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ORIGINAL ARTICLE

Correlates of Early Pharyngeal High-Resolution Manometry Adoption in Expert Speech-Language Pathologists

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Abstract

Pharyngeal high-resolution manometry (HRM) is at a point of entry into speech-language pathologist (SLP) clinical practice. However, the demographic characteristics of SLPs who are early adopters of HRM are unclear; perspectives of early adopters may shape how the technology is received by the field at large. We hypothesized that younger SLPs, those working in outpatient settings, those with a strong knowledge base in HRM, and those with experience in other types of instrumentation are more likely to have interest in adopting HRM. We surveyed the population of board-certified SLPs (BCS-S; n = 262) with a 33% response rate (n = 78). Firth logistic regression was used to determine differences in those expressing interest in adopting HRM into future practice (n = 28) and those who did not (n = 45) from the analytic sample of 73 respondents. The best fitting model predicted that SLPs: (1) with training in more types of instrumentation; and (2) believing they could explain the HRM procedure to a patient were more likely to plan to adopt pharyngeal HRM into regular clinical practice. Experience with a variety of instrumentation techniques may encourage SLPs to use new forms of technology. Knowledge of early adopter demographics will allow for development of targeted trainings and determination of HRM implementation barriers. Identification of a clinician sub-group more likely to adopt other new technologies in the future may also be possible.

Keywords Speech-language pathologist · Deglutition · High-resolution manometry · Instrumentation · Technology

Introduction

High-resolution manometry (HRM) is a technique that objectively measures pressures in the pharynx and esophagus during swallowing with a pressure-sensing catheter placed through the nasopharynx and oropharynx, into the esophagus. This procedure is most commonly used to evaluate pressures in the esophagus [1]. However, in the past decade, researchers and clinicians have used this technology to specifically evaluate pharyngeal swallowing pressures. These pressure data can describe changes to swallowing with age [2, 3], bolus characteristics [4–7], and compensatory maneuvers [8–13] in healthy individuals. Swallowing pressures can also identify dysphagia phenotypes [14–18] and predict risk for negative sequelae of

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dysphagia, such as residue or penetration/aspiration [14, 19, 20]. Such technology has the potential to improve diagnostic accuracy, guide more specific treatments, and result in better patient outcomes.

While only a handful of centers worldwide regularly use pharyngeal HRM for clinical purposes, speech-language pathologists (SLP) are typically involved in these clinics due to their expertise in evaluating swallowing function and managing dysphagia [21]. Historically, SLPs have adapted tools from other medical fields for diagnosis and treatment of dysphagia, for example flexible nasendoscopy [22]. Pharyngeal HRM is in the scope of practice for SLPs in the United States [23], and the technology is at a point of entry into SLP clinical practice, as commercially available esophageal HRM systems are easily adapted to evaluate pressures in the pharynx. However, the characteristics of those SLPs who have chosen to adopt pharyngeal HRM into their regular practice versus those who do not remain unclear. SLPs who adopt innovative technologies may shape how the technologies are both regarded and used by the larger field of clinicians, and an understanding of these SLPs' characteristics may help guide targeted trainings, technology needs assessments, and general trend-tracking.

The purpose of the present study was to determine characteristics of expert SLPs interested in adopting pharyngeal HRM into their routine clinical practice. We hypothesized that younger clinicians, those working in outpatient settings, those with a strong knowledge base in HRM, and those with experience in a variety of instrumental evaluation techniques, would be more likely to show an interest in adopting pharyngeal HRM.

Materials and Methods

Population

A link to the online survey was distributed to the population of SLPs with Board Certified Specialist-Swallowing (BCS-S) distinction (n = 262 as of September 2015), via the messaging service in the member center of American Speech-Language-Hearing Society (ASHA) website. A survey reminder was sent out to each SLP within 2 weeks of the original notice.

