REVISTA CEFAC
SPEECH, LANGUAGE, HEARING SCIENCES AND EDUCATION JOURNAL
Rev. CEFAC. 2020;22(4):e0420 https://doi.org/10.1590/1982-0216/20202240420

Original articles

Relation between acoustic analysis of swallowing and the presence of pharyngeal residue and penetration/aspiration in resistant hypertensive patients with obstructive sleep apnea

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Conflict of interests: Nonexistent

ABSTRACT

Purpose: to evaluate the relationship between acoustic analysis of swallowing sounds and the presence of pharyngeal residue and penetration/aspiration detected by fiber-optic endoscopic evaluation of swallowing in resistant hypertensive patients with obstructive sleep apnea.

Methods: an observational study in which resistant hypertensive individuals diagnosed with obstructive sleep apnea participated through the all-night polysomnography exam. The participants underwent an acoustic analysis of swallowing sounds, using a Doppler sonar and simultaneously a fiberoptic endoscopic evaluation of swallowing. The acoustic parameters analyzed were initial frequency, initial intensity, first peak frequency, second peak frequency, final intensity and swallowing time. Independent samples of t-test and Mann-Whitney test were used for statistical analysis. The level of statistical significance adopted was 5%.

Results: eighty five participants with average age of 58.3±6.3 years were evaluated. There was a statistically significant difference between groups with and without pharyngeal residue, in relation to the following parameters of swallowing acoustic signal: initial frequency and intensity, second peak frequency, final intensity and swallowing time. Only 10 milliliters of pudding consistency showed a statistically significant difference in the second peak frequency of the acoustic signal of swallowing between groups with and without penetration/aspiration.

Conclusion: a relationship between measurements of swallowing acoustic signal and pharyngeal residue in this population was found, but not between swallowing sounds and penetration/aspiration.

Keywords: Deglutition Disorders; Sleep Apnea, Obstructive; Auscultation; Deglutition

Received on: February 3, 2020
Accepted on: July 3, 2020

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INTRODUCTION

Resistant hypertension is defined as the arterial blood pressure that remains above the target, despite concomitant use of three or more different drug classes, or within target with use of four or more drugs[1]. This condition is strongly associated with obstructive sleep apnea (OSA)[2], characterized as a total (apnea) or partial (hypopnea) obstruction of the respiratory flow, due to recurrent collapse of the upper airways during sleep, causing snoring, frequent awakenings and excessive daytime sleepiness[3].

Recent studies show that individuals with OSA may present oropharyngeal dysphagia, reducing safety and efficacy of swallowing, thus, exhibiting penetration/aspiration[4-7] and pharyngeal residue[4,5,8,9]. The methods considered gold standard to evaluate swallowing are videofluoroscopic swallowing study (VFSS) and fiber-optic endoscopic evaluation of swallowing (FEES)[10], although both present some disadvantages and restrict access to the great majority of Brazilian population. The disadvantages of VFSS consist of radiation exposure, limited time to perform the exam, need to transport the patient and loss of events between bolus presentations due to equipment shutdown; while FEES is related to white-out period during the pharyngeal phase, as well as the time and expense involved with endoscope decontamination[10]. Research has shown that acoustic analysis of swallowing can be a promising resource for swallowing evaluation, while also painless, non-invasive, absence of radiation exposure, no need for sedation, portable, easy-to-apply and low-cost[11-15]. The detection of swallowing sounds for acoustic analysis may be performed by different instruments, such as microphone,[16-19] accelerometer[20-22] and Doppler sonar,[11-15,23,24] having the last an excellent diagnostic accuracy in discriminating swallowing sounds[25].

Although several studies have investigated the swallowing acoustic signal by Doppler sonar, all researches to date have been performed in individuals without complaints of dysphagia and without the use of a gold standard exam as a reference, except for one study[23] that assessed swallowing of individuals with spinocerebellar ataxia by VFSS. Besides that, none of these studies investigated the relation between the swallowing acoustic signal captured by Doppler sonar and signs of swallowing dysfunction such as pharyngeal residue and penetration/aspiration.

Thus, the objective of this study was to verify if there is a relation between acoustic analysis of swallowing, using Doppler sonar, and the presence of pharyngeal residue and penetration/aspiration detected by FEES in resistant hypertensive patients presented with OSA.

METHODS

A study approved by Research Ethics Committee of the *Hospital Universitário Clementino Fraga Filho* (number 1.348.512). All study participants signed an Informed Consent Form (ICF).

