $p < 0.0001$ ; moderate vs. no dysphagia,  $t = 3.85$ ;  $p < 0.001$ ). SPM for mild dysphagia cases did not differ significantly from no dysphagia cases ( $t = 1.58$ ;  $p < 0.12$ ). Based on ROC characteristics an optimal threshold of 0.40 SPM was identified to distinguish acute stroke cases with / without dysphagia. This threshold resulted in an area under the curve (AUC) of 0.846 (95% CI = 0.73 – 0.93,  $p < 0.0001$ ). Using the identified SPM threshold, psychometric properties of swallow frequency rate to identify dysphagia were calculated in comparison to the criterion referent MASA (178). Based on this comparison, swallow frequency rate ( $> 0.40$  SPM) was 96% (95% CI = 80.3 – 99.4) sensitive and 68% (95% CI = 50.2 – 82.0) specific in the identification of clinically significant dysphagia (Table 2). Negative predictive value was 96% (95% CI = 79.9 – 99.9), positive

predictive value was 68% (95% CI = 50.2 – 82.0), +likelihood ratio was 2.96, and overall classification accuracy was 79.4%. Reliability of SPM calculation was high both between raters (ICC = 0.95; 95% CI = 0.93 – 0.96) and within raters (ICC = 0.96; 95% CI = 0.94 – 0.97).

### Minimum Required Sampling Period

A 30 minute sampling period was used in the current study. This time frame was based on prior published research in swallow identification and swallow frequency [32]. However, in a prior study validating this technique [29], a 5 minute sampling period was deemed adequate for swallow frequency calculation in healthy adult volunteers. Time series analysis applied to data collected from acute stroke patients indicated that a sampling period between 5 and 10 minutes was adequate to represent the total SSF analysis based on a 30 minute sample. ANOVA of error in forecasted time frequency data (Figure 3) revealed no significant difference between successive 5 minute intervals ( $F(5,6) = 0.274$ ,  $p = 0.912$ ) or between intervals for dysphagia subgroups (dysphagia vs. non-dysphagia:  $F(1,9) = 3.062$ ,  $p = 0.114$ ).

### Discussion

Spontaneous swallowing frequency rate has strong potential to identify dysphagia in acute stroke with a high degree of sensitivity. In addition, spontaneous swallowing frequency rate is related to severity of dysphagia in this population. Based on time series analysis this screening approach may be completed in 5 – 10 minutes without the need for available, trained personnel.

A primary function of a screening test is to identify at risk cases requiring further clinical evaluation. As a screening method for dysphagia in acute stroke, spontaneous swallowing frequency demonstrates high sensitivity (0.96) and high negative predictive value (0.96) indicating that few cases of dysphagia are undetected. This attribute is important as undetected and untreated patients with dysphagia are at elevated risk of increased length of hospital stay, pneumonia, malnutrition, dehydration, and death [33 – 38]. A related attribute of screening methods is high specificity. High specificity is important to minimize negative decisions regarding false identification of a clinically significant problem. In the case of dysphagia in acute stroke, reduced specificity (higher false positive rate) is likely to result in over referral for comprehensive clinical evaluation of potential dysphagia. However, over referral for comprehensive dysphagia assessment would be viewed as a conservative position that is protective for patients who may be at risk. Spontaneous swallowing frequency rate in the present study demonstrated a false positive rate of 32%. Thus, this screening approach is viewed as conservative. Furthermore, review of false positive cases indicated that 9/12 cases demonstrated only slight reductions in swallow frequency rate (range from 0.27 to 0.37 SPM compared to the threshold of 0.40). Given the comparison of swallow frequency rate to dysphagia severity based on MASA scores (Figure 2), these SPM values suggest a degree of confusion between cases of mild dysphagia and no dysphagia based on the MASA. Completion of a larger cohort study will be helpful in establishing stronger thresholds for levels of dysphagia severity that might lower the false positive rate and reduce over referral of non-dysphagia cases in clinical practice.

