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## Original Article

# Effects of Age on the Speed of Hyoid Bone Movement during Swallowing

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## SUMMARY

**Background:** dysphagia has become a pivotal issue due to the increased number of elderly people, and the potential for increased risk of pneumonia from dysphagia with frequent aspiration. Timely and adequate hyoid bone movement is an essential component of the swallowing movement. However, the effects of age on hyoid speed have not been investigated thoroughly. In this study, we aimed to investigate the effects of age on hyoid speed with ultrasonography.

**Methods:** 97 healthy participants were allocated to 3 different age groups (20–39, 40–64, and above 65 years old). An ultrasonography machine with a water balloon fixed to the transducer, which provided better contact, was used. Each participant swallowed 10 mL of juices of 3 different consistencies (mildly thick, moderately thick, and extremely thick juice) while sitting upright. The transducer was placed in the midsagittal plane of the submental area. The speed of hyoid movement was calculated as the maximal hyoid bone displacement divided by start-to-max duration.

**Results:** The speed of hyoid movement during swallowing decreased as the age increased. However, the post-hoc analysis only showed a significant difference between the 20-39 and above 65 age groups when the participants swallowed moderately thick juice.

**Conclusion:** This study illuminates the use of ultrasound in providing quantitative measures of hyoid speed during swallowing. The result adds to the current understanding of swallowing dynamics and the adaptive physiological mechanisms that take place when the age increases. We will analyze the hyoid speed in patients of various dysphagic pathologies.

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## 1. Introduction

Timely and adequate hyoid bone movement is an essential component of the swallowing movement under normal physiologic conditions.<sup>1</sup> The hyoid bone is a suspended bone that connects to the thyroid cartilage and mandible bone through ligaments and muscles (e.g., mylohyoid, geniohyoid, digastrics, hyoglossus).<sup>2</sup> The anterior and superior excursion of the hyoid bone due to the contraction of the attached skeletal muscles is important for effective bolus flow and pharyngeal clearing.<sup>1</sup>

Dysphagia has become one of the pivotal issues recently due to the increased number of elderly people, and the potential for increased risk of pneumonia from dysphagia with frequent aspiration. The extent of the hyoid movement has been reported to be adversely associated with age,<sup>3</sup> and clinicians have considered decreased hyoid movement distance to be a factor contributing to aspiration or residue.<sup>3–6</sup>

However, other studies have found a wide range in hyoid movement distance in the healthy population and have failed to establish a clear relationship between aspiration and reduced hyoid movement distance.<sup>7,8</sup> As a result, attention has been re-

directed to parameters that capture spatiotemporal aspects of hyoid movement including velocity, which is the rate of change in hyoid position over time, measured in a single plane (i.e. anterior or superior) or speed, which is the two-dimensional equivalent, measured along the hypotenuse. Several recent studies suggest that hyoid speed may differ between healthy and pathological swallows, with the latter having significantly reduced speed.<sup>5,9</sup> Nevertheless, most of these studies involved videofluoroscopy recordings, which cannot be performed at the bedside and put the participants at risk for radiation exposure. Furthermore, the barium used in videofluoroscopic images is not identical to the real food bolus. Also, most of the studies on hyoid speed of healthy swallowing recruit young adults.<sup>9–11</sup> The effects of age on hyoid speed have not been investigated thoroughly.

In our previous work, we have demonstrated that submental ultrasonography is a reliable and accurate method for assessing hyoid bone movement and could aid dysphagia screening and evaluation.<sup>12</sup> In this work, we utilized an ultrasonographic machine to investigate the effects of age on the speed of hyoid bone movement by using bolus of different consistencies.

## 2. Design and methods

### 2.1. Participants

This study was approved by the Ethics Committee of National

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Taiwan University Hospital, Taipei City, Taiwan. Written informed consent was obtained from each participant. Between January 2017 and September 2017, 97 healthy adult volunteers, 45 males and 52 females, were studied in three stratified age groups: 20–39 (mean = 29.3, SD = 4.0; n = 35 with 25 males and 10 females), 40–64 (mean = 50.8, SD = 5.6; n = 32 with 10 males and 22 females), and above 65 (mean = 73.9, SD = 6.1; n = 30 with 10 males and 20 females) years old. The subjects had no history of swallowing difficulties, or any medical conditions that might affect deglutition.

