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ICU-Acquired Swallowing Disorders

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Objectives: Patients hospitalized in the ICU can frequently develop swallowing disorders, resulting in an inability to effectively transfer food, liquids, and pills from their mouth to stomach. The complications of these disorders can be devastating, including aspiration, reintubation, pneumonia, and a prolonged hospital length of stay. As a result, critical care practitioners should understand the optimal diagnostic strategies, proposed mechanisms, and downstream complications of these ICU-acquired swallowing disorders.

Data Sources: Database searches and a review of the relevant medical literature.

Data Synthesis: A significant portion of the estimated 400,000 patients who annually develop acute respiratory failure, require endotracheal intubation, and survive to be extubated are determined to have dysfunctional swallowing. This group of swallowing disorders has multiple etiologies, including local effects of endotracheal tubes, neuromuscular weakness, and an altered sensorium. The diagnosis of dysfunctional swallowing is usually made by a speech-language pathologist using a bedside swallowing evaluation. Major complications of swallowing disorders in hospitalized patients include aspiration, reintubation, pneumonia, and increased hospitalization. The national yearly cost of swallowing disorders in hospitalized patients is estimated to be over $500 million. Treatment modalities focus on changing the consistency of food, changing mealtime position, and/or placing feeding tubes to prevent aspiration.

Conclusions: Swallowing disorders are costly and clinically important in a large population of ICU patients. The development of effective screening strategies and national diagnostic standards will enable further studies aimed at understanding the precise mechanisms for these disorders. Further research should also concentrate on identifying modifiable risk factors and developing novel treatments aimed at reducing the significant burden of swallowing dysfunction in critical illness survivors. (*Crit Care Med* 2013; 41:2396–2405)

Key Words: dysphagia; intratracheal intubation; mechanical ventilation; respiratory aspiration; speech-language pathology; swallowing disorders

Over 700,000 patients annually develop acute respiratory failure requiring mechanical ventilation in the United States, costing an estimated $27 billion or 12% of all hospital expenses (1). Based on their in-hospital mortality of 35%, over 400,000 acute respiratory failure patients survive to be extubated each year (1, 2). With an average estimated 5-year survival ranging from 47% to 68% (3, 4), many of these patients suffer from long-term neuromuscular, psychiatric, cognitive, and pulmonary disorders that are associated with poorer functional status, decreased quality of life, and increased caregiver burden (1, 3, 5–9).

Increasingly, attention has focused on these survivors' ability to effectively swallow food, liquids, and pills without aspiration (10–12). The aspiration risks of general anesthesia with concurrent endotracheal intubation were first documented in the early 1950s (13). In the 1960s, several case reports demonstrated aspiration and disordered swallowing in awake patients with tracheostomies (14–18). Although the laryngeal injuries suffered as a result of endotracheal intubation without tracheostomy were widely described in the late 1970s (19–23), it was not until the 1990s when the relationships between prolonged endotracheal intubation, postextubation swallowing reflex impairment, and poorer patient outcomes were first reported (24–27).

In critically ill patients, the return of effective swallowing function results in the removal of feeding tubes, a return to nutritional homeostasis, and transfer out of an ICU. However, the complications of ineffective swallowing can be devastating. Aspiration can lead to acute desaturations, pneumonia and/or pneumonitis, reintubation, and, as a result, prolonged hospital length of stay. Similarly, the passage of oral secretions and/or refluxed gastric contents through the laryngeal defenses and into the airway has the potential to cause numerous infectious and inflammatory pulmonary complications. Bypassing the oropharynx with a temporary nasogastric feeding tube can result in patient discomfort, use of restraints, and either

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inadvertent tube removal or misplacement (28, 29). Surgically placed enteral feeding tubes often assist nursing care but lead to an increased risk of infection and higher healthcare costs, without proven benefits in survival, nutritional status, or patient comfort (30–33). In this review, we will illustrate the physiology of normal swallowing, discuss the mechanisms of dysfunctional swallowing in critical illness survivors, and then discuss the risk factors, diagnosis, associated outcomes, and treatments of swallowing disorders in this population.

PHYSIOLOGY OF NORMAL SWALLOWING

In order to appreciate the pathophysiology of dysfunctional swallowing in survivors of critical illness, it is first necessary to understand the normal swallowing process. Awake and healthy patients effectively swallow approximately once every minute and over 1,000 times a day. The main purpose of swallowing between mealtimes is to remove saliva, which is secreted at a rate of about 0.5 mL/min, facilitates swallowing initiation, and lubricates the transit of the food bolus from the mouth to stomach (34). The ability to swallow results from an intricately timed orchestration of events involving sensory and motor nerves, over 30 muscle groups, and two brainstem centers. Although several nerves of the swallowing process are under involuntary control, and swallowing can be triggered without conscious input, the orchestration of the swallowing process is ultimately under cortical control.

The normal swallowing process can be divided into four stages (**Fig. 1**). First, during the *oral preparatory phase*, solids and liquids are prepared for transit. This process is under voluntary control, and is largely responsible for the pleasure achieved during eating, due to the stimulation of multiple receptors on the tongue and palate. Importantly, saliva is necessary for achieving the proper food consistency, teeth are necessary for mastication, and adequate lip seal is necessary to prevent foods and liquids from moving out of the mouth. The seal between the tongue and palate is also essential to prevent the bolus from moving prematurely into the pharynx, larynx, and unprotected airway. After the tongue and oral muscles position the bolus effectively, the *oral transit stage* begins, also under voluntary control. During this phase, a series of contractions of the anterior tongue, posterior tongue, soft palate, and floor of the mouth propel food and liquid directly into the pharynx.

The entrance of food and liquid into the pharynx marks the beginning of the *pharyngeal phase*. Here, a series of well-timed physiologic movements function to prevent food and liquid from entering the airway. These three sequential movements are as follows: 1) the arytenoids moving medially and anteriorly to touch the epiglottis; 2) the epiglottis moving to cover the arytenoids; and 3) the true and false vocal folds adducting (35). True vocal fold adduction requires functioning superior and recurrent laryngeal nerves. While air can still pass in and out of the trachea up until vocal fold closure, once the vocal folds are closed a patient enters an obligatory period of apnea. On average, this period lasts 0.75 seconds, although it increases with increasing bolus volume and viscosity (36–38). Importantly, the vocal fold closure is the *last* of the three steps, occurring approximately 0.7 seconds after the initiation of the swallow (35, 36). If this delay is increased, it is possible for solids and liquids to pass from the pharynx into the airway. When this occurs, the final airway protection mechanism is a cough, which requires abdominal, intercostal, and diaphragmatic muscle strength, a properly timed glottic closure, and afferent nervous pathways. These afferent pathways travel predominantly on the superior laryngeal nerve which can be damaged by trauma to the piriform sinus. When food and liquids are successfully averted from the airway, they then pass toward the esophagus, the upper esophageal sphincter dilates, and the *esophageal stage* begins. This is the longest and final of the phases of swallowing, lasting between 8 and 20 seconds in normal individuals, depending on bolus size, anatomic obstruction, and the rate and strength of the peristaltic contraction waves (34–36).

