A STUDY OF VOWEL PRODUCTION BY PERSONS WITH DYSPHAGIA

Fredericka Bell-Berti[*], Joanne L. DiMaggio[†], Nancy M. Colodny[*], and Beth M. Gianino[*]

[*]*St. John's University, Jamaica, New York, USA,* [†]*Suffolk Hearing and Speech Center, East Islip, New York, USA*

ABSTRACT

Dysphagia refers to disorders of any stage of swallowing as a result of any one or more underlying pathologies [7], among them difficulties using the oral and/or pharyngeal musculature. Currently, the initial step in the diagnostic process is the Clinical Examination of Swallowing (CES), a non-instrumental bedside examination, which may then be followed by an instrumental examination. Dysphagia, dysarthria, and/or apraxia frequently coexist. We are reporting formant frequency measures and listener identifications of vowels of dysphagic persons with varying severity of dysarthria. Taken together, these may lead to improved understanding of the relation between acoustical variation, articulation disturbance, and the likelihood of developing dysphagia, toward the development of a non-invasive acoustically based predictor or screening tool for dysphagia.

1. INTRODUCTION

This paper presents preliminary results of a study of the acoustical effects of dysphagia, a disorder of swallowing that affects 6 to 10 million Americans [3]. Normal swallowing consists of four distinct stages: the oral preparatory phase, the oral phase, the pharyngeal phase, and the esophageal phase [16]. Any or all phases may be dysfunctional; the severity of dysphagia may range from mild to life threatening [8]. When dysphagia results from a neurological disorder, motor and sensory functions of the oral and pharyngeal mechanisms involved in swallowing are impaired [1]. In addition, neurologically based dysphagias are often accompanied by dysarthria or apraxia—that is, speech disorders having a physiological etiology (e.g., [5, 16, 21]).

The data from this larger study should lead to a better understanding of speech acoustics and, eventually, to the possible development of a non-invasive screening tool for dysphagia. We anticipate, at least, that in limiting one's ability to constrict the pharyngeal cavity, the range of F1 and F2 frequencies across the vowels will be reduced.

2. METHODS

2.1. Subjects

The six subjects whose data are reported here were residents of a nursing home in New York City. Each was competent to give her/his own informed consent. All subjects were natives of New York City and speakers of American English. All were diagnosed as having dysarthria and dysphagia, the former with the Frenchay Dysarthria Assessment [6], and the latter with a CES and FEES® (Fiberoptic Endoscopic Evaluation of Swallowing) [14].

2.1.1. Subject 1. At the time of recording, S1 was an 85-year-old male who had a history of an epidural hematoma, spinal cord injury, and right occipital lobe infarction. His oropharyngeal dysphagia was mild-to-moderate for liquids and moderate-to-severe for solids. He had a mild flaccid dysarthria.

2.1.2. Subject 2. At the time of recording, S2 was an 87-year-old female who had a history of a left CVA with right hemiparesis. She had mild oropharyngeal dysphagia for solids and liquids. She had a mild flaccid dysarthria.

2.1.3. Subject 3. At the time of recording, S3 was an 86-year-old male who had a history of a brainstem infarction and had a history of esophageal stenosis. His oropharyngeal dysphagia was moderate for solids and moderate-to-severe for liquids, with greater pharyngeal than oral phase severity. He had mild flaccid dysarthria.

2.1.4. Subject 4. At the time of recording, S4 was an 82-year-old male with spinocerebellar degeneration. His mild-to-moderate oropharyngeal dysphagia for both solids and liquids. He had moderate ataxic dysarthria.

2.1.5. Subject 5. At the time of recording, S5 was an 83-year-old female who had a history of a left CVA. Her oropharyngeal dysphagia was mild for both solids and liquids. She had a mild flaccid dysarthria.

2.1.6. Subject 6. At the time of recording, S6 was a 66-year-old female who had a history of a left subdural hematoma. She had mild-to-moderate pharyngeal phase dysphagia. She had a mild mixed dysarthria.

