ABSTRACT

Background: Prolonged mechanical ventilation is associated with muscle weakness, pharyngeal dysfunction, and symptomatic aspiration. The authors hypothesized that muscle strength measurements can be used to predict pharyngeal dysfunction (endoscopic evaluation—primary hypothesis), as well as symptomatic aspiration occurring during a 3-month follow-up period.

Methods: Thirty long-term ventilated patients admitted in two intensive care units at Massachusetts General Hospital were included. The authors conducted a fiberoptic endoscopic evaluation of swallowing and measured muscle strength using medical research council score within 24 h of each fiberoptic endoscopic evaluation of swallowing. A medical research council score less than 48 was considered clinically meaningful muscle weakness. A retrospective chart review was conducted to identify symptomatic aspiration events.

Results: Muscle weakness predicted pharyngeal dysfunction, defined as either valleculae and pyriform sinus residue scale of more than 1, or penetration aspiration scale of more than 1. Area under the curve of the receiver-operating curves for muscle strength (medical research council score) to predict pharyngeal, valleculae, and pyriform sinus residue scale of more than 1, penetration aspiration scale of more than 1, and symptomatic aspiration were 0.77 (95% CI, 0.63–0.97; \( P = 0.012 \)), 0.79 (95% CI, 0.56–1; \( P = 0.02 \)), and 0.74 (95% CI, 0.56–0.93; \( P = 0.02 \)), respectively. Seventy percent of patients with muscle weakness showed symptomatic aspiration events. Muscle weakness was associated with an almost 10-fold increase in the symptomatic aspiration risk (odds ratio = 9.8; 95% CI, 1.6–60; \( P = 0.009 \)).

Conclusion: In critically ill patients, muscle weakness is an independent predictor of pharyngeal dysfunction and symptomatic aspiration. Manual muscle strength testing may help identify patients at risk of symptomatic aspiration.

What This Article Tells Us That Is New

• In 30 critically ill adult patients mechanically ventilated more than 10 days, extremity muscle weakness assessed by medical research council score was an independent predictor of swallowing dysfunction and symptomatic aspiration after extubation
that 50% of the prolonged ventilated patients aspirate, the majority of them silently. Symptomatic aspiration (typically presenting as pneumonitis or pneumonia) is an important mechanism of acute lung injury, which translates to weaning failure, delayed hospital discharge, and mortality.

It is unclear how to clinically identify patients at risk of aspiration. Data suggest that a variety of conditions including, but not limited to, decreased level of consciousness, motor neuronal diseases, inadequate cough, structural abnormalities of the pharynx or larynx, and a history of chemotherapy or radiotherapy contribute to the risk of aspiration. Fiberoptic endoscopic evaluation of swallowing (FEES) can be performed at the bedside to predict a patient’s ability to protect the airway, but the test is resource intensive and cannot be routinely applied for daily screening of long-term ventilated patients.

Muscle weakness is common in intensive care unit (ICU) patients and predicts ICU length of stay, and mortality. Importantly, airway muscle weakness is a common mechanism of dysphagia, and dysphagia predisposes patients to aspiration as demonstrated in patients with amyotrophic lateral sclerosis. We hypothesized that clinical muscle strength assessment is associated with pharyngeal dysfunction identified during endoscopic evaluation (primary criterion) and predicts symptomatic aspiration 3 months after the strength measurement (secondary criterion).

Materials and Methods

This was a prospective observational study performed in the Respiratory Acute Care Unit and the Surgical ICU at Massachusetts General Hospital. The study was approved by the Partners institutional review board (Boston, Massachusetts). Written informed consent was obtained from each patient or patient’s healthcare proxy.

Subjects

From January 2011 to April 2012, 30 long-term ventilated subjects were recruited. All patients who had been consulted for FEES during the observation period and met the inclusion criteria of the study were approached for the consent (fig. 1). Patients were included in the study if they were: 18 yr old or more, ventilated for more than 10 days, and underwent a FEES performed by a speech-language pathologist. Patients were excluded from the study if they had: a Richmond Agitation Sedation Scale of less than 0, signs and symptoms of delirium according to the confusion assessment method, degenerative neurological disease, known structural abnormalities of the larynx/pharynx, a history of chemotherapy or radiotherapy to the head or neck, multiorgan dysfunction or failure, or were pregnant. Patients were also excluded from the study if structural abnormalities of the larynx/pharynx were identified during the FEES.