SWALLOWING DISORDERS IN THE ICU

Definitions

Disordered swallowing typically refers to several pathophysiologic processes: dysphagia, gastroesophageal reflux, and aspiration. “Dysphagia” denotes any disorder swallowing occurring from the mouth on the way to the stomach. In contrast, “gastroesophageal reflux” typically refers to the retrograde passage of any gastric contents to the level of the larynx. Both dysphagia and gastroesophageal reflux can result in “aspiration,” defined as the passage of food, liquids, or pills through the vocal cords into the trachea. Usually, signs and symptoms of disordered swallowing in patients with intact sensory

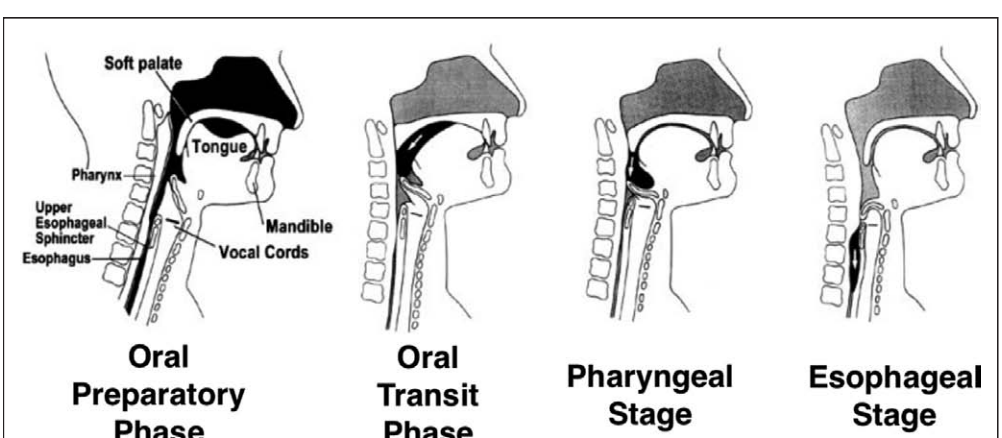

Figure 1. Four phases of swallowing.

input include pain or coughing while swallowing, the sensation of food getting stuck in the throat, a hoarse or wet voice after eating, or the sensation of regurgitation. Depending on the underlying disease process and the phase of swallowing affected, patients in the ICU who develop swallowing disorders may or may not present with typical signs or symptoms. Imaging modalities frequently reveal overt aspiration in hospitalized patients who lack any of these presenting clues. This type of aspiration is often referred to as "silent" and is estimated to occur in over 50% of all patients with documented aspiration (39–41).

Dysphagia that occurs in ICU patients following extubation, often termed "postextubation dysphagia" (or PED), usually is an ICU-acquired disorder. However, because swallowing diseases in the general population can present insidiously, and have varied diagnostic criteria, it is also possible for critical illness to unmask a previously undiagnosed swallowing disease. It is also possible that the primary reason for a patient's admission is a known cause of abnormal swallowing, irrespective of the presence of an endotracheal tube or systemic illness (such as an acute hemispheric cerebrovascular accident or a large laryngeal abscess). While critical care physicians obviously need to make feeding decisions for these patients, this review focuses primarily on the downstream swallowing disorders suffered by patients who either received an endotracheal tube, mechanical ventilation, or became afflicted by a systemic critical illness.

The prevalence of swallowing disorders in a population of extubated acute respiratory failure survivors is unknown, largely because existing epidemiologic studies have intrinsic biases, have used variable screening and diagnostic criteria, and have evaluated heterogenous patient populations. Depending on the population studied and the diagnostic criteria used, the estimated prevalence of dysphagia ranges between 3% and 62% for patients recovering from critical illnesses (12, 24, 27, 42–44). Further well-controlled prospective studies using standardized diagnostic criteria will be necessary to determine the true prevalence of dysphagia in critical illness survivors.

Mechanisms

Patients in the ICU can develop dysfunctional swallowing via six potential mechanisms (**Fig. 2**). First, endotracheal and tracheostomy tubes themselves can cause direct trauma to normal anatomic structures that enable effective swallowing and protect against aspiration. Most importantly, focal ulceration and/or inflammation can damage the vocal cords, the epiglottis, the arytenoids, and/or the base of the tongue, rendering these structures less capable of protecting the airway. This inflammation can either result in granulation tissue or even the scarring together of the vocal cords, known as "synechiae" (19). This granulation tissue and scarring can cause dysphagia, aspiration, an altered voice, or in rarer occasions a threatened airway requiring emergent surgical correction. Furthermore, arytenoid dislocation and subluxation can result in impaired glottic closure during swallowing (45). Additionally, the recurrent laryngeal nerve can be compressed (usually by the endotracheal tube cuff) resulting in vocal cord paresis and paralysis. Lip and dental injuries sustained during the period of intubation have the potential to affect a patient's ability to hold food in the mouth and/or chew appropriately, which can affect bolus size, and swallow timing, resulting in aspiration. Similarly, tongue swelling, or macroglossia, can occur following malpositioned bite blocks. Lingual nerve compression and loss of tongue sensation have been reported after forceful laryngoscopy or a poorly positioned laryngeal mask apparatus (46–50). Finally, other orally inserted foreign bodies, such as larger bore orogastric tubes, transesophageal echocardiogram probes, and suction devices, may also cause direct oral, pharyngeal, laryngeal, or esophageal trauma that can impair subsequent swallowing (45).

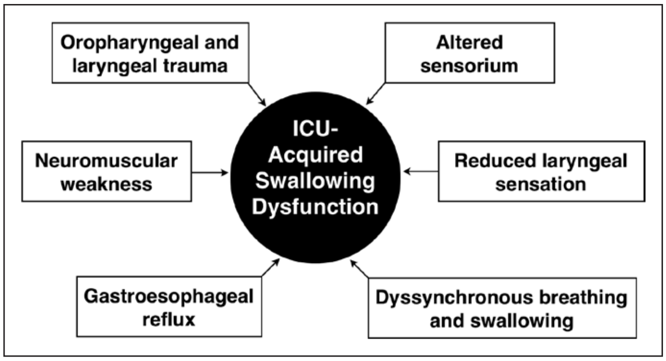

Figure 2. Six potential mechanisms for the development of ICU-acquired swallowing disorders.

The second mechanism for dysphagia in critically ill patients is neuromyopathy resulting in muscular weakness. Multiple muscle groups required from normal swallowing may be affected. For example, infrequent swallowing can result in a disuse atrophy of the muscles of the tongue, pharynx, and larynx in patients receiving prolonged endotracheal intubation or paralytics (26, 36, 51). Furthermore, critical illness polyneuromyopathy is a common peripheral muscular disorder and can lead to diminished overall cough strength and limited glottic clearance (52, 53).

The third mechanism for dysphagia is the development of dysfunctional oropharyngeal and laryngeal sensation. Sensation abnormalities can result from either critical illness polyneuropathy or local edema (54). While laryngeal sensation assessment methods are currently being optimized to evaluate patients (55–57), the proper timing and strength of the laryngeal closure reflex depends on appropriate afferent input and likely plays a role in the pathophysiology of swallowing dysfunction (56, 58–60).

The fourth mechanism for swallowing dysfunction in critical illness survivors is impaired sensorium, either related to ICU-acquired delirium, underlying critical illness, or the effects of sedating medications. Leder et al (61) have recently reported that in a mixed patient population, the odds of liquid aspiration were 31% greater for patients not oriented to person, place, and time. Decreased level of consciousness also limits a patient's ability to participate fully in therapeutic exercises offered by speech-language pathologists. Further controlled studies are necessary to determine the duration and magnitude of the effect of an altered sensorium on swallowing function in critically ill patients.

The fifth mechanism for disordered swallowing in critically ill patients is gastroesophageal reflux. Supine positioning, higher levels of sedation, and the use of paralytics are all reported risk factors for gastroesopheal reflux and subsequent aspiration in *intubated* ICU patients (62). Although not directly investigated, some of these pathophysiologic processes that are responsible for gastroesophageal reflux likely continue in the immediate postextubation period. Impaired gastric motility and tube-based enteral feeding also increase the risk for gastroesophageal reflux (63). Despite debate surrounding optimal volume thresholds, gastric residual volume is frequently used in tube-fed patients to monitor for impaired gastric motility and the risk of subsequent reflux and aspiration (64, 65).