Survey

The survey consisted of 24 yes/no, true/false, single and multiple-answer multiple choice, and demographic items, and was hosted through University of Wisconsin-Madison's Qualtrics license (Qualtrics®, Provo, UT). Survey items probed demographic information, experiences with pharyngeal HRM, and attitudes towards pharyngeal HRM. The authors created survey items specifically focused around themes of knowledge, access, interest, and use. The final two items were questions regarding the respondents' planned attendance at the 2015 ASHA Convention and the 2016 Dysphagia Research Society Meeting, for which a positive response lead to an invitation to participate in a focus group at one of both of those events. The survey was pre-tested on a group of four SLPs and three non-SLP sample respondents and timed at 4 min. The full survey transcript is included as an electronic supplement. The survey was approved by the Health Sciences Institutional Review Board at University of Wisconsin-Madison and informed consent was provided by each respondent.

Analysis

Respondents were separated into *adopters* and *non-adopters* based on response to the survey item "I plan to implement pharyngeal high-resolution manometry into my regular clinical practice" (Adopters: Strongly Agree + Agree; Non-adopters: Disagree + Strongly Disagree). Survey items were selected a priori for statistical analysis to examine differences in demographics, exposure to pharyngeal HRM and other instrumented techniques, and beliefs about knowledge of, confidence in knowledge of, reimbursement for, and benefits of pharyngeal HRM (Table 1).

Firth logistic regression [24] was used to determine which predictor variables (Table 1) or combination thereof most saliently differentiated *adopters* from *non-adopters*. Firth logistic regression was chosen given the relatively limited sample size (n = 73) compared to the large number of potential predictor variables (Table 1) [25]. Omnibus p value of 0.05 was considered to be significant. Forward model selection was performed using the Akaike Information Criterion (AIC); a low AIC signifies a better fit with fewer parameters in the model. Other criteria for model selection were that all predictor variables were significant via Type I Analysis of Variance (ANOVA) and that no multicollinearity of predictor variables was present, assessed with Spearman's rank-order correlation. All statistical analysis was completed in R (R Foundation, Austria).

Results

A total of 78 of the 262 SLPs completed the survey (78/262 = 33%); 73 responded to the survey item "I plan to implement pharyngeal high-resolution manometry into my regular clinical practice" (73/262 = 28%) and were included in our analytic sample. Demographic information of the respondents is in Table 2.

Table 1 Survey items included in the regression analysis

Grouping item
I plan to implement pharyngeal high-resolution manometry into my regular clinical practice
Predictor items
Years of practice with dysphagia, not including fellowship year(s)
Clinical setting (Hospital or university vs. not hospital or university)
Instruments trained on
Videofluoroscopy[a]
Nasal endoscopy/FEES
Oral/Rigid endoscopy
Pharyngeal or esophageal manometry
Insufflation
Tracheoesophageal voice prosthesis placement
Speaking valve placement with tracheostomies or ventilators
Nasometry
Ultrasonography
Scintigraphy[b]
Electromyography
Total: sum of number of above instruments trained on
Education in pharyngeal HRM
Seen a presentation/webinar AND read an article using HRM
Seen a presentation/webinar OR read an article using HRM
Neither seen a presentation/webinar NOR read an article using HRM
Knowledge of HRM: *I do NOT consider myself knowledgeable about pharyngeal HRM*
Confidence in knowledge: *I could explain the procedure and information extracted from pharyngeal HRM to a patient of mine*
Reimbursement: *I would have difficulty getting reimbursed for a pharyngeal HRM study*
Benefits: *The benefits of pharyngeal HRM outweigh the costs*

Items in italics were answered with a 4-point Likert-type scale (Strongly Disagree; Disagree; Agree; Strongly Agree). The full survey transcript is included as an electronic supplement

FEES fiberoptic endoscopic evaluation of swallowing, *HRM* high-resolution manometry

[a]Videofluoroscopy was not included in statistical analysis due to > 98% positive responses

[b]Scintigraphy was not included in statistical analysis due to zero positive responses