Spontaneous swallow frequency rate was not significantly related to the interval from onset of stroke symptoms to dysphagia screening, age, nor level of consciousness as reflected in Glasgow Coma Scale scores. The mean interval between onset of stroke symptoms and swallow frequency screening in this cohort was 4.6 days with a mode of 48 hours. The absence of a significant correlation between the onset-screening interval and the SPM value suggests that spontaneous swallowing frequency is a robust indicator of dysphagia at different time points during the acute phase of stroke. Also, age is reported to contribute to



reduction in spontaneous swallowing frequency [29, 39, 40]. However, in this cohort of acute stroke patients age did not correlate significantly with swallow frequency rate. This result might reflect a skewed age distribution (mean age just under 60 years) or it might reflect a dominant impact of the impaired state (stroke) over any age effect. Larger studies with a greater age range will be helpful in addressing this question. Finally, level of consciousness has been reported to impact spontaneous swallow frequency. Specifically, rates during sleep have been reported to be slower than rates while awake [41]. Using the GCS as a metric of consciousness resulted in no significant correlation between swallow frequency rate and GCS score. However, the range of GCS scores was limited in this sample and further study is required before any confident statements may be made regarding swallow frequency and level of consciousness.

[The sampling period (30 minutes) employed in this study was based on prior published work [32]. However, clinical screening protocols typically require up to 10 minutes to complete [9]. The time series analysis completed in this study indicated that a sampling period as short as 5 minutes was comparable to the longer 30 minutes sampling period. Thus, within a 30 minute window, 5 minute sampling periods demonstrate stability. This degree of stability is not the same as test-retest reliability however. To more fully comprehend the temporal stability of swallow frequency analysis, future studies should examine swallow frequency data obtained at different time periods within a day and across sequential days. Furthermore, any change in swallow frequency over sequential days should be compared to dysphagia status.]

The results of this study offer initial proof of concept that spontaneous swallow frequency analysis has high potential to accurately identify dysphagia and dysphagia severity in a cohort of acute stroke cases. Though modest in size, the sample in this study was comparable to two of four recent validation studies on clinical screening protocols highlighted in the Schepp, et al systematic review [9]. The Emergency Physician Dysphagia Screening [42] was validated on a cohort of 84 acute stroke patients and the Toronto Bedside Screening Test [43] was validate on a total cohort of 59 stroke patients including 24 in acute care and 35 in rehabilitation facilities. Another potential limitation of this study may be the choice of the MASA as the gold standard criterion referent. The MASA is the only stroke-validated clinical examination for dysphagia. The MASA was initially validated against results from videofluorographic swallowing examinations [25, 44]. Furthermore, the four clinical screening tools highlighted in the Schepp, et al systematic review [9] utilized a clinical examination as the primary or secondary criterion referent (three of the four used the MASA). Aside from these observations, we would argue that the fluorographic swallowing study, though clinically valuable, is not an appropriate gold standard for comparison in this type of applied research. No objective scoring system incorporating a threshold between dysphagia and no dysphagia exists for this radiologic study. Moreover, fluorographic outcomes such as ‘any swallow related abnormality’ [43, 44] are highly subjective and difficult to replicate as prior research has demonstrated low agreement on interpretation of these examinations [45]. Finally, as a pragmatic consideration, survey studies have reported that speech-language pathologists conduct clinical swallowing examinations at a high frequency with a much lower frequency of videofluorographic swallowing examination completion [46, 47]. Based on these observations we believe that the MASA is an appropriate criterion referent against which to compare performance of dysphagia screening protocols in acute stroke.

[The current results are encouraging, but should be cautiously interpreted. Studies with larger cohorts are required with inclusion of additional variables that may influence swallow frequency results (e.g. sleep state, oral condition, medications). More detailed analyses of variables that may influence swallow frequency rate may help to lower the false positive rate

identified in the present study. Finally, future studies should compare clinical decisions and health care resource utilization resulting from swallow frequency screening compared to, or combined with, clinical screening protocols. Though these initial data suggest that swallow frequency analysis has high sensitivity in the detection of dysphagia in acute stroke it is possible that the combination of this technique and clinical protocols may further enhance screening sensitivity and lower the false positive rate. Completion of larger cohort studies that incorporate these additional components will be helpful in forming a comprehensive perspective on the value of spontaneous swallowing frequency analysis as a dysphagia screening tool in acute stroke.]