2.2. Speech Tasks

Each subject produced at least 10 repetitions of each of 10 monosyllabic English words (heed, hid, head, had, hod, hawed, hood, who'd, hud, and heard) in random order. Recordings were made with a Marantz PMD 220 cassette tape recorder in a quiet room at the nursing home facility.

2.3. Data Analysis

2.3.1. Vowel Identification. Listening tapes of all tokens of each subject's productions were prepared for listener identification (10 tokens of 10 words; where 11 tokens had been produced, only the first 10 were used). They were presented to 28 listeners, all graduate students of Speech-Language Pathology, in a large classroom.

2.3.2. Acoustic Analysis. The recordings were digitized using SoundEdit 16 software on a Power Macintosh 8600/300 computer. Vowel duration and F1 and F2 frequency measurements were made using Signalyze 2.47 software. Whenever possible, measurements were made of 10 tokens, (in 7 cases, it was possible to measure only 9 tokens; in 2 cases, a subject produced 11 tokens of a word).

Waveforms and synchronized spectrograms were displayed on a time scale in which 1 pixel represented 1ms. An 8ms/125Hz or wider filter setting was used for spectral analysis. Spectrograms and spectra were displayed on a 0-4000Hz scale. Formant frequencies were measured near the vowel midpoint, and formant transitions for /d/ and any regions of diphthongal offglides (especially for /ɔ/) were avoided. Vowel durations were measured on the spectrographic display from the beginning of glottal pulsing following /h/ to the end of F2 and higher formant frequency energy (i.e., at the /d/ closure). F1 and F2 frequencies were measured for each token (attempts were measured and actual position the measuring error of each measuring device was determined in a circle with the diameter 80 mm and a zone around this circle with the diameter 80-120 mm.

3. RESULTS

The new system is capable of recording the movement of the receiver coils in the sagittal plane as well as torsions with a measuring rate up to 1 kHz for each of the 10 measuring channels. For the first time torsion and measuring errors due to the turning of the sensor coils can be assessed and corrected because of the separate measuring of the rotation angle. The data can be saved without any time limit.

In the circle with a diameter of 80 mm and with a torsion angle of 0 degree the new system showed a mean measuring error of 0.12 ± 0.10 mm in comparison to 0.26 ± 0.14 mm for the AG 100® (table 1, 2). In the range of 80-120 mm the measuring error increased to 0.16 ± 0.12 mm when the new construction was used, while 0.61 ± 0.23 mm were recorded by application of the AG 100®.

When diverting from the measuring plane increased measuring errors were recorded for both systems. By a 20 mm lateral deviation from the median sagittal plane the device from Tübingen showed a difference of 0.90 ± 0.10 mm on average, while the AG 100® showed a difference of 2.37 ± 0.14 mm. Even more pronounced was the difference of measuring error in both devices in the range of 80-120 mm. The mean error of the new device was 0.92 ± 0.12 mm, while of the AG 100® it was three times as high with 3.31 ± 0.23 mm.

In the range of 80 mm/80-120 mm a 10 degree torsion of the receiver coil caused the new device to record a mean measuring error of 0.28 ± 0.10/0.31 ± 0.13 mm in the median sagittal plane and the AG 100® of 0.40 ± 0.13 /0.71 ± 0.21 mm, respectively. Here, too, an increased lateral deviation caused an increase in the measuring error of both devices, whereby the AG 100® always recorded the more inaccurate values. An increased lateral deviation as well as torsion of the receiving coil led to an overall increase of the measuring error in both systems.

Worst case of measuring error was recorded at a lateral deviation of 20 mm and a 30 degree torsion in the range of 80 mm/80-120 mm. There the new construction recorded 12.59 ± 0.12 mm/12.74 ± 0.18 mm making the recording almost identical to the one from the AG 100®, which deviated by 12.27 ± 0.14 mm/12.43 ± 0.25 mm.

Measuring the torsion of the receiving coil was only possible when using the newly constructed device due to the system itself. In the following the mean evaluations of the torsions are listed. It is shown that the measuring error was not always the same. In the median sagittal plane at 0 degree a torsion of 1.19 ± 1.63/0.76 ± 1.31 degree was evaluated in the range of 80 mm/80-120 mm (table 3).