The sixth mechanism for swallowing dysfunction is dyssynchronous breathing and swallowing in patients with underlying respiratory impairment and tachypnea. Prevention of aspiration during swallowing is dependent on exact coordination between laryngeal closure, apnea, and the opening of the upper esophageal sphincter (35). As the respiratory rate increases, the periswallowing apneic period shortens, and laryngeal opening can occur prior to passage of the food bolus into the esophagus (66). Patients with hypoxemia and tachypnea aspirate more frequently (67–71). Additionally, these patients possess less physiologic reserve to accommodate aspiration-associated gas exchange abnormalities, which further amplify the deleterious effects of their aspiration.

Risk Factors

Several factors are known to increase the risk for dysphagia, aspiration, and pneumonia in critically ill patients (**Table 1**). Nonintubated patients with stroke and other neuromuscular disease have all been shown to foster an increased risk of aspiration and pneumonia (72, 73). Additionally, supine bed position and frequent gastroesophageal reflux in mechanically ventilated patients have been demonstrated to increase the risk for nosocomial pneumonia (62, 74, 75). Finally, as discussed above, patients with a decreased level of consciousness are more likely to aspirate (76).

TABLE 1. Risk Factors for Swallowing Disorders in Critically Ill Patients

Risk Factors
Preexisting dysphagia
Cancer, surgery, or radiation to head, neck, and/or esophagus
Delirium, excessive sedation, and/or dementia
Stroke or neuromuscular disease
Longer durations of mechanical ventilation
Multiple intubations
Tracheostomy
Severe gastroesophageal reflux
Paralytics and/or critical illness polyneuromyopathy
Supine bed position
Perioperative transesophageal echocardiogram

The study of those factors that increase the risk for impaired swallowing in awake, recently extubated patients without strokes or neuromuscular diseases is less advanced. Specific risk factors for this type of PED have been reported in a few epidemiology studies (12). Perioperative transesophageal echocardiogram was reported to be independently associated with an increased risk of PED in small cohorts of patients undergoing cardiac surgery (27, 43). Additionally, lower preadmission functional status has been independently associated with PED in a cohort of 84 elderly patients (hazard ratio, 1.68; 95% CI, 1.26–3.97) (77). Interestingly, age, intubation duration, diabetes mellitus, renal failure, postoperative pulmonary complications, and tracheostomy all have been both supported and refuted as potential risk factors for PED (25, 27, 42, 43, 78–87). The variable associations between PED and these risk factors likely stem from biased patient selection, heterogenous study populations, and differing diagnostic protocols. For example, while the initial retrospective reports of swallowing dysfunction in patients with tracheostomy paved the way for the study of swallowing in the ICU (26, 82, 87), since then experts have debated the actual effects of tracheostomy on swallowing function (84, 85, 88–90). Because of these debates, the search for modifiable risk factors for PED would be greatly assisted by well-controlled prospective studies and an established diagnostic standard for the disease.

Screening

Although screening for dysphagia in all stroke patients is a component of the current national guidelines and performance measures, no similar standards exist for the evaluation of critically ill patients following extubation (91). A recent nationwide survey of inpatient speech-language pathologists who specialize in the evaluation and management of swallowing disorders revealed that only 41% of hospitals routinely screen extubated patients for dysphagia (92). Nearly all screening protocols involve the attempted swallowing of a quantity of water varying between 3 mL and 90 mL, followed by the observation by either a nurse, speech-language pathologist, or physician for clinical signs of aspiration. The reliability and validity of these screening protocols have been debated in stroke patients, largely due to questionable sensitivity for aspiration (93–95). However, in a recent, large study of a mixed group of hospitalized patients, Suiter and Leder (96) demonstrated that a 3-ounce Water Swallow Test was 96.5% sensitive and 48.7% specific for aspiration as detected by a bedside endoscopy performed immediately afterward. Although these results suggest a potential method to screen patients following extubation, the validity of this and other water-based screening protocols in recently extubated patients is unknown.

Diagnosis

Currently, the most common diagnostic test to evaluate for PED is a bedside swallow evaluation performed by a speech-language pathologist. Although the components of this examination are not standardized and can vary by practitioner (92), patients usually undergo an interview, a structural and functional evaluation of their mouth and their cough response, and an assessment of swallowing function with different food textures and liquid thicknesses. The bedside swallow evaluation has been criticized for poor sensitivity as well as poor inter- and intrajudge reliability (97–99). Although it has not been validated against gold standard tests, a seven-point scale that incorporates the perceived aspiration risk and subsequent dietary recommendations is often used to grade the severity of dysphagia (100, 101).

Although the bedside swallow evaluation is the sole assessment performed in 60% of cases nationwide (92), additional tests may be ordered to assist in the diagnosis of PED. A videofluoroscopic swallow study (VFSS), often referred to as "a modified barium swallow," is available in over 97% of hospitals nationwide (92). To perform this test, patients are transported from the ICU to a fluoroscopy suite and instructed to swallow different consistencies of barium-containing foods and liquids in a sitting position. The procedure is recorded and then reviewed by a radiologist. Despite questionable interobserver variability for abnormalities in other phases of swallowing, this test is highly sensitive and specific for aspiration (102–104). Numerous scoring systems exist to quantify the degree of aspiration (105–107) as well as the degree of overall swallowing impairment (108). Importantly, visualized aspiration on a VFSS has been associated with significantly increased risk of developing subsequent pneumonia in a mixed group of patients (109).

The other gold standard instrumental procedure to evaluate for PED is a fiberoptic endoscopic swallow study (FEES). During this test, a small (usually 3.4–3.6 mm) nasopharyngoscope is passed through one nostril into the pharynx, and the entire glottis is endoscopically visualized during swallowing (**Fig. 3**). Patients frequently receive a small quantity of a local anesthetic to the nasal turbinates to maximize comfort. Both the interobserver variability and the sensitivity for detection of aspiration are slightly better for the FEES than for a modified barium swallow (110–114). A major advantage of the FEES in ICU patients is the ability to perform the test at the patient's bedside. Other advantages include the ability to visualize injury to laryngeal soft tissues, observe secretion management, and test laryngeal sensation directly (56, 58, 115, 116). In a population of acute stroke patients, FEES has been reported to predict both the development of pneumonia and the degree of dependent living at 3 months (117). A nationwide sample of surveyed speech pathologists revealed that FEES is less frequently available than a modified barium swallow and even when available is used less frequently (92).