Twenty-eight respondents (28/73 = 38.4%) indicated they were interested in adopting pharyngeal HRM into their regular clinical practice, whereas 45 respondents (45/73 = 61.6%) indicated that they were not interested. The model that most saliently differentiated *adopters* from *non-adopters* included (1) the total number of instruments the SLP trained on; plus (2) their response to the survey item "I could explain the procedure and information extracted from pharyngeal high-resolution manometry to a patient of mine" (Likelihood Ratio: 20.32; $p < 0.001$; AIC: − 16.32). Models with each single predictor variable are in Table 3. Single-predictor models that were also significant included: (1) the total number of instruments the SLP trained on; (2) confidence in explaining the procedure to a patient; (3) education in pharyngeal HRM; (4) belief that the benefits of HRM outweigh the costs; (5) feeling knowledgeable about pharyngeal HRM; and (6) training in FEES, manometry, insufflation, TEP, or nasometry. Other models that significantly differentiated *adopters* from *non-adopters* are listed provided as an electronic supplement. The distribution of responses to all survey items between *adopters* and *non-adopters* is in Fig. 1.

Discussion

The majority of expert SLPs surveyed (61.6%) do not plan to adopt pharyngeal HRM into their regular clinical practice. Of those who do plan to adopt pharyngeal HRM, 75% felt confident in his or her own ability to explain the pharyngeal HRM procedure to a patient (compared to 45% of non-adopters), and these individuals were trained on almost 2 more instrumentation modalities.

Experience with instrumentation may encourage SLPs to employ other new forms of instrumentation in their practice. Prior experience with most of the other invasive

Table 2 Respondents' demographic information. Information presented is from entire sample of respondents, including those that did not respond to the survey item which classified them as *adopters* or *non-adopters*

Total (*n*)	78
Years of practice	18.49 ± 10.32
Average number of patients seen per week	23.94 ± 12.66
Average hours per week seeing patients	24.76 ± 11.22
Practice setting[a] (*n*)	
University or research hospital	42
Community hospital	25
VA hospital	7
All other hospitals	5
Outpatient rehabilitation center	10
Skilled nursing facility	4
Assisted living	3
Home health agency/patient's home	3
Private practice	10
College/University	13
Research/scientific organization, foundation, lab	4
Other	10
Care level[a] (*n*)	
Outpatient	53
Acute	59
Long-term acute	11
Inpatient rehabilitation	29
Subacute/transitional care	13
Hospice/palliative care	13
Research participants	24
Other	1
Dysphagia caseload (*n*)	
0–24%	3
25–49%	8
50–74%	22
75–100%	45
Instrumentation training[a] (*n*)	
Videofluoroscopy/MBSS	77
Nasal endoscopy/FEES	70
Oral/rigid endoscopy	35
Pharyngeal or esophageal manometry	15
Insufflation	24
Tracheoesophageal voice prosthesis placement	42
Speaking valve placement with tracheostomies or ventilators	73
Nasometry	9
Ultrasonography	3
Electromyography (EMG)	23

Continuous data are presented as mean ± standard deviation

[a]Categories are not mutually exclusive

instrumental modalities was associated with plans to adopt pharyngeal HRM, such as FEES, insufflation, and TEP. Additionally, having been trained in nasometry, a non-invasive technique, was independently associated with plans to adopt pharyngeal HRM. It may be that institutions with more instrumental resources may attract clinicians with a greater interest in and comfort level with adopting new technologies.

Confidence in explaining the procedure of pharyngeal HRM to a patient may be related to interest in adoption of

Table 3 Models of each individual predictor variable and the model that most saliently differentiated speech-language pathologists who indicated plans to adopt pharyngeal high-resolution manometry into their regular clinical practice from those who did not

Variables included in model	Fit		
	Likelihood ratio	*p* value	AIC
Best model: instrument[a] + confidence[b]	20.32	< 0.001	− 16.32
Years of practice	0.26	0.61	1.74
Practice setting	1.32	0.26	0.67
Instrument[a]	14.75	< 0.001	− 12.75
Confidence[b]	13.97	< 0.001	− 11.97
Education[c]	6.86	0.009	− 4.90
Benefits[d]	4.19	0.04	− 2.19
Knowledgeable[e]	12.00	< 0.001	− 10.00
Reimbursement[f]	3.3	0.067	− 1.36
FEES	5.95	0.014	− 3.96
Oral endoscopy	3.73	0.053	− 1.73
Manometry	15.46	< 0.001	− 13.46
Insufflation	8.23	0.004	− 6.23
TEP	10.76	0.001	− 8.76
Speaking valve	0.18	0.68	1.82
Nasometry	4.75	0.029	− 2.75
Ultrasonography	0.002	0.96	2.00
EMG	1.06	0.30	0.94