Without lateral deviation the measured torsion was mostly equal to the adjusted torsion. However, with lateral deviation of 10 and 20 mm an increased torsion resulted in a greater measuring error. Therefore, at a lateral deviation of 20 mm and a 20 degree torsion in the range of 80 mm/80-120 mm an only average angle of 16.35 ± 0.91/14.53 ± 0.76 degree was assessed. However, the deviation decreased again at the maximal torsion of 30 degree. In the range of 80 mm/80-120 mm a torsion of 27.85 ± 0.62/26.99 ± 0.60 degree was measured with a 20 degree lateral deviation and a 30 degree torsion.

deviation (mm)	torsion (degree)	mean (mm) (80 mm)	std (mm) (80 mm)	mean (mm) (80-120 mm)	std (mm) (80-120 mm)
0	0	0.12	0.10	0.16	0.12
10	0	0.60	0.10	0.64	0.12
20	0	0.90	0.10	0.92	0.12
0	10	0.28	0.10	0.31	0.13
10	10	1.82	0.10	1.85	0.14
20	10	4.17	0.10	4.21	0.12
0	20	0.41	0.10	0.45	0.14
10	20	3.70	0.10	3.73	0.14
20	20	8.18	0.11	8.33	0.15
0	30	0.64	0.11	0.76	0.14
10	30	5.76	0.11	5.65	0.15
20	30	12.59	0.12	12.74	0.18

Table 1: Measuring error of the new construction concerning the calculated position (mean and standarddeviation) in the zones 80 mm and 80-120 mm

deviation (mm)	torsion (degree)	mean (mm) (80 mm)	std (mm) (80 mm)	mean (mm) (80-120 mm)	std (mm) (80-120 mm)
0	0	0.26	0.14	0.61	0.23
10	0	1.05	0.15	1.44	0.24
20	0	2.37	0.14	3.31	0.23
0	10	0.40	0.13	0.71	0.21
10	10	2.31	0.14	2.53	0.26
20	10	4.46	0.14	5.02	0.25
0	20	0.54	0.15	0.68	0.20
10	20	3.80	0.14	3.89	0.28
20	20	7.64	0.14	7.99	0.21
0	30	0.56	0.15	0.63	0.24
10	30	6.30	0.15	6.35	0.22
20	30	12.27	0.14	12.43	0.25

Table 2: Measuring error of the AG 100® concerning the calculated position (mean and standarddeviation) in the zones 80 mm and 80-120 mm

deviation (mm)	torsion (degree)	mean (deg) (80 mm)	std (deg) (80 mm)	mean (deg) (80-120 mm)	std (deg) (80-120 mm)
0	0	1.19	1.63	0.76	1.31
10	0	0.00	0.00	0.00	0.00
20	0	0.00	0.00	0.00	0.00
0	10	9.86	0.96	9.92	0.76
10	10	7.86	1.28	7.01	0.87
20	10	0.00	0.00	0.00	0.00
0	20	20.59	0.45	20.61	0.42
10	20	19.69	0.44	19.35	0.30
20	20	16.35	0.91	14.53	0.76
0	30	30.72	0.25	30.89	0.34
10	30	30.10	0.25	30.09	0.33
20	30	27.85	0.62	26.99	0.60

Table 3: Calculated torsion of the new construction (mean and standarddeviation) in the zones 80 mm and 80-120 mm

4. DISCUSSION

By comparing studies about the measuring accuracy of the AG 100® EMA-system it has to be noted that different authors used different calibrating procedures and that the system was optimized by the manufacturer in recent years.

Schönle recorded a measuring error of 1.9 mm in the measuring field of 8 x 14 cm [6]. The maximal deviation was 5.65 mm. In the central field of 8 x 6 cm the median deviation was 1.29 mm. A maximal deviation of 1.4 mm was measured with lateral deviation of 1 cm from the median sagittal plane, 2 cm away from the central calibration point. A torsion of $\pm$ 30 degree resulted in a deviation of 1.1 mm at a distance of 2 cm from the calibration point. A combination of lateral deviation of 1 cm and a torsion of 15 degree resulted in an error of 3.7 mm, while at 30 degree of 7.2 mm.