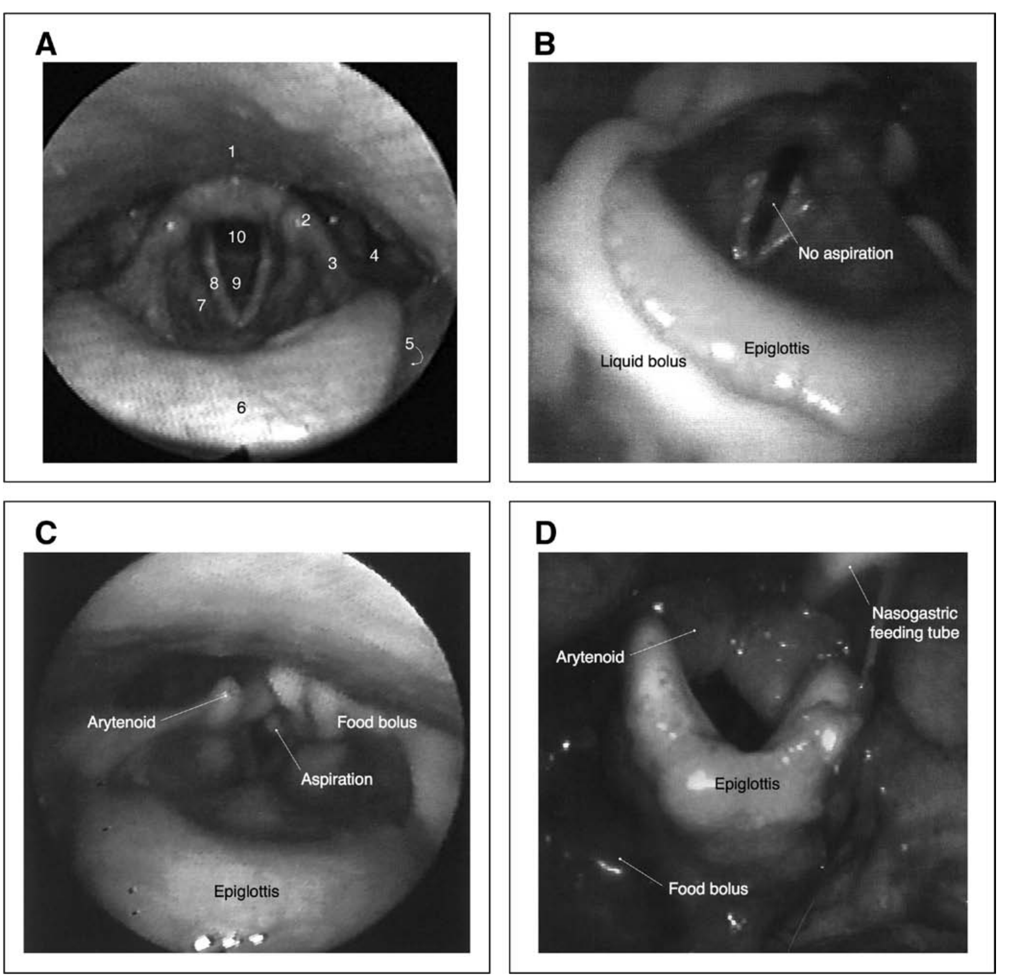

Figure 3. The glottis as viewed endoscopically during a fiberoptic endoscopic evaluation of swallowing. **A**, Normal pharynx and larynx in the resting position (1, posterior pharyngeal wall; 2, arytenoid; 3, aryepiglottic fold; 4, pyriform sinus; 5, vallecula; 6, epiglottis; 7, false vocal fold; 8, true vocal cord; 9, subglottic shelf; 10, trachea). **B**, Movement of liquid in the pharynx surrounding the larynx without aspiration. **C**, Food bolus (on the *right*) being aspirated into the trachea. **D**, Food bolus in the vallecula and on the epiglottis in a recently extubated patient. Note the significant arytenoid edema and a small-bore nasogastric feeding tube (*upper right*).

Patient Outcomes

The independent association between aspiration, the development of pneumonia, and poor outcomes in nonintubated patients is well reported (118–121). In addition to malnutrition and increased mortality, dysphagia and aspiration can result in chronic cough, increased institutionalized care, social isolation, decreased quality of life, and depression (73, 122–124). However, few prospective cohort studies have examined the associations between patient outcomes and

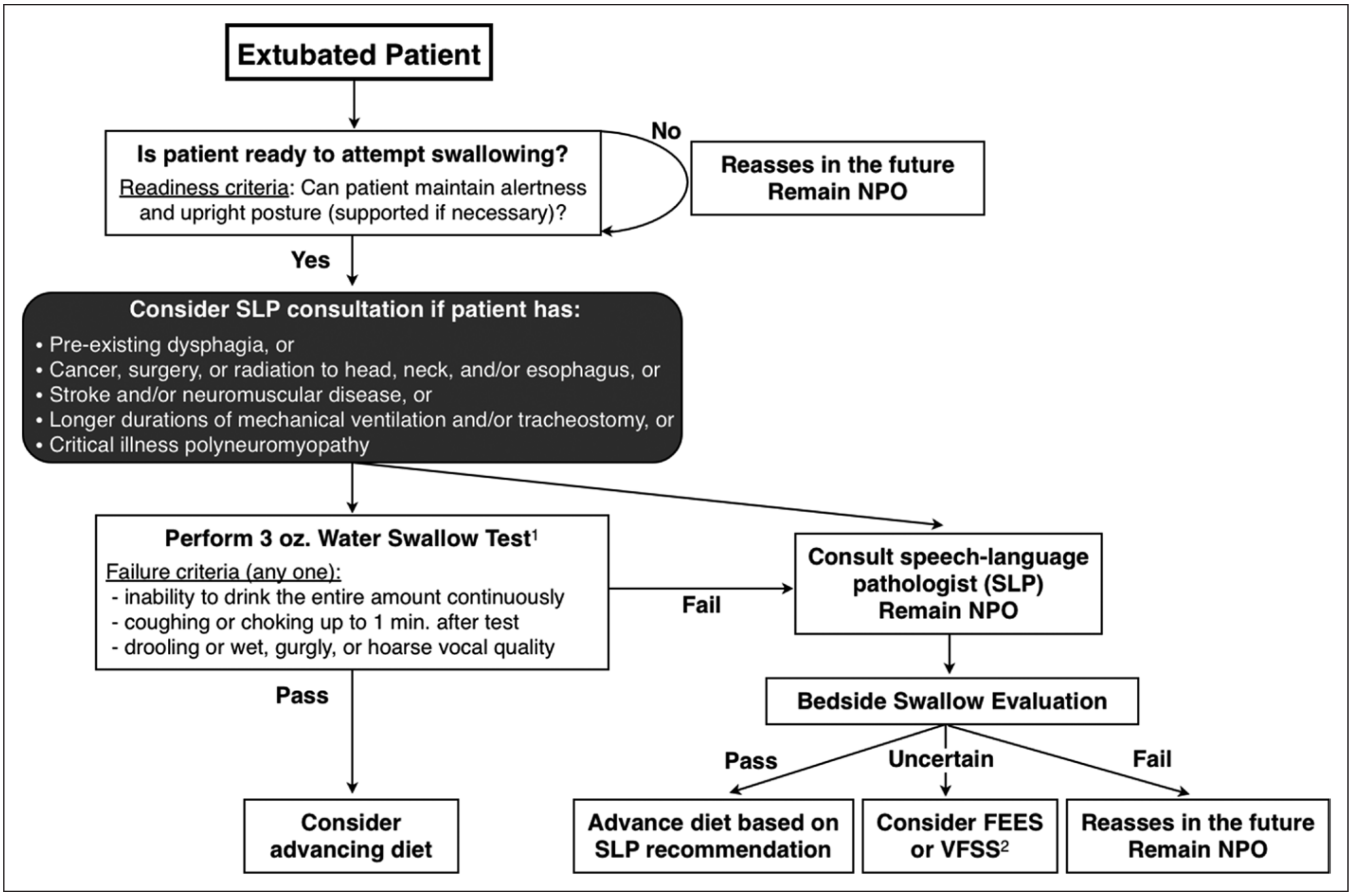

Figure 4. Algorithm for management of swallowing disorders in recently extubated patients. [1]The 3-ounce Water Swallow Test can be performed by a nurse, a speech-language pathologist (SLP), or a physician. Patients are given 3 ounces of water and instructed to drink the entire amount, via cup or straw, completely and without interruption (cup can be held to patients mouth by examiner). The volume of water, failure criteria, and number of administrations have not been validated in recently extubated patients. Devices that improve sensorium should be in place (glasses, dentures, and hearing aids). [2]These instrumental tests are usually performed when results of the bedside swallow evaluation are uncertain. The benefit of protocols using instrumental tests in recently extubated patients has not been established. NPO = nil per os, VFSS = videofluoroscopic swallow study, FEES = fiberoptic endoscopic evaluation of swallowing.

dysphagia severity specifically in a population of recently extubated critically ill patients. One recent, large retrospective cohort study of extubated ICU patients demonstrated an independent association between dysphagia and a composite outcome of pneumonia, reintubation, or death (adjusted odds ratio, 3.31 [1.78–4.56]; $p < 0.01$) (86). The presence of dysphagia was also significantly associated with longer hospitalization, discharge to a nursing home, and feeding tube placement. However, this study was limited by selection bias and the use of only bedside swallow evaluations to diagnosis dysphagia. A recent retrospective review of National Hospital Discharge Survey data demonstrated a significant association between dysphagia and both hospital length of stay and mortality in a heterogenous hospital population. The same study estimated the national yearly cost of dysphagia in hospitalized patients to be over $500 million (125). These costs are, in part, related to increasing dysphagia assessments by speech-language pathologists. Speech-language pathologists currently devote 56% of their inpatient efforts to the evaluation and treatment of dysphagia, representing a 19% increase over the past 9 years (126). Further prospective studies are necessary to determine both the short- and long-term outcomes of patients with PED, as well as the most cost-effective methods for screening, diagnosis, and treatment.