AIC, Akaike Information Criterion, *HRM* high-resolution manometry, *FEES* fiberoptic endoscopy evaluation of swallowing, *TEP* tracheoesophageal prosthesis, *EMG* electromyography

[a]Total number of instruments trained on

[b]Response to "I could explain the procedure and information extracted from pharyngeal HRM to a patient of mine"

[c]Education in pharyngeal HRM (presentation/webinar, article, both, or none)

[d]Response to "The benefits of pharyngeal HRM outweigh the costs"

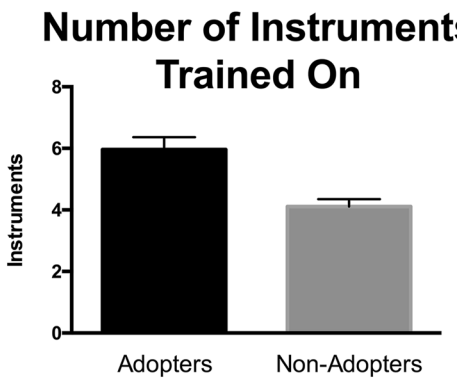
[e]Response to "I do NOT consider myself knowledgeable about pharyngeal HRM"

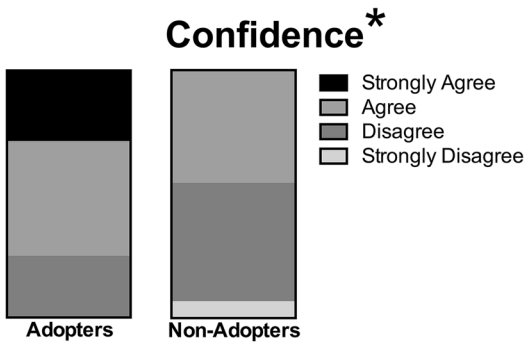
[f]Response to "I would have difficulty getting reimbursed for a pharyngeal HRM study"

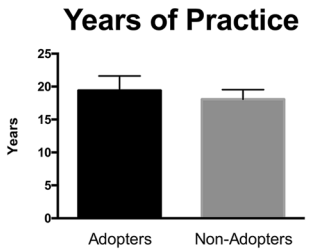
the technology in a few ways. It may reflect knowledge of the technology and its potential benefits to patient care, as well as experience in other similar instrument modalities [26]. On the other hand, lack of confidence in explaining the procedure may be a barrier to adoption of this technology. Fortunately, confidence can be addressed with increased education, exposure, and training [27].

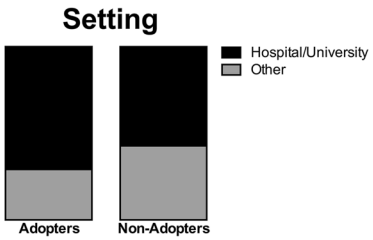
Other SLP beliefs and traits were predictive of intention to adopt pharyngeal HRM, although they were not the most significant predictors. A clinician with less exposure to pharyngeal HRM through research articles and presentations may be less aware of its potential benefits and thus may be less likely to adopt the technology. Given that this education component, along with the feeling of being knowledgeable about HRM and believing that the benefits outweigh the costs, are significant predictors of plans for adoption, increased awareness of the technology may lead to increased adoption in the future.