We recorded the following variables: age, sex, body mass index, Charlson Comorbidity Index, duration of mechanical ventilation (intubation and tracheostomy; mode of mechanical ventilation), ICU length of stay, hospital length of stay before and after FEES, confusion assessment method score, Richmond Agitation Sedation Scale score, albumin, leukocyte count, nasogastric tube presence, presence of a percutaneous endoscopic gastrostomy tube, diabetes mellitus diagnosis, and sepsis at the time of FEES.

Measurement of Pharyngeal Dysfunction: FEES

FEES equipment consisted of a 3.4-mm diameter adult flexible fiberoptic rhinolaryngoscope (FNL-10RP3, Pentax, Montvale, NJ), light source (LH-150PC, Pentax), camera (PSV-4000, Pentax), and color monitor (model AL1715, Acer, San Jose, CA).

Valleculae and pyriform sinus residue scale (VPSR scale; numeric rating scale: 0–4) was used to quantify pharyngeal swallowing and clearing of secretions. The VPSR has five grades: 0 is no residue; 1 is residue covers less than 10% of all width of valleculae or pyriform sinuses; 2 and 3 are assigned if residue covers from more than 10% to less than 50%; 4 is if residue covers more than 50%.

The penetration aspiration scale (PAS; numeric rating scale: 1–8) was used to quantify a patient’s ability to protect his airway during FEES. The PAS is an ordinal scale consisting of eight scores based on compared observations. A score of 1 indicates normal protection of the upper airway during a swallow with no food residue entering into the airway. Scores between 2 and 8 demonstrate abnormal swallowing, and as the grade increases so does the severity of dysphagia with food residue entering further into the airway. Scores between 2 and 5 are considered “penetration” such that residue stays above the vocal folds (scores 2 and 3), or courses to the level of vocal folds (scores 4 and 5) but no further. Scores between 6 and 8 are considered “aspiration” as the materials passes below the vocal folds. Whether or not material is ejected from the airway with the effort made also contributes to the judgement of severity of aspiration (for examples, please see fig. 2 and the video provided as Supplemental Digital Content 1, http://links.lww.com/ALN/A927).

The swallowing consult was requested by the subject’s critical care team. Swallowing evaluation and FEES were performed at the bedside by one of two experienced speech-language pathologists. According to departmental guidelines, a swallowing evaluation is only performed on a patient who has the potential to receive an oral diet based on the clinical assessment of the care team but is suspected of being at risk of aspiration and aspiration-related morbidity. Additionally, the patient must be capable of cooperating with the speech-language pathologist throughout the study.

Before the FEES, the subject was placed in an upright position, and the endoscope was passed transnasally into the velopharynx. No topical anesthesia was administered to the nasal mucosa. The tip of the scope was held in “high position,” below the velopharyngeal port and above the epiglottis, in order to view the entire pharynx and...
Clinical swallowing evaluation prior to diet advancement
Possible dysphagia?

Yes
No

Not enrolled

Fiberoptic endoscopic evaluation of swallow consult

Screening for enrollment (N=66)

Approached for consent (N=46)

Enrolled patients (N=30)

Muscle strength measurement*
1. MRC score (0-60)
2. Grip strength (kg)

Fiberoptic endoscopic evaluation
1. PAS (1-8)
2. VPSR grade (0-4)

Pharyngeal dysfunction
(PAS >1 or VPSR grade >1)

Muscle weakness if MRC <48
No muscle weakness if MRC ≥48

MRC <48, N=20
MRC ≥48, N=10

3 month follow-up
(chart review)
Symptomatic aspiration?