Treatment

Treatments for all types of dysphagia have been relatively underexplored, especially for patients recovering from critical illnesses. Based on the evidence largely obtained in noncritically ill patients with chronic neuromuscular disease, the current state of treatment involves dietary texture modification, postural change, therapeutic exercises, and/or enteral feeding tubes (127–132). In rare cases, surgical technique such as an upper esophageal sphincter myotomy has been performed, with variable results (133, 134). The goal of the myotomy is to reduce the resistance of a functionally obstructing upper esophageal sphincter to facilitate the movement of the food bolus from the pharynx into the cervical esophagus. No controlled trials have shown strong benefits of any modalities described above, and speech-language pathologists and surgeons vary in their use of, and perceived effectiveness, different treatments (92). Given the potentially reversible sensory and neuromotor mechanisms for PED, novel therapeutic exercise protocols may be beneficial. For example, surface electromyography biofeedback has recently been incorporated into a rehabilitation program with early success (135, 136). This technology allows patients to visually monitor their own muscle activity during the swallowing process. Additionally, bundled exercise programs for both outpatients and acute stroke patients have shown promising results in small trials and deserve further study in critical illness survivors (137–139). Preliminary evidence also suggests a benefit in outpatients with other direct treatment modalities such as neuromuscular electrical stimulation or cricopharyngeal botulinum toxin injection (140, 141).

Recommendations for Screening and Diagnosis

Accurate identification of swallowing disorders in ICU patients is crucial to determine the safety and type of oral alimentation. Although we anxiously await further well-conducted trials examining screening, diagnostic, and treatment protocols for dysphagia, the diagnostic algorithm outlined in **Figure 4** represents our current recommendations for recently extubated ICU patients. Given the complexity of swallowing dysfunction in these patients, any proposed algorithm must be accompanied by appropriate caveats. Although the 3-ounce Water Swallow Test has been shown to be highly sensitive in a mixed population of all hospitalized patients, this test has not been validated in recently extubated ICU patients (96, 142, 143). The optimal volume of water to use for such a screening test, and the criteria for a failed test in ICU patients, remain to be determined. Furthermore, the bedside swallow evaluation by a speech-language pathologist deserves further exploration to limit its subjectivity and interrater variability. Ideally, determining the most useful components of the 3-ounce Water Swallow Test would improve the standardization and efficiency of its performance. Finally, subsequent studies should test the role for both FEES and VFSS to determine how critical care physicians, critical care nurses, and speech-language pathologists should optimally use these tests and reduce the burden of swallowing disorders in our patients.

CONCLUSIONS

Although the potential for artificial airways to cause laryngeal damage and impaired swallowing was initially raised in the mid 1960s (14, 17), the critical care community has been largely silent when faced with questions about our patients' swallowing function. Aided in great part by an increasing awareness of the long-term complications of critical illness (8, 144), and the expertise of speech-language pathologists, we are beginning to seek answers to a number of questions. Who should be screened for dysphagia after extubation? What is the optimal screening test? How can we limit the development of dysphagia? How do we treat it? Given the vast number of patients who require intensive care, and an improving ICU mortality, identifying the proper answers to these questions is important. Furthermore, swallowing disorders involve multiple organ systems and affect aspects of both acute and chronic care. Therefore, advancements in our understanding of these disorders will require effective collaboration between nurses, speech pathologists, neurologists, otolaryngologists, gastroenterologists, intensivists, and primary care physicians.

REFERENCES

1. Wunsch H, Linde-Zwirble WT, Angus DC, et al: The epidemiology of mechanical ventilation use in the United States. *Crit Care Med* 2010; 38:1947–1953
2. Vincent JL, Akça S, De Mendonça A, et al; SOFA Working Group. Sequential organ failure assessment: The epidemiology of acute respiratory failure in critically ill patients(*). *Chest* 2002; 121:1602–1609
3. Herridge MS, Tansey CM, Matté A, et al; Canadian Critical Care Trials Group: Functional disability 5 years after acute respiratory distress syndrome. *N Engl J Med* 2011; 364:1293–1304
4. Niskanen M, Kari A, Halonen P: Five-year survival after intensive care–Comparison of 12,180 patients with the general population. Finnish ICU Study Group. *Crit Care Med* 1996; 24:1962–1967
5. Griffiths RD, Jones C: Recovery from intensive care. *BMJ* 1999; 319:427–429
6. Adhikari NK, McAndrews MP, Tansey CM, et al: Self-reported symptoms of depression and memory dysfunction in survivors of ARDS. *Chest* 2009; 135:678–687
7. De Jonghe B, Sharshar T, Lefaucheur JP, et al; Groupe de Réflexion et d'Etude des Neuromyopathies en Réanimation: Paresis acquired in the intensive care unit: A prospective multicenter study. *JAMA* 2002; 288:2859–2867
8. Desai SV, Law TJ, Needham DM: Long-term complications of critical care. *Crit Care Med* 2011; 39:371–379
9. Hopkins RO, Weaver LK, Collingridge D, et al: Two-year cognitive, emotional, and quality-of-life outcomes in acute respiratory distress syndrome. *Am J Respir Crit Care Med* 2005; 171:340–347
10. Heffner JE: Swallowing complications after endotracheal extubation: Moving from "whether" to "how". *Chest* 2010; 137:509–510
11. Needham DM, Davidson J, Cohen H, et al: Improving long-term outcomes after discharge from intensive care unit: Report from a stakeholders' conference. *Crit Care Med* 2012; 40:502–509
12. Skoretz SA, Flowers HL, Martino R: The incidence of dysphagia following endotracheal intubation: A systematic review. *Chest* 2010; 137:665–673
13. Culver GA, Makel HP, Beecher HK: Frequency of aspiration of gastric contents by the lungs during anesthesia and surgery. *Ann Surg* 1951; 133:289–292
14. Betts RH: Post-tracheostomy aspiration. *N Engl J Med* 1965; 273:155
15. Bonanno PC: Swallowing dysfunction after tracheostomy. *Ann Surg* 1971; 174:29–33
16. Cameron JL, Reynolds J, Zuidema GD: Aspiration in patients with tracheostomies. *Surg Gynecol Obstet* 1973; 136:68–70
17. Feldman SA, Deal CW, Urquhart W: Disturbance of swallowing after tracheostomy. *Lancet* 1966; 1:954–955
18. Robbie DS, Feldman SA: Experience with fifty patients treated with artificial ventilation. *Br J Anaesth* 1963; 35:771–782
19. Stauffer JL, Olson DE, Petty TL: Complications and consequences of endotracheal intubation and tracheotomy. A prospective study of 150 critically ill adult patients. *Am J Med* 1981; 70:65–76
20. Whited RE: Laryngeal dysfunction following prolonged intubation. *Ann Otol Rhinol Laryngol* 1979; 88:474–478
21. Whited RE: A prospective study of laryngotracheal sequelae in long-term intubation. *Laryngoscope* 1984; 94:367–377
22. Whited RE: A study of post-intubation laryngeal dysfunction. *Laryngoscope* 1985; 95:727–729
23. Whited RE: A study of endotracheal tube injury to the subglottis. *Laryngoscope* 1985; 95:1216–1219
24. de Larminat V, Dureuil B, Montravers P, et al: [Impairment of deglutition reflex after prolonged intubation]. *Ann Fr Anesth Reanim* 1992; 11:17–21
25. de Larminat V, Montravers P, Dureuil B, et al: Alteration in swallowing reflex after extubation in intensive care unit patients. *Crit Care Med* 1995; 23:486–490