## 2.2. Ultrasonographic examination

This study used a self-designed ultrasonographic machine with a curvilinear transducer (Convex Array, 3.75 MHz, P701-C04; LELTEK Corporation, Taipei City, Taiwan). The machine was connected to a laptop computer, placed on a cart, and could be easily used at the bedside (LT701 ultrasonographic machine, LT701-000; LELTEK Corporation). The result of each ultrasonographic examination was recorded as a series of dynamic images. Images were recorded at a frame rate of 30/s. Connection of the machine to the laptop enabled prompt storage of the dynamic images. Participants were assessed when sitting upright comfortably, with their heads leaning back on the chair. The transducer was placed in the midsagittal plane at the submental area (Fig. 1A). We capped a self-designed water bag on the transducer to improve the contact between the skin and the transducer (Fig. 1B, C). Participants were instructed to hold their head steady during swallowing. Each participant swallowed 10 mL of juices of 3 different consistencies:

Mildly thick, 50 mL of apple juice mixed with 0.6 gram of RESOURCE® THICKENUP CLEAR® (0.012 g/mL), International Dysphagia Diet Standardization Initiative (IDDSI) level 2.

Moderately thick, 50 mL of apple juice mixed with 1.2 gram of RESOURCE® THICKENUP CLEAR® (0.024 g/mL), IDDSI level 3.

Extremely thick juice, 30 mL of apple juice mixed with 1.2 gram of RESOURCE® THICKENUP CLEAR® (0.04 g/mL), IDDSI level 4.

Our swallow materials, composed of juice with RESOURCE® THICKENUP CLEAR® (xanthan gum based product) as a thickening agent, were prepared with precision controls for consistency (Fig. 2). We read the consistencies 10 seconds after we put the sample to test. We repeated every task for 3 times and took the mean value. All boluses were of room temperature (25 degree Celsius), calibrated in amount, and presented via syringes. We prepared the boluses 15 minutes prior to the trials on participants.

Subjects were instructed to begin upon (not before) the verbal command to swallow, try to complete each given task in a single

swallow, and relax the tongue to the floor of the mouth immediately after each swallow. Two trials of each task were carried out. Hyoid bone movement during swallowing was recorded and later analyzed frame by frame. We took the best performance out of the two trials of each task. From the measured event timing and coordinate changes, two dependent variables were derived:

Start-to-max duration (s): interval from the onset of swallow-related hyoid motion to the first moment of maximal displacement in the forward movement trajectory.

Maximal hyoid bone displacement (mm): maximal two-dimensional displacement in the forward movement trajectory, relative to the hyoid position at the start of its swallow-related motion; the distance between the starting and the ending points in the forward movement trajectory, calculated from the measured X and Y coordinates as the square root of the sum of squares.

The speed of hyoid movement was calculated as the maximal hyoid bone displacement divided by start-to-max duration (mm/s).

Fig. 3 shows the structures observed in the submental ultrasonography at the midsagittal plane. The position of the mandible and the hyoid bone was identified on the scan as a high echogenic area with a posterior acoustic shadow. The mandible was used as the reference point to calculate the maximal hyoid bone displacement (Fig. 3A). The reference point was defined as the anterior border of the bottom of the acoustic shadow of the mandible. Using a two-axis coordinate system, the position of the hyoid bone in relation to the mandible in each frame was represented as coordinate pairs. The distance between two coordinates before and during swallowing denoted the hyoid bone displacement (Fig. 3B). The software employed in this study was developed using the C Sharp programming language (Microsoft Visual Studio 2015; Microsoft, Redmond, WA, USA).

The measurements of hyoid movement were made by a physician who has undergone training on temporal measurements using our software. The physician making the measurements of hyoid movement was blinded to the task at the time of making the measurement.

## 2.3. Statistical analysis

Statistical tests were conducted using IBM SPSS software (SPSS Statistics 20.0; SPSS Inc., Chicago, IL, USA), and  $p < 0.05$  was considered to indicate significance. Differences among age groups were analyzed for the speed of hyoid movement during swallowing. Our participant subgroups were not sex-balanced, and we investigated the possible interaction between age, sex and consistency



Fig. 1. Submental ultrasonographic examination.