Symptomatic aspiration
Definition of clinical sequellae

No symptomatic aspiration

Fig. 1. Subject progression through the study algorithm. We enrolled consecutive patients who presented to our speech and swallow therapists for evaluation of readiness for oral food intake. After screening these patients for inclusion criteria, and obtaining their approval, dysphagia potential was assessed by fiberoptic endoscopic evaluation of swallowing (FEES), and graded using validated rating scales. *Muscle strength was measured by an investigator blinded to FEES results within 24 h of FEES. A chart review was then performed following subjects’ hospital discharge to identify signs and symptoms of symptomatic aspiration in the 3 months after FEES. MRC = medical research council scale; PAS = Penetration Aspiration Scale; VPSR = valleculae and pyriform sinus residue scale.

The main outcome of the FEES was laryngeal penetration with increased risk of aspiration, defined as either (1) abnormal bolus retention in the valleculae and pyriform sinuses after the pharyngeal swallow (VPSR > grade 1), or (2) material entrance to the airway (PAS > score 1).

Muscle Strength Evaluation

Muscle strength measurement was performed within 24 h of the FEES.

Muscle Testing with the Medical Research Council (MRC) Score. The MRC scale is a clinical assessment of muscle power and assigns a score of 0 (no movement) to 5 (normal...
Assessment of Symptomatic Aspiration

Two blinded physicians reviewed the charts for the diagnosis or possibility of symptomatic aspiration. Symptomatic aspiration was defined as aspiration accompanied by acute symptoms of coughing, choking, shortness of breath, or respiratory distress with or without confirmed signs of aspiration by a chest radiograph. Patients with symptomatic aspiration were followed-up by chart review to identify clinical sequelae occurring within 3 months of the FEES.

Statistical Analysis

The primary outcome (endpoint) was pharyngeal dysfunction determined by FEES. We tested the hypotheses that MRC-derived diagnosis of muscle weakness (MRC score <48) predicts (1) abnormal bolus retention in the valleculae and pyriform sinuses after the pharyngeal swallow (VPSR > grade 1, primary), and (2) material entrance to the airway (PAS > score 1, coprimary). We tested the secondary hypothesis that a MRC score less than 48 predicts symptomatic aspiration. We also tested the hypothesis that pharyngeal dysfunction based on FEES is associated with symptomatic aspiration.

For power analysis, we expected a correlation of 0.5 between the MRC-derived muscle strength (MRC <48) and FEES-driven values (PAS score and VPSR grade >1). Accordingly, we calculated that a sample size of 30 patients will provide a power of more than 0.80 to detect a difference of −0.5 between the null hypothesis correlation of 0 and the alternative hypothesis correlation of 0.5, using a two-sided hypothesis test with a significance level of 0.05. Logistic regression analysis was used for hypothesis testing and to identify additional predictors of outcome. Statistical calculations were made using IBM SPSS Statistics for Windows, Version 19.0 (IBM Corp., Armonk, NY), Hintze J. (2011) PASS 11 (NCSS, LLC., Kaysville, UT), and Sigma Plot Version 12.3 (Systat Software, San Jose, CA). Data were presented in mean ± SD and a P value less than 0.05 was considered as significant.

Two speech and swallow therapists reviewed all the video-recorded FEES and rerated them. K Statistic was performed to determine consistency among raters for VPSR and PAS.

Results

Data from 16 men and 14 women was included. The subjects’ mean age was 55 ± 14 yr (range 35–66 yr). The subjects’ mean duration of mechanical ventilation was 136 ± 423 days.
CRITICAL CARE MEDICINE

0.012), and 0.79 (95% CI, 0.56–1; P = 0.02; fig. 3, A and B), respectively.

Other independent variables evaluated for confounder control (age, weight, leukocyte count, sex, body mass index, albumin, grip strength, ICU length of stay before testing, diabetes, or the presence of a nasogastric tube) did not predict pharyngeal dysfunction.

Secondary Outcome Criterion

Effects of Muscle Weakness on Symptomatic Aspiration Events. Logistic regression revealed the following variables to be associated with symptomatic aspiration events: muscle strength measured by MRC (area under the curve = 0.74 [95% CI, 0.56–0.93]; odds ratio = 0.864 [95% CI, 0.86–0.87]; P = 0.02; fig. 3A), PAS score more than 1 (P = 0.025), grip strength (P = 0.04), and duration of mechanical ventilation (P = 0.027).