## Summary/Conclusions

Results of this study indicate high potential for development of a psychometrically strong dysphagia screening tool for acute stroke based upon spontaneous swallowing frequency analysis. Development of this approach could obviate the need for trained and available personnel to administer and interpret clinically focused dysphagia screening tools. Thus, this type of screening tool for dysphagia in acute stroke could result in increased accessibility which may translate to increased screening compliance and faster referral for comprehensive assessment and treatment of dysphagia in this population.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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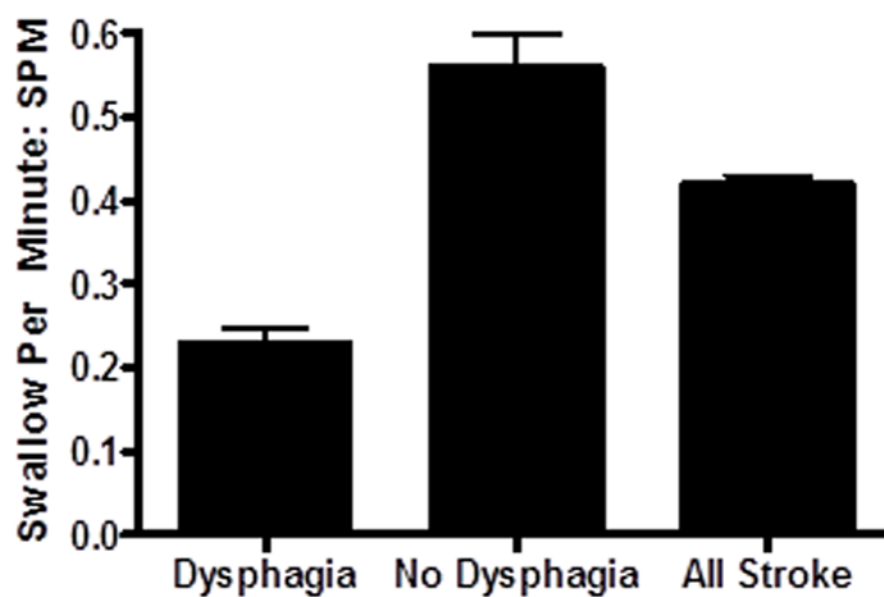
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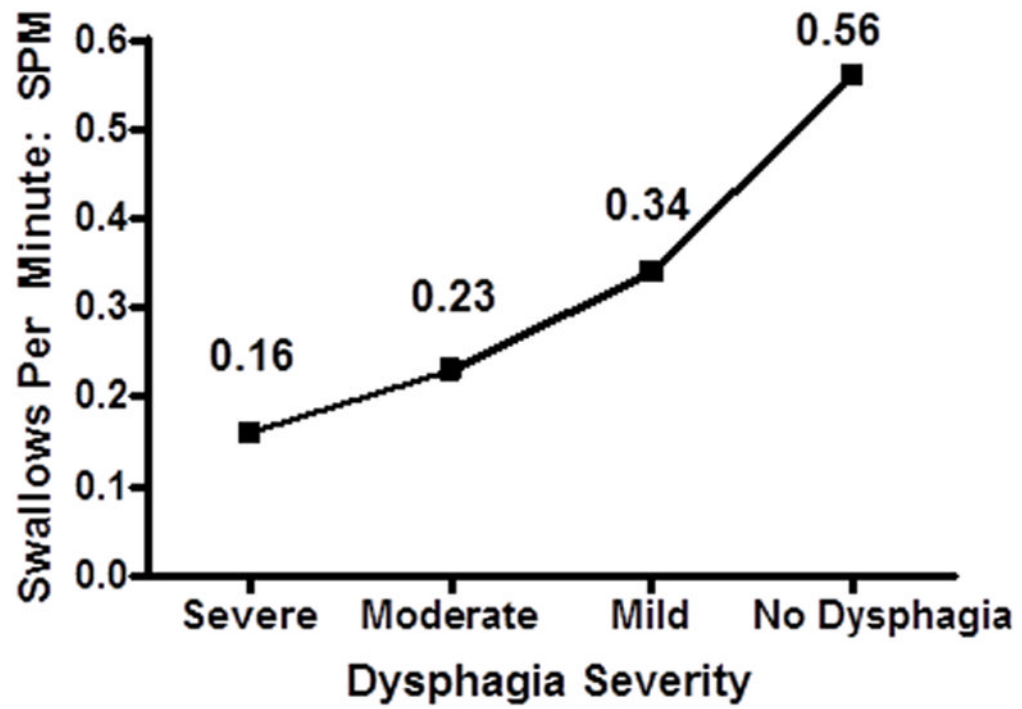
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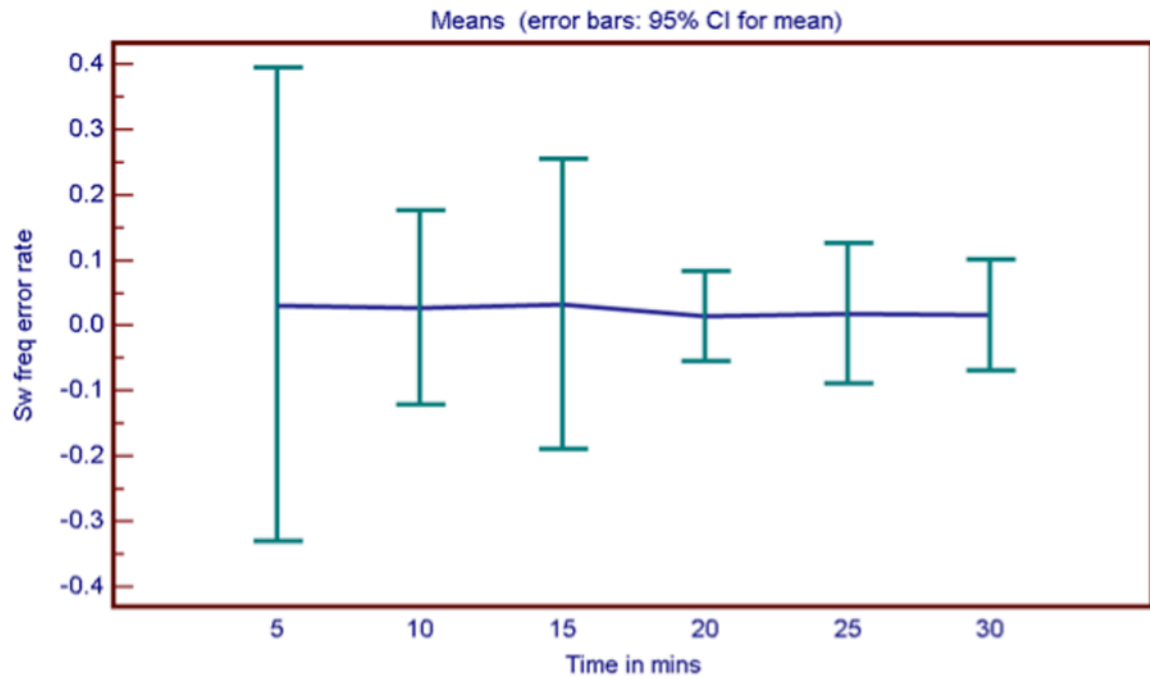
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**Figure 1.**  
Mean swallow frequency rate for acute stroke cases with vs. without dysphagia and all cases in the cohort