26. DeVita MA, Spierer-Rundback L: Swallowing disorders in patients with prolonged orotracheal intubation or tracheostomy tubes. *Crit Care Med* 1990; 18:1328–1330
27. Hogue CW Jr, Lappas GD, Creswell LL, et al: Swallowing dysfunction after cardiac operations. Associated adverse outcomes and risk factors including intraoperative transesophageal echocardiography. *J Thorac Cardiovasc Surg* 1995; 110:517–522
28. de Aguilar-Nascimento JE, Kudsk KA: Clinical costs of feeding tube placement. *JPEN J Parenter Enteral Nutr* 2007; 31:269–273
29. Quill TE: Utilization of nasogastric feeding tubes in a group of chronically ill, elderly patients in a community hospital. *Arch Intern Med* 1989; 149:1937–1941
30. Callahan CM, Buchanan NN, Stump TE: Healthcare costs associated with percutaneous endoscopic gastrostomy among older adults in a defined community. *J Am Geriatr Soc* 2001; 49:1525–1529
31. Dennis MS, Lewis SC, Warlow C; FOOD Trial Collaboration: Effect of timing and method of enteral tube feeding for dysphagic stroke patients (FOOD): A multicentre randomised controlled trial. *Lancet* 2005; 365:764–772
32. Erdil A, Saka M, Ates Y, et al: Enteral nutrition via percutaneous endoscopic gastrostomy and nutritional status of patients: Five-year prospective study. *J Gastroenterol Hepatol* 2005; 20:1002–1007
33. Finucane TE, Christmas C, Travis K: Tube feeding in patients with advanced dementia: A review of the evidence. *JAMA* 1999; 282:1365–1370
34. Dodds WJ, Stewart ET, Logemann JA: Physiology and radiology of the normal oral and pharyngeal phases of swallowing. *AJR Am J Roentgenol* 1990; 154:953–963
35. Langmore S: Endoscopic Evaluation and Treatment of Swallowing Disorders. New York, Thieme, 2001
36. Goldsmith T: Evaluation and treatment of swallowing disorders following endotracheal intubation and tracheostomy. *Int Anesthesiol Clin* 2000; 38:219–242
37. Perlman A, Schulze-Delrieu K: Deglutition and Its Disorders: Anatomy, Physiology, Clinical Diagnosis, and Management. San Diego, London, Singular, 1997
38. Shaker R, Dodds WJ, Dantas RO, et al: Coordination of deglutitive glottic closure with oropharyngeal swallowing. *Gastroenterology* 1990; 98:1478–1484
39. Garon BR, Sierzant T, Ormiston C: Silent aspiration: Results of 2,000 video fluoroscopic evaluations. *J Neurosci Nurs* 2009; 41:178–185; quiz 186
40. Hafner G, Neuhuber A, Hirtenfelder S, et al: Fiberoptic endoscopic evaluation of swallowing in intensive care unit patients. *Eur Arch Otorhinolaryngol* 2008; 265:441–446
41. Kikuchi R, Watabe N, Konno T, et al: High incidence of silent aspiration in elderly patients with community-acquired pneumonia. *Am J Respir Crit Care Med* 1994; 150:251–253
42. Ferraris VA, Ferraris SP, Moritz DM, et al: Oropharyngeal dysphagia after cardiac operations. *Ann Thorac Surg* 2001; 71:1792–1795; discussion 1796
43. Rousou JA, Tighe DA, Garb JL, et al: Risk of dysphagia after transesophageal echocardiography during cardiac operations. *Ann Thorac Surg* 2000; 69:486–489; discussion 489–490
44. Stanley GD, Bastianpillai BA, Mulcahy K, et al: Postoperative laryngeal competence. The laryngeal mask airway and tracheal tube compared. *Anaesthesia* 1995; 50:985–986
45. Sue RD, Susanto I: Long-term complications of artificial airways. *Clin Chest Med* 2003; 24:457–471
46. Colice GL, Stukel TA, Dain B: Laryngeal complications of prolonged intubation. *Chest* 1989; 96:877–884
47. Colton House J, Noordzij JP, Murgia B, et al: Laryngeal injury from prolonged intubation: A prospective analysis of contributing factors. *Laryngoscope* 2011; 121:596–600
48. Hagberg C, Georgi R, Krier C: Complications of managing the airway. *Best Pract Res Clin Anaesthesiol* 2005; 19:641–659
49. Megarbane B, Be Hong T, Kania R, et al: Early laryngeal injury and complications because of endotracheal intubation in acutely poisoned patients: A prospective observational study. *Clin Toxicol (Phila)* 2010; 48:331–336
50. Van der Meer G, Ferreira Y, Loock JW: The S/Z ratio: A simple and reliable clinical method of evaluating laryngeal function in patients after intubation. *J Crit Care* 2010; 25:489–492
51. Feng X, Todd T, Lintzenich CR, et al: Aging-related geniohyoid muscle atrophy is related to aspiration status in healthy older adults. *J Gerontol A Biol Sci Med Sci* 2013; 68:853–860
52. Puthucheary Z, Harridge S, Hart N: Skeletal muscle dysfunction in critical care: Wasting, weakness, and rehabilitation strategies. *Crit Care Med* 2010; 38:S676–S682
53. Tobin MJ, Laghi F, Jubran A: Narrative review: Ventilator-induced respiratory muscle weakness. *Ann Intern Med* 2010; 153:240–245
54. Hermans G, De Jonghe B, Bruyninckx F, et al: Clinical review: Critical illness polyneuropathy and myopathy. *Crit Care* 2008; 12:238
55. Aviv JE, Kim T, Sacco RL, et al: FEESST: A new bedside endoscopic test of the motor and sensory components of swallowing. *Ann Otol Rhinol Laryngol* 1998; 107:378–387
56. Aviv JE, Spitzer J, Cohen M, et al: Laryngeal adductor reflex and pharyngeal squeeze as predictors of laryngeal penetration and aspiration. *Laryngoscope* 2002; 112:338–341
57. Perlman PW, Cohen MA, Setzen M, et al: The risk of aspiration of pureed food as determined by flexible endoscopic evaluation of swallowing with sensory testing. *Otolaryngol Head Neck Surg* 2004; 130:80–83
58. Aviv JE: Clinical assessment of pharyngolaryngeal sensitivity. *Am J Med* 2000; 108(Suppl 4a):68S–72S
59. Bradley RM: Sensory receptors of the larynx. *Am J Med* 2000; 108(Suppl 4a):47S–50S
60. Shaker R, Hogan WJ: Reflex-mediated enhancement of airway protective mechanisms. *Am J Med* 2000; 108(Suppl 4a):8S–14S
61. Leder SB, Suiter DM, Lisitano Warner H: Answering orientation questions and following single-step verbal commands: Effect on aspiration status. *Dysphagia* 2009; 24:290–295
62. Metheny NA, Clouse RE, Chang YH, et al: Tracheobronchial aspiration of gastric contents in critically ill tube-fed patients: Frequency, outcomes, and risk factors. *Crit Care Med* 2006; 34:1007–1015
63. Metheny NA: Preventing respiratory complications of tube feedings: Evidence-based practice. *Am J Crit Care* 2006; 15:360–369
64. McClave SA, Lukan JK, Stefater JA, et al: Poor validity of residual volumes as a marker for risk of aspiration in critically ill patients. *Crit Care Med* 2005; 33:324–330
65. Metheny NA, Schallom L, Oliver DA, et al: Gastric residual volume and aspiration in critically ill patients receiving gastric feedings. *Am J Crit Care* 2008; 17:512–519; quiz 520
66. Boden K, Cedborg AI, Eriksson LI, et al: Swallowing and respiratory pattern in young healthy individuals recorded with high temporal resolution. *Neurogastroenterol Motil* 2009; 21:1163–e101
67. Gross RD, Atwood CW Jr, Ross SB, et al: The coordination of breathing and swallowing in chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2009; 179:559–565
68. Martin-Harris B, Brodsky MB, Michel Y, et al: Breathing and swallowing dynamics across the adult lifespan. *Arch Otolaryngol Head Neck Surg* 2005; 131:762–770
69. Matsuo K, Hiiemae KM, Gonzalez-Fernandez M, et al: Respiration during feeding on solid food: Alterations in breathing during mastication, pharyngeal bolus aggregation, and swallowing. *J Appl Physiol* 2008; 104:674–681
70. Matsuo K, Palmer JB: Coordination of mastication, swallowing and breathing. *Jpn Dent Sci Rev* 2009; 45:31–40
71. Shaker R, Li Q, Ren J, et al: Coordination of deglutition and phases of respiration: Effect of aging, tachypnea, bolus volume, and chronic obstructive pulmonary disease. *Am J Physiol* 1992; 263:G750–G755
72. Katzan IL, Dawson NV, Thomas CL, et al: The cost of pneumonia after acute stroke. *Neurology* 2007; 68:1938–1943
73. Smithard DG, O'Neill PA, Parks C, et al: Complications and outcome after acute stroke. Does dysphagia matter? *Stroke* 1996; 27:1200–1204
74. Drakulovic MB, Torres A, Bauer TT, et al: Supine body position as a risk factor for nosocomial pneumonia in mechanically ventilated patients: A randomised trial. *Lancet* 1999; 354:1851–1858