Addition of the variable “duration of mechanical ventilation” to the logistic regression model, revealed that both MRC and PAS score more than 1 explained significant variance of symptomatic aspiration, independent of the duration of mechanical ventilation (P = 0.045 and 0.037, respectively). Of note, muscle weakness (MRC <48) was associated with a 10-fold increased risk of a symptomatic aspiration event (odds ratio = 9.75; 95% CI, 1.6–60; P = 0.009; table 1). The MRC threshold for muscle weakness at 48 is estimated to have a sensitivity of 93% (95% CI, 66–99) for prediction of symptomatic aspiration and specificity of 60% (95% CI, 33–82). These values yield a positive likelihood ratio of 2.3 and a negative likelihood ratio of 0.11 with a posttest probability of 70%.

Grip Strength. Grip strength (2 ± 4, range 0–18 kg) was associated with MRC (45.5 ± 8.3, 25–59 [r = 0.5; P = 0.005]). However, grip strength values predicted neither risk of aspiration (VPSR >1 and PAS >1), nor incidence of aspiration after adjustment for MRC, mechanical ventilation, and PAS (P > 0.05).

Reliability Assessment. κ Statistics revealed outstanding and substantial indicators of agreement between the two speech-language pathologists during their assessment of aspiration risk using VPRS (0.816, 95% CI, 0.694–0.937; P < 0.001) and PAS (0.907, 95% CI, 0.738–1; P < 0.001).

Discussion

In critically ill patients, muscle weakness is an independent predictor of pharyngeal dysfunction as well as symptomatic aspiration. Pharyngeal dysfunction is also associated with symptomatic aspiration, suggesting that the link between muscle weakness and aspiration can in part be explained by pharyngeal dysfunction.

ICU-acquired muscle weakness affects weaning from the ventilator, it increases length of stay in the ICU and the hospital, and translates to long-term morbidity.33–35 An association between ICU-acquired muscle weakness and pharyngeal dysphagia leading to aspiration likely contributes to such poor clinical outcomes. Notably, aspiration does not always lead to pathology and can remain asymptomatic or “silent.” For
Muscle weakness is associated with increased aspiration risk. For example, in amyotrophic lateral sclerosis, pathological diffuse muscle weakness can affect the ability to protect the airway while swallowing and dysphagia is frequently reported. Even at the time of diagnosis of amyotrophic

### Table 1. Baseline Demographic and Clinical Characteristics

<table>
<thead>
<tr>
<th>Characteristics/Independent Predictors</th>
<th>Total Cohort N = 30</th>
<th>Symptomatic Aspiration</th>
<th>P Value Unadjusted</th>
<th>P Value Adjusted</th>
<th>OR (95% CI)</th>
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<tr>
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<tr>
<td>PAS &gt;1</td>
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<td>9</td>
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<td>0.037</td>
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<td>VPSR &gt;1</td>
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<td>7</td>
<td>0.27</td>
<td>0.9</td>
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<td>&lt;48 clinically significant muscle weakness</td>
<td>20</td>
<td>14</td>
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<td>≥48</td>
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<td>1</td>
<td>9</td>
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<td>Sex</td>
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<tr>
<td>Women</td>
<td>14</td>
<td>6</td>
<td>8</td>
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<td>Men</td>
<td>16</td>
<td>9</td>
<td>7</td>
<td></td>
<td></td>
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<td>Age (yr)</td>
<td>55±14</td>
<td>56±14</td>
<td>53±14</td>
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<td>Grip strength, kg</td>
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<td>Duration of mechanical ventilation, d</td>
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<tr>
<td>Mean ± SD</td>
<td>136±423</td>
<td>201±603</td>
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<td>ICU length of stay, d</td>
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<tr>
<td>Mean ± SD</td>
<td>24±16</td>
<td>21±17</td>
<td>25±15</td>
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<td>9–58</td>
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<td>Discharge time after FEES, d</td>
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<tr>
<td>Mean ± SD</td>
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<td>Hospital length of stay, d</td>
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<td>Mean ± SD</td>
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<td>37±28</td>
<td>34±17</td>
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<td>Albumin (mg/dl)</td>
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<tr>
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<td>2.8±0.7</td>
<td>0.693</td>
<td>0.698</td>
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<td>1–4</td>
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<tr>
<td>WBC (10³/μl)</td>
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<td></td>
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<tr>
<td>Mean ± SD</td>
<td>12±6</td>
<td>14.5±6</td>
<td>10±6.3</td>
<td>0.056</td>
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<td>1.8–21.8</td>
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<td>BMI</td>
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<tr>
<td>Mean ± SD</td>
<td>26±9</td>
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<td>Sepsis</td>
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<tr>
<td>Diabetes</td>
<td>30</td>
<td>8</td>
<td>22</td>
<td>0.790</td>
<td>0.246</td>
</tr>
</tbody>
</table>

