Increased age is an independent risk factor for radiographic aspiration and laryngeal penetration after thoracotomy for pulmonary resection

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Objectives: Aspiration is an increasingly recognized complication after thoracotomy for pulmonary resection, but mechanisms of postoperative aspiration are poorly characterized. This study sought to evaluate risk factors to better define postthoracotomy aspiration.

Methods: Three hundred twenty-one consecutive patients underwent clinical bedside swallowing evaluations after thoracotomy for pulmonary resection on postoperative day 1. Results of videofluoroscopic swallowing studies were independently reviewed by 2 speech pathologists and were assigned aspiration–penetration scores of either 1 (normal) or greater than 1 (abnormal) based on the worst swallow. Operative, demographic, and outcomes data were abstracted for each patient, and multivariate regression analysis was performed.

Results: Seventy-three (22.7%) patients failed bedside evaluation and proceeded to undergo videofluoroscopic swallowing studies. Forty-four (60.3%) patients had an abnormal videofluoroscopic swallowing study result with a mean aspiration–penetration score of 3.9 ± 0.3 . Multivariate analysis showed that older age (68.8 vs 56.2 years, $P = .002$), prior premature spillage ($P = .0006$), and vallecular residuals after the swallow ($P < .0002$) were all associated with aspiration. Interestingly, certain variables were not independently associated with aspiration, including presence of gastroesophageal reflux disease, operative approach or degree of resection, mediastinal lymphadenectomy, preoperative thoracic radiation, same hospitalization reoperation, and pathology.

Conclusions: Postoperative risk of aspiration after thoracotomy for pulmonary resection is characterized by repeatable episodes of oropharyngeal discoordination on videofluoroscopic swallowing studies. We recommend routine videofluoroscopic swallowing studies for all patients older than 67 years before the initiation of oral intake to diminish the incidence of postoperative aspiration. (J Thorac Cardiovasc Surg 2010;140:573-7)

Complications after thoracotomy for pulmonary resection have been investigated since the inception of thoracic surgery. Aspiration has recently been characterized as a complication after thoracic surgery, with a reported incidence nearing 20%.¹ The exact mechanism and risk factors associated with aspiration, however, remain poorly defined.

In one of the few studies to address the topic of aspiration after thoracic surgery, Herrera and colleagues² demonstrated that head and neck malignancies contribute to postoperative aspiration after pulmonary resection. The purpose of the current study was to expand on prior research to detail risk factors associated with aspiration after thoracotomy for pulmonary resection and to better define the pathophysiology of radiographic aspiration and penetration in these patients. In undertaking this study, we hypothesized that advanced age,

prior head and neck radiation, and mediastinal lymphadenectomy would predispose patients to postoperative aspiration. In addition, we hypothesized that global dysfunction affecting multiple aspects of swallowing mechanics would lead to aspiration after thoracotomy.

MATERIALS AND METHODS

Experimental Design

After approval by the Institutional Review Board at the University of South Florida and the H. Lee Moffitt Cancer Center, a protocol was initiated by which consecutive patients undergoing thoracotomy for pulmonary resection from January 1, 2005, through December 31, 2007, underwent a clinical bedside swallowing investigation by a licensed speech pathologist on postoperative day 1. This protocol was part of a larger quality control measure within the hospital and was considered local standard of care, and therefore no informed consent was obtained. Standard surgical procedure at the H. Lee Moffitt Cancer Center included the use of double-lumen endotracheal tubes, a variety of surgical approaches depending on the anatomic location of the lesion, and thoracic epidural catheters for postoperative pain management. All patients were first evaluated at the bedside by a certified speech pathologist. Bedside evaluations were conducted with the patient in an upright position, and they were instructed to swallow a variety of substances ranging from thin liquids to thickened liquids to a pureed diet to solid food. Clinical signs of dysphagia or aspiration were noted and included throat clearing, coughing after a swallow, a change in oxygen saturations or respiratory rate after per os presentations, or a change of wet vocal quality after the swallow. Failure of the bedside swallowing