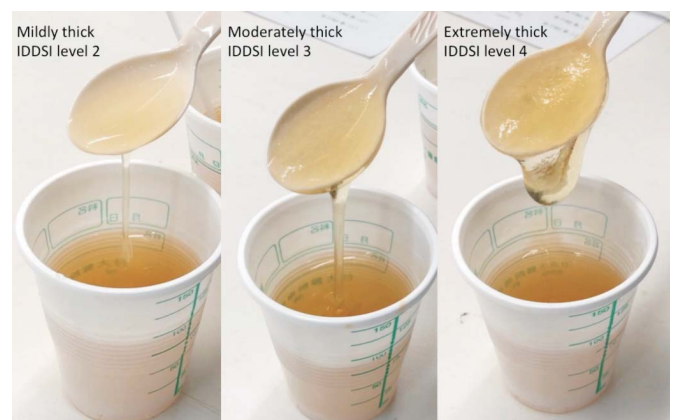


Fig. 2. Three different consistencies of juices that each participant swallowed.

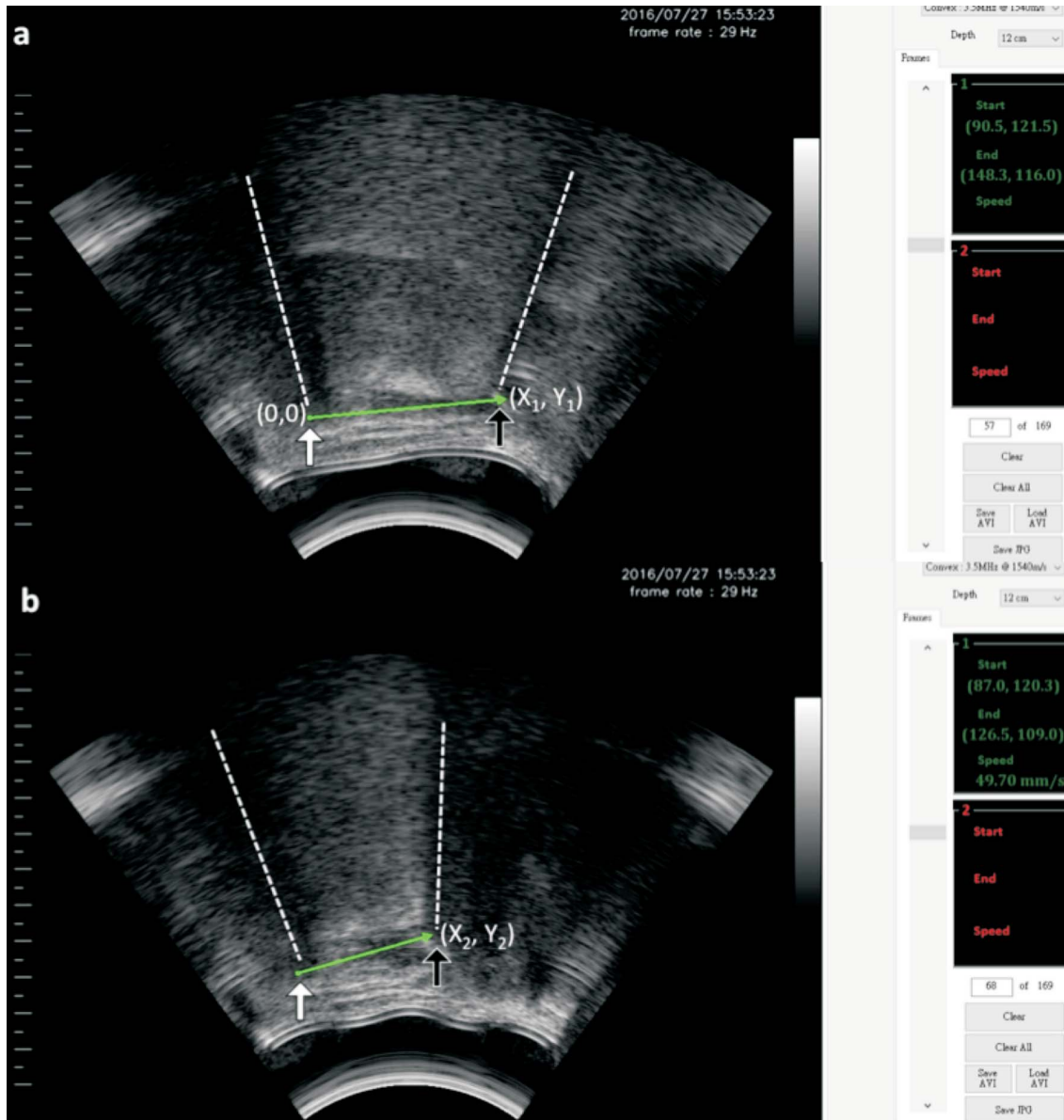


Fig. 3. Calculation of the hyoid bone displacement with a self-designed program.