Baseline demographics and clinical characteristics of the subjects.

BMI = body mass index; FEES = fiberoptic endoscopic evaluation of swallowing; ICU = intensive care unit; OR = odds ratio; PAS = Penetration Aspiration Scale; VPSR = valleculae and pyriform sinus residue scale; WBC = leukocyte count.

example, 45% of individuals aspirate during sleep, and 70% of patients aspirate during periods of impaired consciousness. Therefore, we evaluated both the incidence of aspiration, through FEES, and the incidence of its more clinically meaningful outcome, i.e., symptomatic aspiration. Muscle weakness is associated with increased aspiration risk. For example, in amyotrophic lateral sclerosis, pathological diffuse muscle weakness can affect the ability to protect the airway while swallowing and dysphagia is frequently reported. Even at the time of diagnosis of amyotrophic
lateral sclerosis more than 50% of patients present with pharyngeal dysfunction identified by FEES. In our long-term ventilated patients in the ICU, two thirds presented with clinically meaningful weakness, and this agrees with the observations of others.39,40

In our sample, 70% of subjects with clinical muscle weakness had a meaningful aspiration event, whereas only 10% of subjects without clinical muscle weakness had such an occurrence. Given the study population, perhaps more important variables are the positive and negative predictive values of MRC score for the prediction of symptomatic aspiration: 70 and 90%, respectively. These results suggest clinical muscle weakness, measured by manual muscle strength testing, is useful in screening and stratifying patients into those with high or low aspiration risk, but that absence of clinical muscle weakness does not preclude the probability of aspiration. It is noted that the etiology of aspiration after prolonged ventilation is usually multifactorial. The presence of other risk factors, such as impaired cough during tracheal suctioning, should warrant additional diagnostic measures, such as a FEES exam to identify all patients needing global aspiration precautions.

We identified clinically meaningful muscle weakness through a MRC score of less than 48,30,32 and measured grip strength, an easily assessable variable, which has been associated with hospital mortality. In our study, grip strength correlated significantly with muscle weakness as assessed by MRC, but did not predict pharyngeal dysphagia or symptomatic aspiration. Similar to our finding, Butler et al.31 did not find an association between grip strength and aspiration—even though grip strength correlated in their study with isometric tongue strength, which in turn was associated with aspiration risk. On the basis of these findings and recent data in critically ill patients reported by our group20,42 and others,39,40 we concluded that grip strength may not be able to reflect small variation in muscle strength in patients with reduced muscle strength.

We controlled for confounders by evaluating the effects of other known predictors of aspiration and including them in our statistical model. We considered Charlson Comorbidity Index, albumin, length of mechanical ventilation, leukocyte count, sepsis, and length of stay, all of which have been associated with aspiration risk or muscle weakness.32,44–46 In our study, in accordance with others, we identified an association between duration of mechanical ventilation and aspiration risk2,47; however, when clinically significant muscle weakness was added as a covariate, this association became insignificant.