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Abbreviations and Acronyms

ASP-PEN	= aspiration-penetration scale
CVA	= cerebrovascular accident
FEESST	= fiberoptic endoscopic evaluation of swallowing with sensory testing
VFSS	= videofluoroscopic swallowing study

investigation led to a videofluoroscopic swallowing study (VFSS). Per the recommendations of the speech pathologist, patients failing VFSSs were maintained on a modified diet or nothing per os as the situation mandated until improvement of swallowing could be documented. Patients with minor swallowing derangements were treated with dietary modification and positional swallowing maneuvers, whereas patients with more severe changes in swallowing patterns were not allowed oral intake and were re-evaluated both clinically and radiographically in 2 to 4 days. Patient demographics, surgical data, and outcomes were all prospectively recorded and stored in a secure database.

Evaluation for Aspiration

All patients failing bedside evaluation underwent further testing with a VFSS. Each VFSS was independently reviewed and scored based on the worst swallow by 2 separate speech pathologists using the aspiration-penetration scale (ASP-PEN) developed by Rosenbek and associates (Table 1).³ Patients were then subsequently grouped according to their ASP-PEN scores: patients with a score of 1 were deemed to have normal swallowing function, whereas patients with a score of greater than 1 were labeled as having abnormal function and at risk for aspiration events. Based on the recommendations of the speech pathologists, each VFSS was scored on 16 anatomic and physiologic abnormalities often seen in dysphagia to try to establish a pattern consistent with postoperative penetration and aspiration in this subset of patients (Table 2).

Data Analysis

All data pertaining to risk factor analysis was submitted to univariate analysis, including all variables listed in Table 2. Univariate analysis was conducted with the Mantel-Haenszel test or Fisher's exact test for categorical variables and the 2-sided Student's *t* test for continuous variables. Backward logistic regression multivariate analysis with a significance level of .1 was summarily used to adjust for possible confounders. Data are presented as medians with means $\pm$ standard deviations, where appropriate.

RESULTS

Three hundred twenty-one consecutive patients underwent a bedside clinical swallowing evaluation, and 73 (22.7%) failed and required VFSSs for further evaluation of swallowing dysfunction. Forty-four (60.3%) patients had an abnormal VFSS result with a median ASP-PEN score of 3.0 (3.9 ± 1.9 ; ASP-PEN score of 2 in 9 patients, ASP-PEN score of 3 in 20 patients, ASP-PEN score of 5 in 9 patients, and ASP-PEN score of 8 in 6 patients). The overall incidence of laryngeal penetration or aspiration (ASP-PEN score >1) was 13.7% (44/321 patients). One patient experienced a witnessed aspiration event after negative bedside evaluation (0.3%).

The perioperative mortality rate was 2.7%, with a single death in each group (ie, ASP-PEN score >1 and ASP-PEN

score of 1). Likewise, 1 patient in each group required reintubation during hospitalization. For patients with ASP-PEN scores of greater than 1, a percutaneous gastrostomy was required in a single patient, and 3 patients required placement of a tracheostomy for severe respiratory failure. There were no tracheostomies or gastrostomies placed in patients with an ASP-PEN score of 1. Length of stay was 6 days (6.6 ± 3.7 days) for patients with an ASP-PEN score of 1 and 7 days (9.3 ± 8.6 days) for patients with an ASP-PEN score of greater than 1 ($P = .08$).

Clinical Risk Factors Associated With Postoperative Penetration and Aspiration

Univariate analysis identified male sex, prior head and neck cancer, and advanced age as significant risk factors associated with postoperative aspiration and penetration (Table 3). When subjected to multivariate analysis, advanced age and certain physiologic swallowing derangements were significantly associated with both events (Table 4).