by using a two-way analysis of variance (ANOVA) for repeated measures with consistency as the within-subject variable, and age and sex as between subject variables. Wilk's Lambda was used to determine the significance ( $p < 0.05$ ).

**3. Results**

In terms of inter-rater reliability, designated swallows of 25 randomly selected participants (25.8%) when they took 10 mL of moderately thick juice were re-analyzed for inter-rater reliability by a second independent rater. The second rater was a speech language pathologist who has undergone training on temporal measurements using our software. Intraclass correlation coefficient (ICC) was calculated to determine the relationship between the first and second measurements. The ICC value obtained was 0.845 ( $p < 0.01$ ), indicating excellent reproducibility.

The speed of hyoid bone movement, including mean values and measures of dispersion (standard deviation and 95% confidence interval boundaries), when the participants swallowed 10 mL of juices of 3 different consistencies was shown in Table 1. The average

**Table 1**

The speed of hyoid bone movement when the participants swallowed 10 mL of juices of 3 different consistencies.

	Mean	SD	95% CI
Mildly thick			
Age			
20–39	38.7	15.45	33.43–44.05
40–64	31.7	13.19	26.93–36.43
Above 65	31.3	12.14	26.76–35.82
Moderately thick*			
Age			
20–39	34.5	12.86	30.03–38.87
40–64	30.3	11.72	26.08–34.53
Above 65	27.0	9.10	23.55–30.35
Extremely thick			
Age			
20–39	37.2	12.07	33.02–41.32
40–64	36.0	15.66	30.33–41.63
Above 65	29.9	11.29	25.71–34.14

Unit of the speed: mm/s.

\* Significant difference between the 20–39 and above 65 age groups in moderately thick consistency.

speed of hyoid bone movement when the participants swallowed 10 mL of moderately thick juice was 34.5 mm/s, 30.3 mm/s, and 27.0 mm/s in the 20–39, 40–64, and above 65 age group, respectively ( $p < 0.05$ ). The post-hoc analysis showed a significant difference between the 20–39 and above 65 age groups. The average speed of hyoid bone movement when the participants swallowed 10 mL of extremely thick juice was 37.2 mm/s, 36.0 mm/s, and 29.9 mm/s in the 20–39, 40–64, and above 65 age group, respectively ( $p = 0.07$ ). The average speed of hyoid bone movement when the participants swallowed 10 mL of mildly thick juice was 38.7 mm/s, 31.7 mm/s, and 31.3 mm/s in the 20–39, 40–64, and above 65 age group. No significant difference was observed in the comparison of different age groups.

As for the possible effect of sex-imbalance on our results, there was no significant difference regarding the hyoid speed between male and female in all three kinds of consistency. In addition, there was no interaction among age, sex and consistency.

The results showed an overall trend of reduced hyoid movement speed during swallowing in older participants. However, the post-hoc analysis only showed a significant difference between the 20–39 and above 65 age groups when the participants swallowed moderately thick juice.

#### 4. Discussions

Our study reveals an influence of age on the speed of XY hypotense hyoid movement, reflected by decreased, i.e., slower, hyoid movement speeds in the elderly. The reason might be that atrophy of the surrounding muscles (digastric muscle, mylohyoid muscle, stylohyoid muscle, geniohyoid muscle) results in less tension and in loosening of ligaments during swallowing.<sup>13</sup> Also, sensory function changes with age and is influenced by declining perception of spatial tactile recognition on the lip and tongue, diminished perception of consistency in the oral cavity, poorer oral stereognosis, and reductions in taste perception with increasing age.<sup>14</sup>

Dysphagia is a common problem in older individuals, which occurs in 15–22% of community-dwelling persons over 50 years of age.<sup>15–17</sup> While the etiology of aspiration pneumonia is multifactorial, there is a strong association between dysphagia and the development of aspiration pneumonia.<sup>18</sup> It has been suggested that the increased incidence of pneumonia with aging may be a consequence of impairment of swallowing and the cough reflex.<sup>19</sup> From our results, one may expect to find a decreased hyoid speed in the elderly. However, the connection between the decreased hyoid speed and dysphagia or even aspiration pneumonia in the elderly needs more clarifications.