75. Orozco-Levi M, Torres A, Ferrer M, et al: Semirecumbent position protects from pulmonary aspiration but not completely from gastroesophageal reflux in mechanically ventilated patients. *Am J Respir Crit Care Med* 1995; 152:1387–1390
76. Metheny NA: Risk factors for aspiration. *JPEN J Parenter Enteral Nutr* 2002; 26:S26–S31; discussion S32–S33
77. El Solh A, Okada M, Bhat A, et al: Swallowing disorders post orotracheal intubation in the elderly. *Intensive Care Med* 2003; 29:1451–1455
78. Ajemian MS, Nirmul GB, Anderson MT, et al: Routine fiberoptic endoscopic evaluation of swallowing following prolonged intubation: Implications for management. *Arch Surg* 2001; 136:434–437
79. Barker J, Martino R, Reichardt B, et al: Incidence and impact of dysphagia in patients receiving prolonged endotracheal intubation after cardiac surgery. *Can J Surg* 2009; 52:119–124
80. Barquist E, Brown M, Cohn S, et al: Postextubation fiberoptic endoscopic evaluation of swallowing after prolonged endotracheal intubation: A randomized, prospective trial. *Crit Care Med* 2001; 29:1710–1713
81. Effros RM, Jacobs ER, Schapira RM, et al: Response of the lungs to aspiration. *Am J Med* 2000; 108(Suppl 4a):15S–19S
82. Elpern EH, Scott MG, Petro L, et al: Pulmonary aspiration in mechanically ventilated patients with tracheostomies. *Chest* 1994; 105:563–566
83. Leder SB, Cohn SM, Moller BA: Fiberoptic endoscopic documentation of the high incidence of aspiration following extubation in critically ill trauma patients. *Dysphagia* 1998; 13:208–212
84. Leder SB, Joe JK, Ross DA, et al: Presence of a tracheotomy tube and aspiration status in early, postsurgical head and neck cancer patients. *Head Neck* 2005; 27:757–761
85. Leder SB, Ross DA: Confirmation of no causal relationship between tracheotomy and aspiration status: A direct replication study. *Dysphagia* 2010; 25:35–39
86. Macht M, Wimbish T, Clark BJ, et al: Postextubation dysphagia is persistent and associated with poor outcomes in survivors of critical illness. *Crit Care* 2011; 15:R231
87. Romero CM, Marambio A, Larrondo J, et al: Swallowing dysfunction in nonneurologic critically ill patients who require percutaneous dilatational tracheostomy. *Chest* 2010; 137:1278–1282
88. Brady SL, Wesling M, Donzelli J: Pilot date on swallow function in nondysphagic patients requiring a tracheotomy tube. *Int J Otolaryngol* 2009; 2009:610849
89. Donzelli J, Brady S, Wesling M, et al: Effects of the removal of the tracheotomy tube on swallowing during the fiberoptic endoscopic exam of the swallow (FEES). *Dysphagia* 2005; 20:283–289
90. Leder SB, Ross DA: Investigation of the causal relationship between tracheotomy and aspiration in the acute care setting. *Laryngoscope* 2000; 110:641–644
91. Reeves MJ, Parker C, Fonarow GC, et al: Development of stroke performance measures: Definitions, methods, and current measures. *Stroke* 2010; 41:1573–1578
92. Macht M, Wimbish T, Clark BJ, et al: Diagnosis and treatment of postextubation dysphagia: Results from a national survey. *J Crit Care* 2012; 27:578–586
93. Daniels SK, Anderson JA, Willson PC: Valid items for screening dysphagia risk in patients with stroke: A systematic review. *Stroke* 2012; 43:892–897
94. Schepp SK, Tirschwell DL, Miller RM, et al: Swallowing screens after acute stroke: A systematic review. *Stroke* 2012; 43:869–871
95. Steele CM, Molfenter SM, Bailey GL, et al: Exploration of the utility of a brief swallow screening protocol with comparison to concurrent videofluoroscopy. *Can J Speech Lang Pathol Audiol* 2011; 35:228–242
96. Suiter DM, Leder SB: Clinical utility of the 3-ounce water swallow test. *Dysphagia* 2008; 23:244–250
97. McCullough GH, Wertz RT, Rosenbek JC, et al: Inter- and intrajudge reliability of a clinical examination of swallowing in adults. *Dysphagia* 2000; 15:58–67
98. McCullough GH, Wertz RT, Rosenbek JC: Sensitivity and specificity of clinical/bedside examination signs for detecting aspiration in adults subsequent to stroke. *J Commun Disord* 2001; 34:55–72
99. Ramsey DJ, Smithard DG, Kalra L: Early assessments of dysphagia and aspiration risk in acute stroke patients. *Stroke* 2003; 34:1252–1257
100. American Speech Language Hearing Association National Outcomes Measurement System (ASHA-NOMS) for swallowing: Adult Speech-Language Pathology User's Guide. Rockville, MD, American Speech-Language Hearing Association, 2003, pp 1–22. Available at: http://www.asha.org/uploadedFiles/members/research/NOMS/AdultNOMSFCMs.pdf. Accessed January 1, 2013
101. Mullen R: Evidence for whom?: ASHA's National Outcomes Measurement System. *J Commun Disord* 2004; 37:413–417
102. McCullough GH, Wertz RT, Rosenbek JC, et al: Inter- and intrajudge reliability for videofluoroscopic swallowing evaluation measures. *Dysphagia* 2001; 16:110–118
103. Scott A, Perry A, Bench J: A study of interrater reliability when using videofluoroscopy as an assessment of swallowing. *Dysphagia* 1998; 13:223–227
104. Stoeckli SJ, Huisman TA, Seifert B, et al: Interrater reliability of videofluoroscopic swallow evaluation. *Dysphagia* 2003; 18:53–57
105. O'Neil KH, Purdy M, Falk J, et al: The Dysphagia Outcome and Severity Scale. *Dysphagia* 1999; 14:139–145
106. Robbins J, Coyle J, Rosenbek J, et al: Differentiation of normal and abnormal airway protection during swallowing using the penetration-aspiration scale. *Dysphagia* 1999; 14:228–232
107. Rosenbek JC, Robbins JA, Roecker EB, et al: A penetration-aspiration scale. *Dysphagia* 1996; 11:93–98
108. Martin-Harris B, Brodsky MB, Michel Y, et al: MBS measurement tool for swallow impairment–MBSImp: Establishing a standard. *Dysphagia* 2008; 23:392–405
109. Pikus L, Levine MS, Yang YX, et al: Videofluoroscopic studies of swallowing dysfunction and the relative risk of pneumonia. *AJR Am J Roentgenol* 2003; 180:1613–1616
110. Colodny N: Interjudge and intrajudge reliabilities in fiberoptic endoscopic evaluation of swallowing (fees) using the penetration-aspiration scale: A replication study. *Dysphagia* 2002; 17:308–315
111. Kelly AM, Leslie P, Beale T, et al: Fibreoptic endoscopic evaluation of swallowing and videofluoroscopy: Does examination type influence perception of pharyngeal residue severity? *Clin Otolaryngol* 2006; 31:425–432
112. Kelly AM, Drinnan MJ, Leslie P: Assessing penetration and aspiration: How do videofluoroscopy and fiberoptic endoscopic evaluation of swallowing compare? *Laryngoscope* 2007; 117:1723–1727
113. Leder SB, Acton LM, Lisitano HL, et al: Fiberoptic endoscopic evaluation of swallowing (FEES) with and without blue-dyed food. *Dysphagia* 2005; 20:157–162
114. Rao N, Brady SL: Analysis of the videofluoroscopic and fiberoptic endoscopic swallow examinations. *J Appl Res* 2012; 1–6
115. Cohen MA, Setzen M, Perlman PW, et al: The safety of flexible endoscopic evaluation of swallowing with sensory testing in an outpatient otolaryngology setting. *Laryngoscope* 2003; 113:21–24
116. Ota K, Saitoh E, Baba M, et al: The secretion severity rating scale: A potentially useful tool for management of acute-phase fasting stroke patients. *J Stroke Cerebrovasc Dis* 2011; 20:183–187
117. Warnecke T, Ritter MA, Kroger B, et al: Fiberoptic endoscopic Dysphagia severity scale predicts outcome after acute stroke. *Cerebrovasc Dis* 2009; 28:283–289
118. Loeb M, McGeer A, McArthur M, et al: Risk factors for pneumonia and other lower respiratory tract infections in elderly residents of long-term care facilities. *Arch Intern Med* 1999; 159:2058–2064
119. Marik PE, Kaplan D: Aspiration pneumonia and dysphagia in the elderly. *Chest* 2003; 124:328–336
120. Martin BJ, Corlew MM, Wood H, et al: The association of swallowing dysfunction and aspiration pneumonia. *Dysphagia* 1994; 9:1–6
121. Vergis EN, Brennen C, Wagener M, et al: Pneumonia in long-term care: A prospective case-control study of risk factors and impact on survival. *Arch Intern Med* 2001; 161:2378–2381
122. Ekberg O, Hamdy S, Woisard V, et al: Social and psychological burden of dysphagia: Its impact on diagnosis and treatment. *Dysphagia* 2002; 17:139–146