Dysfunctional Swallowing Mechanics

Univariate analysis identified the following dysfunctional mechanisms in patients experiencing aspiration: penetration of laryngeal vestibule before/during the swallow, residuals in the pyriform sinuses, residuals in the valleculae, decreased laryngeal elevation, reduced tongue base retraction, and premature spillage. When subjected to multivariate analysis, residuals in the valleculae and premature spillage of swallowed contents into the pharynx were demonstrated to be significantly associated with aspiration. These are the radiographic hallmarks of penetration and aspiration in this cohort of patients.

DISCUSSION

Aspiration has long been recognized as a potential complication in certain patient populations, including patients who undergo cerebrovascular events, those who undergo operations on the cervical spine, and those who undergo extensive head and neck surgery.⁴⁻⁶ Nearly 80% of patients with acute cerebrovascular accidents (CVAs) have dysphagia.⁷ In this patient population advanced age in conjunction with aspiration was an independent risk factor for the development of pneumonia.⁸ Age has also been shown to be an independent predictor of aspiration pneumonia during the first 6 months after acute CVA.⁹ The exact mechanism of dysphagia and aspiration after CVA is unclear, but a recent study indicated that decreased laryngeal sensation and decreased pharyngeal transit time of the food bolus might predispose this group of patients to an increased incidence of aspiration.¹⁰

Aspiration has been overlooked, however, as a source of potential morbidity and mortality in the thoracic surgical literature in spite of the fact that patients undergoing thoracic

TABLE 1. Aspiration–Penetration scale

Category	Score	Descriptions
No penetration or aspiration	1	Contrast does not enter the airway
Penetration	2	Contrast enters the airway, remains above vocal folds; no residue
	3	Contrast remains above vocal folds; visible residue remains
	4	Contrast contacts vocal folds; no residue
	5	Contrast contacts vocal folds; visible residue remains
Aspiration	6	Contrast passes glottis; no subglottic residue visible
	7	Contrast passes glottis; visible subglottic residue despite patient’s response
	8	Contrast passes glottis; visible subglottic residue; absent patient response

Used with permission from Rosenbek and associates.³

operations have multiple risk factors for aspiration. Manuscripts detailing outcomes have failed to mention aspiration as a complication. When aspiration has been detailed, the incidence has been dismissively small.¹¹ Recent work by our group details a much higher incidence, thus proving aspiration as a source of potential postoperative morbidity.¹

Our purpose in undertaking this study was to not only try and delineate risk factors contributing to postoperative aspiration but also to further understand the pathophysiology of aspiration in this patient population. Patients in this study represent a consecutive series and were not selected in any fashion. The demographic data of the cohort are consistent with those of published surgical series.

Bedside evaluation first identified those patients in need of further radiographic interrogation. Given our low false-negative rate and documentation in the medical literature that bedside evaluation is an effective tool, we believe this approach is effective in screening for those patients who warrant further testing.¹² Aspiration and penetration of contents into the larynx was assessed by using a VFSS. This is a radiographic test requiring transport of the patient to the radiology department for fluoroscopic assessment of substances enriched with barium and swallowed. With the aid of real-time fluoroscopy, all aspects of the swallow and its physiology can be assessed. Other tools, however, are available for swallowing assessment, including fiberoptic endoscopic evaluation of swallowing and fiberoptic endoscopic evaluation of swallowing with sensory testing (FEESST). Both of these tests are bedside evaluations that use endoscopic methods to assess aspiration physiology and volume of retained foodstuffs. FEESST, however, uses air through a port in the endoscope to simulate a patient’s response to laryngeal residuals. In a randomized trial comparing FEESST

TABLE 2. Physiologic abnormalities on videofluoroscopic swallowing studies

Decreased oral containment
Decreased bolus formation
Decreased bolus transit
Delay in pharyngeal onset of swallow
Reduced tongue base retraction
Decreased epiglottic inversion
Decreased laryngeal elevation
Decreased hyoid excursion
Decreased posterior pharyngeal wall contraction
Decreased upper esophageal sphincter relaxation
Residuals in the valleculae
Residuals in the pyriform sinuses
Esophageal stasis
Penetration of laryngeal vestibule before/during the swallow
Aspiration
Reflexive cough

with VFSSs, there was no difference in aspiration pneumonia between 2 groups of patients evaluated with either one or the other method.¹³ We chose to use VFSSs for this study based on the expertise of the speech pathologists in working with this diagnostic tool.