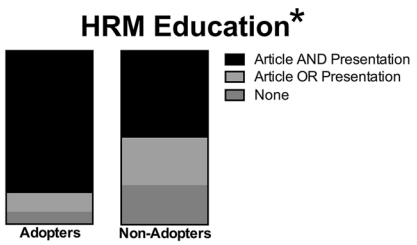
Some predictors that we hypothesized would influence adoption of pharyngeal HRM were not statistically related. Years of practice were similar in both groups of expert SLPs. We had hypothesized that younger SLPs (with fewer years of practice) were more likely to adopt this new technology than older SLPs. However, in order to obtain the BCS-S distinction, one must have practiced for a minimum of 3 years post-ASHA certification, performed work that has a clinical focus in dysphagia, received dysphagia-specific continuing education, and passed a rigorous written examination. This devotion to dysphagia clinical care likely outweighs any hesitations to new technologies that come with age [28, 29]. Additionally, we had predicted that clinicians practicing in an outpatient setting would be more inclined to adopt pharyngeal HRM. While more *adopters* practiced in an outpatient setting compared to other settings (Fig. 1), the distribution was not significantly different from *non-adopters*. Thus, working in an outpatient setting does not drive interest in adopting pharyngeal HRM. Finally, we hypothesized that beliefs of reimbursement and would differ between *adopters* and *non-adopters*. While this survey item was not an independent predictor of

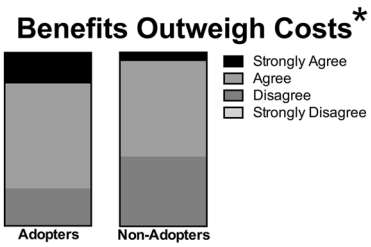

Number of Instruments Trained On *
Instruments
8
6
4
2
0
Adopters
Non-Adopters

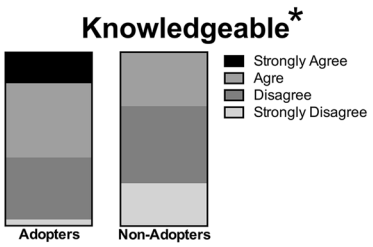

Confidence*
Strongly Agree
Agree
Disagree
Strongly Disagree
Adopters
Non-Adopters

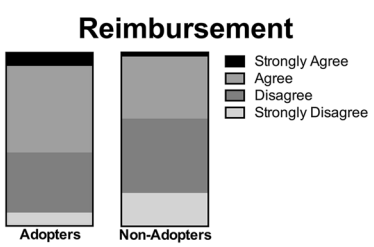

Years of Practice
Years
25
20
15
10
5
0
Adopters
Non-Adopters

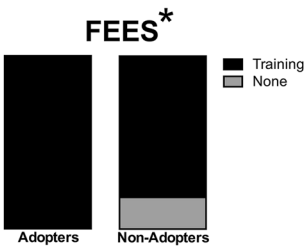

Setting
Hospital/University
Other
Adopters
Non-Adopters

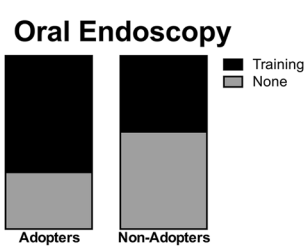

HRM Education*
Article AND Presentation
Article OR Presentation
None
Adopters
Non-Adopters

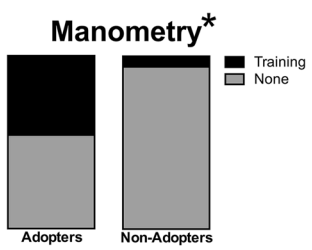

Benefits Outweigh Costs*
Strongly Agree
Agree
Disagree
Strongly Disagree
Adopters
Non-Adopters

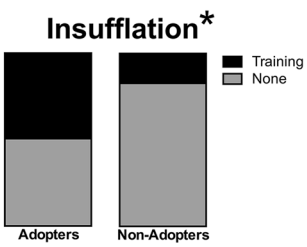

Knowledgeable*
Strongly Agree
Agre
Disagree
Strongly Disagree
Adopters
Non-Adopters

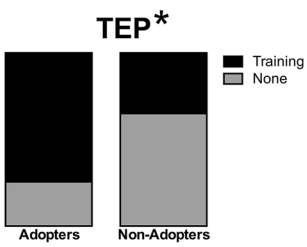

Reimbursement
Strongly Agree
Agree
Disagree
Strongly Disagree
Adopters
Non-Adopters