The speed of hyoid movement might be governed by the functional goal of closing the laryngeal vestibule in a timely manner for the sake of preventing aspiration.<sup>5,9</sup> The motion of the hyoid bone has been reported as an important factor involved in the swallowing mechanism that includes tongue movements, and the opening of the upper esophageal sphincter.<sup>20</sup> The epiglottis is involved in the closure of the airway, and if the glottic and supraglottic protective mechanisms fail, or are not coordinated with bolus as it moves through the pharynx, aspiration can occur.<sup>21</sup> The duration of supraglottic closure, and the maximal vertical excursion of the hyoid bone were increased in older subjects, more than 65 years of age, compared to younger subjects.<sup>22</sup> This might reflect a compensatory mechanism to improve airway protection in the elderly.

Previous studies evaluating hyoid speed in normal swallowing used lateral projection videofluorography.<sup>9–11</sup> In our previous work,<sup>12</sup> we tried to verify the reproducibility of using ultrasonography to

evaluate hyoid bone displacement during swallowing through the assessment of inter- and intrarater reliability and examine its accuracy by comparing the results with videofluorography. We demonstrated that submental ultrasonography is a reliable and accurate method for assessing hyoid bone movement. Also, using ultrasonography to evaluate hyoid bone movement comes with the advantage of avoiding radiation exposure. It can be easily performed at bedside and uses real food as a test material.

Compared with previous studies, the value for hyoid speed when our 20–39 age group participants swallowed mildly thick juice (38.7 mm/s, 95% confidence interval: 33.4–44) was similar to the anterior hyoid burst movement speed reported by Nagy et al. in 2014 (37 mm/s, 95% confidence interval: 32–41).<sup>9</sup> The value for hyoid speed when our above-65 age group participants swallowed mildly thick juice (31.3 mm/s, 95% confidence interval: 26.8–35.8) was also similar to the mean speed of hyoid excursion when the old participants swallowed 10 mL of thin liquid boluses reported by Ragland et al. in 2016 (30.2 mm/s, SD = 1.92).<sup>23</sup> Our results were compatible with the study conducted by Ragland et al. They found the speed of hyoid excursion in older populations was significantly slower than in younger ones, and there was no sex difference or interaction in the speed of hyoid excursion.<sup>23</sup> Another study conducted by Yabunaka et al. also supported our result.<sup>13</sup> They used ultrasonography to evaluate hyoid bone movement trajectories and the age-related changes during swallowing in healthy subjects. They suggested that average swallowing duration increased with age, and the measurement of the maximally elevated point of the hyoid bone decreased with age. We further demonstrated that the trend of decreased hyoid speed as the age increased could be observed in all three kinds of consistencies (mildly thick, moderately thick, and extremely thick). Compared with previous studies using ultrasonography to evaluate hyoid movement,<sup>13,24</sup> our self-designed water bag, which was capped on the transducer, prevented the hard transducer from over-pressing thyroid cartilage and hyoid bone. It provided the subjects with a more comfortable environment for natural swallowing.

Our study illuminates the use of ultrasound in providing quantitative measures of speed of hyoid movement during swallowing. The result adds to the current understanding of swallowing dynamics and the adaptive physiological mechanisms that take place when the age increases. With this powerful tool, we can analyze the speed of hyoid bone movement in those with dysphagia of various pathologies.

#### 5. Conclusions

The results demonstrated that the speed of hyoid movement during swallowing decreased as the age increased. However, the post-hoc analysis only showed a significant difference between the 20–39 and above 65 age groups when the participants swallowed moderately thick juice.

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#### Conflict of interest

The authors declare that there is no conflict of interest. This



paper presents independent results and research; the views expressed are those of the authors and not necessarily those of National Taiwan University Hospital. Ethical approval: This study was approved by the Ethics Committee of National Taiwan University Hospital, Taipei City, Taiwan.