We chose to measure aspiration using the ASP–PEN scale developed by Rosenbek and associates.³ This is a validated tool used in a variety of patient populations to determine the degree of aspiration and penetration using a scoring system ranging from 1 (no penetration or aspiration) to 8 (silent aspiration). This scoring tool has previously shown both intra-examiner and interexaminer reliability.¹⁴ We chose to divide patient groups based on either a score of 1 or greater than 1. Although other breakpoints have been used (eg, mild/moderate/severe based on ASP–PEN), we thought this inappropriate for our patient population. Because these patients are at increased risk for pulmonary complications caused by recent pulmonary resection and decreased postoperative airway clearance and pulmonary toilet, we believe that any patient who has any penetration of contrast into the airway (ASP–PEN score of 2) is at risk for potential aspiration.

Risk factors associated with a significant risk of penetration or aspiration in our study included increased age, premature spillage of food into the pharynx, and vallecular residuals after the swallow. Although age has long been described as a risk factor for aspiration in other patient populations and for other thoracic complications, it follows that increased age was also a significant risk factor for aspiration after thoracotomy.¹⁴ As patients age, pharyngeal discoordination increases as well, thus leading to premature spillage of food contents into the trachea before epiglottic elevation.¹⁴ This discoordination, which includes premature spillage of food into the pharynx and vallecular residuals after the swallow, leads to increasing aspiration events as patients age.

TABLE 3. Univariate analysis results

	ASP-PEN score = 1 (29 patients)	ASP-PEN score >1 (44 patients)	P value
Male sex	9 (31.0%)	25 (56.8%)	.032
Age (y)	56.2 ± 2.5	68.8 ± 1.2	<.001
Prior neurologic disorder	1 (3.4%)	3 (6.8%)	.54
Prior coronary artery bypass grafting	1 (3.4%)	2 (4.5%)	.82
Peripheral vascular disease	3 (10.3%)	3 (6.8%)	.59
History of hypertension	8 (27.6%)	24 (54.5%)	.02
Gastroesophageal reflux disease	7 (24.1%)	4 (9.1%)	.08
Current proton pump inhibitor use	6 (20.7%)	10 (22.7%)	.84
Current smoking	8 (27.6%)	10 (22.7%)	.64
Neoadjuvant chemotherapy	9 (31.0%)	10 (22.7%)	.38
Diabetes	2 (6.9%)	9 (20.5%)	.17
Prior thoracic radiation	2 (6.9%)	2 (4.5%)	.67
Operative approach	PLT, 14 (50.0%) AT, 11 (39.3%) PT, 2 (7.1%) Sternotomy, 1 (3.6%)	PLT, 21 (48.8%) AT, 19 (44.2%) PT, 3 (7.0%) Sternotomy, 0	.50
Nerve compromise at time of operation	1 (3.4%)	3 (6.8%)	.52
Mediastinal lymphadenectomy	20 (69.0%)	31 (70.5%)	.89
Current or prior head and neck cancer	0	7 (15.9%)	.02
Stage I NSCLC	6 (20.7%)	19 (43.2%)	.06
Postoperative complications	4 (13.8%)	7 (15.9%)	.81
Same hospitalization reoperation	3 (10.3%)	2 (4.5%)	.34
Decreased oral containment	0	0	NS
Decreased bolus formation	0	0	NS
Decreased bolus transit	0	0	NS
Delay in pharyngeal onset of swallow	4 (13.8%)	1 (2.3%)	.06
Reduced tongue base retraction	0	6 (13.6%)	.04
Decreased epiglottic inversion	1 (3.5%)	6 (13.6%)	.15
Decreased laryngeal elevation	3 (10.4%)	21 (47.7%)	.001
Decreased hyoid excursion	0	4 (9.1%)	.10
Decreased posterior pharyngeal wall contraction	1 (3.5%)	2 (4.5%)	.82
Decreased upper esophageal sphincter relaxation	0	0	NS
Residuals in the valleculae	2 (6.9%)	25 (56.8%)	<.001
Residuals in the pyriform sinuses	2 (6.9%)	16 (36.4%)	.005
Esophageal stasis	16 (55.2%)	23 (52.3%)	.81
Penetration of laryngeal vestibule before/during the swallow	0	44 (100%)	<.001