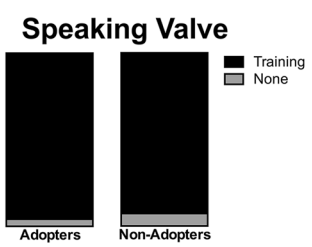

FEES*
Training
None
Adopters
Non-Adopters

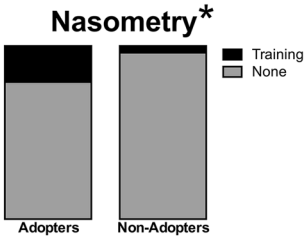

Oral Endoscopy
Training
None
Adopters
Non-Adopters

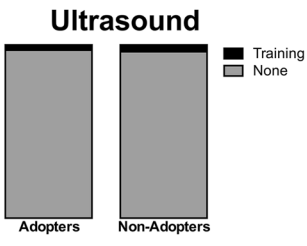

Manometry*
Training
None
Adopters
Non-Adopters

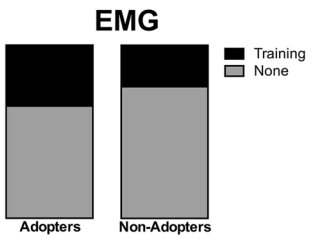

Insufflation*
Training
None
Adopters
Non-Adopters


TEP*
Training
None
Adopters
Non-Adopters


Speaking Valve
Training
None
Adopters
Non-Adopters


Nasometry*
Training
None
Adopters
Non-Adopters


Ultrasound
Training
None
Adopters
Non-Adopters


EMG
Training
None
Adopters
Non-Adopters

◀**Fig. 1** Distribution of survey answers from *adopters* and *non-adopters*. Height of bars indicate 100% of respondents in each group (except for number of instruments trained on and years of practice). Asterisk indicates significant firth logistic regression model with single predictor variable. *Knowledgeable* response valence was changed to match the other responses

plans to adopt pharyngeal HRM, the belief that the costs of pharyngeal HRM are outweighed by the benefits approached significance (Table 3). It may be that SLPs who are at institutions that can bear the cost of the device are more likely to adopt it into clinical practice. While not directly addressed in the present study, the relationships between healthcare system and institutional factors on opinions regarding new technologies can be examined in a larger population of international SLPs.

Practices of adopting new technologies have been explored in other areas of healthcare [30–33]. Behavioral intention to adopt a new form of technology has been described by the Unified Theory of Acceptance and Use of Technology (UTAUT). This model consists of four core factors that determine intention to adopt a new technology: (1) Performance Expectancy, belief that use of the technology will improve job performance; (2) Effort Expectancy, the degree of ease using the system; (3) Social Influence, how the individual perceives that experts in the field believe the new technology should be used; and 4) Facilitating Conditions, the degree to which the environment will support the use of the new technology [34]. The UTAUT also addresses four mediators of the core factors: (1) gender; (2) age; (3) experience; and 4) voluntariness of use. Data from the present study somewhat support the UTAUT framework. Belief that the benefits outweigh the costs (performance expectancy), confidence in knowledge of the technique (effort expectancy), education in HRM (experience), and training in other types of instrumentation (experience). However, more important will be consideration of this model as implementation of new technologies spreads to the general SLP population, outside of experts with the BCS-S distinction.

There are some limitations associated with this project. While expert SLPs are thought-leaders in the field, their experience and proficiency may be different from the entire population of SLPs who evaluate and treat dysphagia. However, we chose to focus on this population, as they are likely to be among the first practitioners to adopt new practices. SLPs are not the only profession who will implement pharyngeal HRM for dysphagia management. Future work should focus on how different disciplines decide on use of HRM. While it may appear that this study had a relatively low response rate (33%), this is a standard response rate for a web-based survey with a brief window [35]. A secondary goal of this survey was to recruit for a series of focus groups at an upcoming academic conference, and a relatively quick turnaround time was required. More time to acquire responses and more opportunities to send out reminders may have yielded a higher response rate. Finally, this survey aimed to address experiences with and attitudes towards use of pharyngeal HRM without addressing opinions on the current state of data acquisition and analysis in the field. As these issues get resolved with additional research and clinical work, expert clinicians may adjust plans to adopt such technology.