123. Smith Hammond CA, Goldstein LB: Cough and aspiration of food and liquids due to oral-pharyngeal dysphagia: ACCP evidence-based clinical practice guidelines. *Chest* 2006; 129:154S–168S
124. Smithard DG: Feeding and swallowing problems in the institutionalized elderly. *Clin Rehabil* 1996; 10:153–154
125. Altman KW, Yu GP, Schaefer SD: Consequence of dysphagia in the hospitalized patient: Impact on prognosis and hospital resources. *Arch Otolaryngol Head Neck Surg* 2010; 136:784–789
126. American Speech-Language-Hearing Association: Report on the ASHA Speech-Language Pathology Health Care Survey 2011. SLP Health Care Survey Summary Report: Number and Type of Responses. Available at: http://www.asha.org/uploadedFiles/HC11-Summary-Report.pdf. Accessed January 1, 2013
127. Bath PM, Bath FJ, Smithard DG: Interventions for dysphagia in acute stroke. *Cochrane Database Syst Rev* 2000; 2:CD000323
128. Deane KH, Whurr R, Clarke CE, et al: Non-pharmacological therapies for dysphagia in Parkinson's disease. *Cochrane Database Syst Rev* 2001; 1:CD002816
129. Hill M, Hughes T, Milford C: Treatment for swallowing difficulties (dysphagia) in chronic muscle disease. *Cochrane Database Syst Rev* 2004; 2:CD004303
130. Rasley A, Logemann JA, Kahrilas PJ, et al: Prevention of barium aspiration during videofluoroscopic swallowing studies: Value of change in posture. *AJR Am J Roentgenol* 1993; 160:1005–1009
131. Robbins J, Gensler G, Hind J, et al: Comparison of 2 interventions for liquid aspiration on pneumonia incidence: A randomized trial. *Ann Intern Med* 2008; 148:509–518
132. Sonies BC: Evaluation and treatment of speech and swallowing disorders associated with myopathies. *Curr Opin Rheumatol* 1997; 9:486–495
133. Kos MP, David EF, Klinkenberg-Knol EC, et al: Long-term results of external upper esophageal sphincter myotomy for oropharyngeal Dysphagia. *Dysphagia* 2010; 25:169–176
134. Shama L, Connor NP, Ciucci MR, et al: Surgical treatment of dysphagia. *Phys Med Rehabil Clin N Am* 2008; 19:817–835
135. Carnaby-Mann GD, Crary MA: McNeill dysphagia therapy program: A case-control study. *Arch Phys Med Rehabil* 2010; 91:743–749
136. Yoshida M, Groher ME, Crary MA, et al: Comparison of surface electromyographic (sEMG) activity of submental muscles between the head lift and tongue press exercises as a therapeutic exercise for pharyngeal dysphagia. *Gerodontology* 2007; 24:111–116
137. Carnaby G, Hankey GJ, Pizzi J: Behavioural intervention for dysphagia in acute stroke: A randomised controlled trial. *Lancet Neurol* 2006; 5:31–37
138. Logemann JA, Rademaker A, Pauloski BR, et al: A randomized study comparing the Shaker exercise with traditional therapy: A preliminary study. *Dysphagia* 2009; 24:403–411
139. Mepani R, Antonik S, Massey B, et al: Augmentation of deglutitive thyrohyoid muscle shortening by the Shaker Exercise. *Dysphagia* 2009; 24:26–31
140. Alfonsi E, Merlo IM, Ponzio M, et al: An electrophysiological approach to the diagnosis of neurogenic dysphagia: Implications for botulinum toxin treatment. *J Neurol Neurosurg Psychiatry* 2010; 81:54–60
141. Clark H, Lazarus C, Arvedson J, et al: Evidence-based systematic review: Effects of neuromuscular electrical stimulation on swallowing and neural activation. *Am J Speech Lang Pathol* 2009; 18:361–375
142. DePippo KL, Holas MA, Reding MJ: Validation of the 3-oz water swallow test for aspiration following stroke. *Arch Neurol* 1992; 49:1259–1261
143. Leder SB, Suiter DM, Warner HL, et al: Safe initiation of oral diets in hospitalized patients based on passing a 3-ounce (90 cc) water swallow challenge protocol. *QJM* 2012; 105:257–263
144. Herridge MS: Legacy of intensive care unit-acquired weakness. *Crit Care Med* 2009; 37:S457–S461