ASP-PEN, Aspiration-penetration scale; PLT, posterolateral thoracotomy; AT, axillary thoracotomy; PT, posterior thoracotomy; NSCLC, non-small cell lung cancer; NS, not significant.

Of almost equal importance to the variables reaching statistical significance were those that did not. We found no procedure-related significance within our results. Notably, aspiration was independent of operative approach, pathology,

stage, and same-hospitalization reoperation. Also, the addition of mediastinal lymphadenectomy to pulmonary resection yielded no increased incidence of aspiration. Albeit there was a small total sample size (4 total; 1 patient with an ASP-PEN score of 1 and 3 patients with ASP-PEN scores >1), recurrent laryngeal nerve compromise at the time of surgical intervention also was statistically independent in univariate and multivariate analysis. What is absent in this dataset, however, are the sizes of the double-lumen tubes routinely used for endotracheal intubation and single-lung ventilation. Given the data present, there are no procedural factors that affect the risk of postoperative aspiration.

There were also notable exceptions to preoperative variables reaching statistical significance for aspiration.

TABLE 4. Multivariate logistic regression analysis

	Odds ratio	95% Confidence interval	P value
Age	1.2	1.1–1.4	.002
Penetration of laryngeal vestibule before/during the swallow	55.6	5.6–553.4	.0006
Residuals in valleculae	186.8	12.5–undefined	.0002

Gastroesophageal reflux disease has been associated with aspiration in certain populations, including patients with lung disease, but gastroesophageal reflux disease did not reach statistical significance in our study. Neither prior thoracic radiation, neoadjuvant chemotherapy, nor diabetes proved to be statistically significant. Male sex and hypertension were significant in univariate analysis but dropped out of multivariate analysis. We included both sex and hypertension in our data collection because both are known risk factors for CVA, and by capturing these variables, we theorized that we might capture patients who could have multiple small infarcts without a clinically significant stroke.

Although this study does much to further the collective understanding of a newly recognized complication, it does have limitations. Ultimately, the patient population analyzed was small, and certain procedures, including pneumonectomy, were few in this dataset. We believe that certain variables might gain significance given greater statistical power. Additionally, this is a single-institution study with a single surgeon and 2 speech pathologists, and this study is subject to bias based on those facts. Certain information that might have affects on postoperative aspiration was not present in this dataset, including endotracheal tube size, difficulty of intubation, and medication regimen administered through the thoracic epidural. This study was designed to solely focus on the anatomic and physiologic derangements of the oropharynx. Therefore any aspiration event originating distal to the upper thoracic esophagus would be missed with the current method of examination. It was not the design of this study to detail an effect on patient outcome, and therefore this information is limited. Patients undergoing thoracotomy for pulmonary resection were not included in this study, which reveals another potential pitfall of this study and limits its external validity.

Based on this research, our current protocol calls for every patient undergoing thoracotomy for pulmonary resection to receive a bedside clinical evaluation on postoperative day 1. Those patients who are older than 67 years, have current or prior head and neck cancer, and fail bedside examination are then referred for VFSS. In spite of the fact that multivariate analysis failed to demonstrate head and neck malignancies as a significant variable predicting penetration and aspiration, the work of Herrera and colleagues² and our own observations compel us to further research in this area. Our current protocol, however, mandates that all patients with head and neck cancer are referred for a preoperative VFSS to establish a baseline examination of swallowing. Based on the results of the postoperative study, patients then undergo dietary modification or advancement based on the recommendation

of the speech pathologist. For patients with severe aspiration without amelioration on repeat VFSSs, they undergo either placement of a small-bore nasogastric tube or percutaneous gastrostomy based on discussion between the speech pathologist, surgeon, and patient.