Results from this survey highlight traits of expert SLPs with interest in adopting a new technique of dysphagia evaluation. Although the *adopters* in the present study did not have more years of practice than *non-adopters*, increases in training on other technologies and confidence in their ability to explain such technology were key in planning to use pharyngeal HRM in their regular clinical practice. Knowledge of early-adopter demographics among expert clinicians can allow for development of targeted trainings and determination of barriers to adoption of pharyngeal HRM and other new technologies. While the questions in the present survey were focused on adopting pharyngeal HRM, the results may inform on a clinician sub-group that are more likely to adopt other new technologies in the future.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval The procedures done in this study were in accordance with ethical standards according to the 1964 Helsinki declaration and the local Institutional Review Board. All participants provided informed consent.

References

1. Kahrilas PJ, Bredenoord AJ, Fox M, Gyawali CP, Roman S, Smout AJ, Pandolfino JE. The Chicago classification of esophageal motility disorders, v3.0. Neurogastroenterol Motil. 2015;27:160–74.

2. Nativ-Zeltzer N, Logemann JA, Zecker SG, Kahrilas PJ. Pressure topography metrics for high-resolution pharyngeal-esophageal manofluorography-a normative study of younger and older adults. Neurogastroenterol Motil. 2016;28:721–31.
3. McCulloch TM. Normative data and clinical value of pharyngeal high-resolution manometry: a technology and procedure development thesis. 2015.
4. Hoffman MR, Ciucci MR, Mielens JD, Jiang JJ, McCulloch TM. Pharyngeal swallow adaptations to bolus volume measured with high resolution manometry. Laryngoscope. 2010;120:2367–73.
5. Lin T, Xu G, Dou Z, Lan Y, Yu F, Jiang L. Effect of bolus volume on pharyngeal swallowing assessed by high-resolution manometry. Physiol Behav. 2014;128:46–51.
6. Jungheim M, Kallusky J, Ptok M. Effect of bolus volume on pharyngeal swallowing dynamics evaluated with small high-resolution manometry catheters. Laryngorhinootologie. 2017;96:112–7.
7. Cock C, Jones CA, Hammer MJ, Omari TI, McCulloch TM. Modulation of upper esophageal sphincter (UES) relaxation and opening during volume swallowing. Dysphagia. 2017;32:216–24.
8. Babaei A, Lin EC, Szabo A, Massey BT. Determinants of pressure drift in Manoscan() esophageal high-resolution manometry system. Neurogastroenterol Motil. 2015;27:277–84.
9. Hammer MJ, Jones CA, Mielens JD, Kim CH, McCulloch TM. Evaluating the tongue-hold maneuver using high-resolution manometry and electromyography. Dysphagia. 2014;29(5):564–70.
10. Hoffman MR, Mielens JD, Ciucci MR, Jones CA, Jiang JJ, McCulloch TM. High-resolution manometry of pharyngeal swallow pressure events associated with effortful swallow and the Mendelsohn maneuver. Dysphagia. 2012;27:418–26.
11. McCulloch TM, Hoffman MR, Ciucci MR. High-resolution manometry of pharyngeal swallow pressure events associated with head turn and chin tuck. Ann Otol Rhinol Laryngol. 2010;119:369–76.
12. O'Rourke A, Morgan LB, Coss-Adame E, Morrison M, Weinberger P, Postma G. The effect of voluntary pharyngeal swallowing maneuvers on esophageal swallowing physiology. Dysphagia. 2014;29:262–8.
13. Takasaki K, Umeki H, Kumagami H, Takahashi H. Influence of head rotation on upper esophageal sphincter pressure evaluated by high-resolution manometry system. Otolaryngol Head Neck Surg. 2010;142:214–7.
14. Hoffman MR, Mielens JD, Omari TI, Rommel N, Jiang JJ, McCulloch TM. Artificial neural network classification of pharyngeal high-resolution manometry with impedance data. Laryngoscope. 2013;123:713–20.