In the ICU setting, symptomatic aspiration is the leading cause of pneumonia, and contributes significantly to the overall morbidity and mortality.68 In the perioperative setting, aspiration is the third most common reason for reintubation and subsequent unplanned ICU admission, a situation that has been associated with a 90-fold increase of in-hospital mortality.69 In our study, muscle weakness was associated with both pharyngeal dysfunction, and symptomatic aspiration and its clinical sequellae (fig. 4). In addition, variables of pharyngeal dysfunction (PAS > score 1 or VPSR > score 1) were associated with symptomatic aspiration. This combination of findings suggests that muscle weakness may increase the risk of symptomatic aspiration by affecting the pharyngeal muscles involved in swallowing. This suggestion is also supported by the findings of Butler et al.,31 who reported that isometric tongue strength, and not grip strength, is associated with aspiration risk.

Stratifying patients by aspiration risk allows physicians to better identify those who will benefit from aspiration precautions. Moreover, patients identified as higher risk secondary to muscle weakness can be selected for further individualized assessments with the aim of safe and adequate nutrition.50 The additional assessments may involve bedside FEES or radiological evaluations, to assist in deciding which interventions are most appropriate, and may include: direct exercises (practicing correct swallows with food boluses), indirect exercises (strengthening neuromotor controls and the swallowing process without food),50,51 rehabilitative measures such as swallow therapy,52 and dietary modifications specific to the patient’s swallowing ability.50,53

Muscle strength is not the only factor leading to proper swallowing. In swallowing, the human larynx closes, elevates, and arcs anteriorly under the tongue; this expands the hypopharyngeal space and opens the upper esophageal sphincter. The epiglottis folds posteriorly over the laryngeal aditus and directs the ingested bolus into the pyriform recesses toward the now relaxed upper esophageal sphincter. Airflow ceases as the bolus moves through the hypopharynx.54 Accordingly, in swallowing, a combination of adequate sensing, intact protective aerodigestive reflexes, along with pharyngeal muscle strength are required to maintain a patent airway.54 This highlights the fact that absence of weakness cannot predict absence of swallowing dysfunction.

In accordance with others,55–57 we used FEES to make the diagnosis of pharyngeal dysfunction. In our hospital,
as well as elsewhere. FEES is used as a bedside evaluation to identify patients at high risk of aspiration. It is a valid alternative method to define the optimal time to initiate oral feeding in critically ill patients, who have endured prolonged mechanical ventilation with the advantages of reproducibility, minimal risk, and discomfort. However, a videofluoroscopic swallowing study, also referred to as the modified barium swallow, has been considered the "gold standard" for the evaluation of a swallowing disorder. Videofluoroscopic swallowing study requires the transport of critically ill patients (e.g., ventilator-dependent patients) outside the ICU, which limits the feasibility to be used as a bedside diagnostic test in critically ill patients. FEES has increasingly been used as a bedside assessment tool to evaluate the aspiration risk.

The limitations of our study included the absence of a baseline swallowing study, selection bias, and small sample size. The association between muscle weakness and aspiration risk was studied in a collective of patients with high pretest probability of aspiration, which needs to be taken into account when interpreting our findings. Our sample size was relatively small and the number of outcomes few. Therefore, it is not possible to perform a rigorous multivariate regression analysis to fully account for the factors that might confound a causal relationship between muscle weakness and aspiration.

Our study was powered for FEES-derived evidence of pharyngeal dysfunction (a well-defined endpoint). Our secondary clinical outcome was "symptomatic aspiration." On the basis of the data we present here, we are now able to power our next trial on the association of muscle weakness and symptomatic aspiration—including a higher sample size and a broader range of muscle strength values for comparison. Accordingly, we conclude that the observed association between muscle weakness and symptomatic aspiration should be considered "hypothesis-generating" rather than "proven."

In critically ill patients, muscle weakness is an independent predictor of pharyngeal dysfunction as well as asymptomatic aspiration. Pharyngeal dysfunction is also associated with symptomatic aspiration, suggesting that the link between muscle weakness and aspiration can, in part, be explained by pharyngeal dysfunction.

References


Anesthesiology 2013; 119:389-97

Muscle Weakness Predicts Symptomatic Aspiration

Mirzakhani et al.