This study serves to further our understanding of the process of postoperative aspiration after thoracotomy for pulmonary resection. Based on the high incidence of postoperative aspiration events in this patient population, we continue to advocate for routine postoperative screening, as outlined above. The results of the current study have served to further define the pathophysiology of aspiration after thoracotomy for pulmonary resection. Additionally, patients older than 67 years are at particular risk, and routine postoperative swallowing studies are of benefit in this age group.

References

1. Keeling WB, Lewis V, Blazick E, Maxey TS, Garrett JR, Sommers KE. Routine evaluation for aspiration after thoracotomy for pulmonary resection. *Ann Thorac Surg.* 2007;83:193-6.
2. Herrera LJ, Correa AM, Vaporciyan AA, Hofstetter WL, Rice DC, Swisher SG, et al. Increased risk of aspiration and pulmonary complications after lung resection in head and neck cancer patients. *Ann Thorac Surg.* 2006;82:1982-8.
3. Rosenbek JC, Robbins JA, Roecker EB, Coyle JL, Wood JL. A penetration-aspiration scale. *Dysphagia.* 1996;11:93-8.
4. Horner J, Massey EW, Riski JE, Lathrop DL, Chase KN. Aspiration following stroke: clinical correlates and outcome. *Neurology.* 1988;38:1359-62.
5. Smith-Hammond CA, New KC, Pietrobon R, Curtis DJ, Scharver CH, Turner DA. Prospective analysis of incidence and risk factors of dysphagia in spine surgery patients: comparison of anterior cervical, posterior cervical, and lumbar procedures. *Spine.* 2004;29:1441-6.
6. Hirano M, Kuroiwa Y, Tanaka S, Matsuoka H, Sato K, Yoshida T. Dysphagia following various degrees of surgical resection for oral cancer. *Ann Otol Rhinol Laryngol.* 1992;101:138-41.
7. Martino R, Foley N, Bhogal S, Diamant N, Speechley M, Teasell R. Dysphagia after stroke: incidence, diagnosis, and pulmonary complications. *Stroke.* 2005;36:2756-63.
8. Walter U, Knoblich R, Steinhagen V, Donat M, Benecke R, Kloth A. Predictors of pneumonia in acute stroke patients admitted to a neurological intensive care unit. *J Neurol.* 2007;254:1323-9.
9. Mann G, Hankey GJ, Cameron D. Swallowing function after stroke: prognosis and prognostic factors at 6 months. *Stroke.* 1999;30:744-8.
10. Power ML, Hamdy S, Singh S, Tyrrell PJ, Turnbull I, Thompson DG. Deglutitive laryngeal closure in stroke patients. *J Neurol Neurosurg Psychiatry.* 2007;78:141-6.
11. Sugarbaker DJ, Jaklitsch MT, Bueno R, Richards W, Lukanich J, Mentzer SJ, et al. Prevention, early detection, and management of complications after 328 consecutive extrapleural pneumonectomies. *J Thorac Cardiovasc Surg.* 2004;128:138-46.
12. Smith-Hammond CA, Goldstein LB, Horner RD, Ying J, Gray L, Gonzalez-Rothi L, et al. Predicting aspiration in patients with ischemic stroke: comparison of clinical signs and aerodynamic measures of voluntary cough. *Chest.* 2009;135:769-77.
13. Aviv JE. Prospective, randomized outcome study of endoscopy versus modified barium swallow in patients with dysphagia. *Laryngoscope.* 2000;110:563-74.
14. Colodny N. Interjudge and intrajudge reliabilities in fiberoptic endoscopic evaluation of swallowing (FEES) using the penetration-aspiration scale: a replication study. *Dysphagia.* 2002;17:308-15.