**Figure 2.**  
Dysphagia severity levels and mean swallow frequency rate



**Figure 3.**  
Time forecast of mean square error rate in swallow frequency over successive five minute time periods

**Table 1**

Demographic characteristics of the total cohort and the dysphagia subgroups. Means and standard deviations ( ) are reported unless otherwise noted.

<b>Variable</b>	<b>Total Cohort</b>	<b>Dysphagia Subgroup</b>	<b>No Dysphagia Subgroup</b>
Age	59.2 (15.2)	65.2 (17.1)	56.1 (12.8) *
Male/Female	33/30	12/14	21/16
Type Stroke (N)			
Ischemic	39	16	23
Hemorrhagic	24	10	14
Interval Stroke Onset to Assessment			
Mean (SD) Days	4.6 (4.1)	5.23 (4.99)	4.14 (3.54)
Median- Days	3.0	3.5	3.0
Mode - Hours	48	48	48
NIHSS		10.9 (6.0)	4.4 (3.4) *
Rankin		4.2 (1.08)	2.1 (1.32) *
Barthel		5.9 (6.38)	16.3 (4.52) *
GCS		13.4 (2.94)	14.8 (0.05) *
MASA		144.7 (28.6)	193.0 (4.9) *
FOIS		3.5 (2.2)	6.9 (0.46) *

\* Variables that differ significantly between dysphagia subgroups (p<0.05)

NIHSS = National Institutes of Health Stroke Scale. GCS – Glasgow Coma Scale. MASA = Mann Assessment of Swallowing Ability. FOIS = Functional Oral Intake Scale



**Table 2**

Evidence of dysphagia using the optimal spontaneous swallow frequency threshold (  $\geq 0.40$ ) compared to the Mann Assessment of Swallowing Ability (MASA) criterion referent.

		<u>MASA</u>	
		<u>Dysphagia</u>	<u>No Dysphagia</u>
Swallow Frequency: SPM $\geq 0.40$	Dysphagia	25	12
	No Dysphagia	1	25
	Totals	26	37