With an 18 degree torsion and a lateral distance of 10 mm to the median sagittal range Engelke reported in 1994 an absolute error of 7 mm in direction of the y-axis as well as 0.6 mm in direction of the x-axis [3].

In comparison Honda reported in 1993 a 4 mm deviation with 10 mm displacement, 0 degree tilt, and 20 degree twist [5].

The assessed values for the AG 100® of our study are comparable with the ones of the manufacturer's study of measuring accuracy, because the calibrating method was identical [2]. The measurings were conducted in a circle of 45 mm in comparison to our central measuring field of 80 mm diameter. The results varied in all 5 measuring channels. The mean error was 0.15-0.31 mm in the median sagittal plane without torsion of coils in comparison to the values 0.26 mm for the AG 100® and 0.12 mm for the device from Tübingen measured by us.

With a lateral deviation of 10 mm without torsion Carstens records a mean error of 0.48-1.06 mm. This is in contrast to the values achieved by us with 1.05 mm for the AG 100® and 0.90 mm for the new construction.

With 20 degree torsion without lateral deviation the manufacturer evaluated a mean measuring error of 0.15-0.25 for the AG 100®, while we measured 2.37 mm for the AG 100® and 0.90 mm for the new device.

There is no explanation as to why in this particular case the manufacturer's data is in such strong contrast to our findings up to now. It has been shown, however, that it was useful to test both types of devices in a direct comparison, because the studies cited in literature are only partly comparable. This is because of different calibrating methods used and due to different study conditions.

4. CONCLUSION

With the aid of the newly designed instrument it is possible to record torsion of the receiving coils in the magnetic field for the first time. Because of the continuously saved data and its comfortable wear this measuring device provides new possibilities for investigation of orofacial malfunctions especially in children and adolescence. With the new articulograph the measuring accuracy could be improved in comparison to the Articulograph AG 100®.

When choosing measuring points for observation it has to be considered that especially different kinds of torsion of coils and lateral deviation causes more and more incorrectness in the measuring accuracy. This has to be considered or the assessment of the marked courses of movement.

REFERENCES

[1] Andrianopoulos M V, Hanson M L 1987. Tongue-thrust and the stability of overjet correction. *Angle Orthodontist* 57 (2) 121-135

[2] Carstens Medizinelektronik 1994: *Unpublished product description by the manufacturer*

[3] Engelke, W., Hoch, G. 1994 Simultane elektromagnetische Artikulographie und Videoendoskopie. Ein kasuistischer Beitrag zur objektiven Diagnostik des velopharyngealen Sphinkters. *Fortschr. Kieferorthop.* 55, 297-303 (Nr. 6)

[4] Engelke W, Schönle P W 1991. Elektromagnetische Artikulographie: Eine neue Methode zur Untersuchung von Bewegungsfunktionen des Gaumensegels. *Folia Phoniatrica* 43 147-152

[5] Honda, M., Kaburagi, T. 1993. Comparison of electromagnetic and ultrasound techniques for monitoring tongue motion. *Forschungsberichte 31/1993. Institut für Phonetic und Sprachliche Kommunikation der Universität München*, 121-136

[6] Schönle, P. W., Müller, C. Wenig, P. 1989. Echtzeitanalyse von orofazialen Bewegungen mit Hilfe der elektromagnetischenArtikulographie. *Biomed. Technik 34,* 126-130

[7] Stone M, Shawker T 1986. An ultrasound examination of tongue movement during swallowing. *Dysphagia* 1: 78-83

[8] Straub W J 1960 Malfunction of the tongue (1). *American Journal of Orthodontics* 46 404-424

[9] Straub W J 1961 Malfunction of the tongue (2). *American Journal of Orthodontics* 47 596-617

[10] Tränkmann J 1988. Kieferorthopädische Mißerfolge nach übersehenen orofazialen Dyskinesien. *Fortschritte der Kieferorthopädie* 49: 388-399