## References

- Ekberg O. The normal movements of the hyoid bone during swallow. *Invest Radiol*. 1986;21:408–410.
- Sonoda N, Tamatsu Y. Observation on the attachment of muscles onto the hyoid bone in human adults. *Okajimas Folia Anat Jpn*. 2008;85:79–90.
- Kim Y, McCullough GH. Maximum hyoid displacement in normal swallowing. *Dysphagia*. 2008;23:274–279.
- Martin-Harris B, Brodsky MB, Michel Y, et al. Mbs measurement tool for swallow impairment—mbsimp: Establishing a standard. *Dysphagia*. 2008;23:392–405.
- Paik NJ, Kim SJ, Lee HJ, et al. Movement of the hyoid bone and the epiglottis during swallowing in patients with dysphagia from different etiologies. *J Electromyogr Kinesiol*. 2008;18:329–335.
- Steele CM, Bailey GL, Chau T, et al. The relationship between hyoid and laryngeal displacement and swallowing impairment. *Clin Otolaryngol*. 2011;36:30–36.
- Molfenter SM, Steele CM. Kinematic and temporal factors associated with penetration-aspiration in swallowing liquids. *Dysphagia*. 2014;29:269–276.
- Molfenter SM, Steele CM. Physiological variability in the deglutition literature: Hyoid and laryngeal kinematics. *Dysphagia*. 2011;26:67–74.
- Nagy A, Molfenter SM, Péladeau-Pigeon M, et al. The effect of bolus volume on hyoid kinematics in healthy swallowing. *Biomed Res Int*. 2014;2014:738971.
- Nagy A, Molfenter SM, Péladeau-Pigeon M, et al. The effect of bolus consistency on hyoid velocity in healthy swallowing. *Dysphagia*. 2015;30:445–451.
- Ueda N, Nohara K, Kotani Y, et al. Effects of the bolus volume on hyoid movements in normal individuals. *J Oral Rehabil*. 2013;40:491–499.
- Chen YC, Hsiao MY, Wang YC, et al. Reliability of ultrasonography in evaluating hyoid bone movement. *J Med Ultrasound*. 2017;25:90–95.
- Yabunaka K, Sanada H, Sanada S, et al. Sonographic assessment of hyoid bone movement during swallowing: A study of normal adults with advancing age. *Radiol Phys Technol*. 2011;4:73–77.
- Humbert IA, Robbins J. Dysphagia in the elderly. *Phys Med Rehabil Clin N Am*. 2008;19:853–866.
- Lindgren S, Janzon L. Prevalence of swallowing complaints and clinical findings among 50–79-year-old men and women in an urban population. *Dysphagia*. 1991;6:187–192.
- Barczy SR, Sullivan PA, Robbins J. How should dysphagia care of older adults differ? Establishing optimal practice patterns. *Semin Speech Lang*. 2000;21:347–361.
- Cook IJ, Kahrilas PJ. A technical review on management of oropharyngeal dysphagia. *Gastroenterology*. 1999;116:455–478.
- Marik PE, Kaplan D. Aspiration pneumonia and dysphagia in the elderly. *Chest*. 2003;124:328–336.
- Pontoppidan H, Beecher HK. Progressive loss of protective reflexes in the airway with the advance of age. *Jama*. 1960;174:2209–2213.
- Ishida R, Palmer JB, Hiemae KM. Hyoid motion during swallowing: Factors affecting forward and upward displacement. *Dysphagia*. 2002;17:262–272.
- Kahrilas PJ, Lin S, Rademaker AW, et al. Impaired deglutitive airway protection: A videofluoroscopic analysis of severity and mechanism. *Gastroenterology*. 1997;113:1457–1464.
- Kang BS, Oh BM, Kim IS, et al. Influence of aging on movement of the hyoid bone and epiglottis during normal swallowing: A motion analysis. *Gerontology*. 2010;56:474–482.
- Ragland MC, Park T, McCullough G, et al. The speed of the hyoid excursion in normal swallowing. *Clin Arch Commun Disord*. 2016;1:30–35.
- Chi-Fishman G, Sonies BC. Effects of systematic bolus consistency and volume changes on hyoid movement kinematics. *Dysphagia*. 2002;17:278–287.