15. Hoffman MR, Jones CA, Geng Z, Abelhalim SM, Walczak CC, Mitchell AR, Jiang JJ, McCulloch TM. Classification of high-resolution manometry data according to videofluoroscopic parameters using pattern recognition. Otolaryngol Head Neck Surg. 2013;149:126–33.
16. Jones CA, Ciucci MR. Multimodal swallowing evaluation with high-resolution manometry reveals subtle swallowing changes in early and mid-stage parkinson disease. J Parkinsons Dis. 2016;6:197–208.
17. Lippert D, Hoffman MR, Britt CJ, Jones CA, Hernandez J, Ciucci MR, McCulloch TM. Preliminary evaluation of functional swallow after total laryngectomy using high-resolution manometry. Ann Otol Rhinol Laryngol. 2016;125:541–9.
18. Rommel N, Omari TI, Selleslagh M, Kritas S, Cock C, Rosan R, Rodriguez L, Nurko S. High-resolution manometry combined with impedance measurements discriminates the cause of dysphagia in children. Eur J Pediatr. 2015;174:1629–37.
19. Omari TI, Dejaeger E, Van Beckevoort D, Goeleven A, De Cock P, Hoffman I, Smet MH, Davidson GP, Tack J, Rommel N. A novel method for the nonradiological assessment of ineffective swallowing. Am J Gastroenterol. 2011;106:1796–802.
20. Omari TI, Dejaeger E, Tack J, Vanbeckevoort D, Rommel N. An impedance-manometry based method for non-radiological detection of pharyngeal postswallow residue. Neurogastroenterol Motil. 2012;24:e277–84.
21. Knigge MA, Thibeault S, McCulloch TM. Implementation of high-resolution manometry in the clinical practice of speech language pathology. Dysphagia. 2014;29:2–16.
22. Langmore SE, Schatz K, Olson N. Endoscopic and videofluoroscopic evaluations of swallowing and aspiration. Ann Otol Rhinol Laryngol. 1991;100:678–81.
23. (ASHA) AS-L-HA: emerging areas of clinical practice report. ASHA, 2008.
24. Siino M, Fasola S, Muggeo VM. Inferential tools in penalized logistic regression for small and sparse data: a comparative study. Stat Methods Med Res. 2018;27(5):1365–75.
25. Agresti A. An introduction to categorical data analysis. 2nd ed. Hoboken, NJ: Wiley; 2007.
26. Lam MK, Nguyen M, Lowe R, Nagarajan SV, Lincoln M. "I can do it": does confidence and perceived ability in learning new ICT skills predict pre-service health professionals' attitude towards engaging in e-healthcare? Stud Health Technol Inform. 2014;204:60–6.
27. Adhikari S, Schmier C, Marx J. Focused simulation training: emergency department nurses' confidence and comfort level in performing ultrasound-guided vascular access. J Vasular Access. 2015;16:515–20.
28. Olson KE, O'Brien MA, Rogers WA, Charness N. Diffusion of technology: frequency of use for younger and older adults. Ageing Int. 2011;36:123–45.
29. Czaja SJ, Charness N, Fisk AD, Hertzog C, Nair SN, Rogers WA, Sharit J. Factors predicting the use of technology: findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). Psychol Aging. 2006;21:333–52.
30. Hsieh HL, Kuo YM, Wang SR, Chuang BK, Tsai CH. A study of personal health record user's behavioral model based on the PMT and UTAUT integrative perspective. Int J Environ Res Public Health. 2016;14(1):8.
31. Abdekhoda M, Salih KM. Determinant factors in applying Picture Archiving and Communication Systems (PACS) in healthcare. Perspect Health Inf Manag. 2017;14:1c.
32. Wildenbos GA, Peute L, Jaspers M. Facilitators and barriers of electronic health record patient portal adoption by older adults: a literature study. Stud Health Technol Inform. 2017;235:308–12.
33. Germonpre S, Gemmel P, Beeckman D, Trybou J. Determinants of using (non-)fluoroscopy-guided positioning for radiographs: a case study research. J Radiol Protect. 2016;36:667–79.
34. Venkatesh V, Morris MG, Davis GB, Davis FD. User acceptance of information technology: toward a unified view. MIS Q. 2003;27:425–78.
35. Dillman D, Smyth J, Christian L. Internet, phone, mail and mixed-mode surveys: the tailored design method. 4th ed. Hoboken, NJ: Wiley; 2014.

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