It is an observational study in which individuals diagnosed with OSA from the Hypertension Program of a university hospital were recruited between February 2016 and July 2018. The diagnosis of OSA was made through an all-night polysomnography exam performed at the Sleep Laboratory of this same hospital. Electroencephalogram, electrooculogram, submental electromyogram, nasal airflow, oximetry, respiratory effort, electrocardiogram and anterior tibial electromyogram were recorded. The exam report was prepared by a qualified physician, specialist and certified in Sleep Medicine, who was unaware of the patients' clinical data. The apnea-hypopnea index (AHI) was calculated as the number of events of apnea-hypopnea by hour of sleep. OSA severity was defined as mild (AHI: 5-14), moderate (AHI: 15-30) and severe (AHI >30).

All participants were resistant hypertensive individuals, diagnosed with OSA, age ≥ 18 years, and without spontaneous complaint of dysphagia. Of the 397 resistant hypertensive patients with OSA, individuals > 65 years (n=242), with neurological disease (n=46), who did not sign the ICF (n=11), cognitive/behavioral deficit (n=4), chronic obstructive pulmonary disease (n=3), hospitalized for kidney transplantation (n=2), head and neck cancer (n=1), tracheostomy (n=1) and vocal fold paralysis (n=1) were excluded. The following variables were analyzed: sex, age, smoke, body mass index, neck circumference, apnea-hypopnea index, OSA severity and CPAP use. All study participants underwent FEES simultaneously with acoustic evaluation of swallowing.

Fiberoptic Endoscopic Evaluation of Swallowing - FEES

The FEES was performed with an ENT-30PIII Machida nasofibroendoscopy equipment, by an otolaryngologist and a speech therapist. The endoscopic positioning for the exam followed the recommendations proposed by Hiss and Postma[26]. Two swallows of 5 ml, 10 ml and 15 ml of fine liquid (water), nectar, honey and pudding, stained with blue food coloring were evaluated. The thickener used was Nestlé ThickenUp® Clear in amounts indicated by the manufacturer for handling nectar, honey and pudding consistencies.

The exams were analyzed in real time and frame by frame, using Virtual Dub software version 1.10.4 by two speech therapists independently and without knowledge of patients' data, both with experience in dysphagia and FEES. The first evaluator has eight years of experience and the second evaluator has three years of experience in FEES. In case of disagreement, the evaluation of an otolaryngologist with expertise in the exam was considered. The evaluators used the Yale pharyngeal residue severity rating scale[27] and the penetration-aspiration scale (PAS)[28]. Individuals were divided into two groups: presence of penetration/aspiration if the patient presented abnormal penetration aspiration score (PAS > 2) and absence of penetration/aspiration (PAS ≤ 2); as well as presence of pharyngeal residue (mild, moderate or severe) and absence of pharyngeal residue (none or trace).

Acoustic analysis of swallowing

A portable Doppler sonar *Angel Sounds Fetal Doppler* (Jumper® CE 0482) equipment was used, connected to a portable computer to register the acoustic signal of swallowing during the FEES. The Doppler sonar was placed on the skin surface of the patient's neck, on the right side, just below the cricoid cartilage. Conductive gel was used as contact. As proposed by Santos and Macedo Filho,[11] the acoustic signal of swallowing was recorded and analyzed with CTS Informática Voxmetria software, with intensity window between 10 and 100 decibels (dB) and frequency window between 60 and 1.200 Hertz (Hz)[12]. The following acoustic parameters were analyzed:

- Initial frequency (FI): frequency, measured in Hz, of the first tracing of sound wave;[11]
- Initial intensity (II): initial intensity, measured in dB, of the acoustic tracing of swallowing;[11]
- First peak frequency (F1P): frequency, in Hz, of the first peak of acoustic wave of swallowing;[11]
- Second peak frequency (F2P): frequency, in Hz, of the second peak of acoustic wave of swallowing;[11]
- Final intensity (IF): final intensity, in dB, of acoustic sinal;[11]
- Time (T): tempo, in seconds, between the beginning and the end of the acoustic signal[11,12].

Statistical analysis

Statistical analysis was performed using SPSS 21 software. Categorical data were expressed as absolute or relative frequency, while quantitative data were expressed as measures of central tendency. The Kappa coefficient was used to evaluate inter-rater agreement. For categorical data analysis, Pearson's chi-square test was used, or Fisher's exact test, in case of cells expecting a count lower than 5. For quantitative data analysis, independent samples t-test or Mann-Whitney test were used, according to the satisfaction of the assumptions of normality and homogeneity of variances, evaluated by the Kolmogorov-Smirnov test and Levene test, respectively. The level of statistical significance adopted was 5%.

RESULTS

Of 86 individuals able to participate in the study, only one was excluded for not completing the FEES. The final sample totaled 85 participants, 74.1% being females, with a median age of 60 [55-63] years and apnea-hypopnea index of 22 [10-38]. Also, 35.3% of the participants presented mild OSA, 27.1% moderate and 37.6% severe.

Figure 1 shows frequency of participants that exhibited penetration/aspiration distributed by volume and consistency. The Kappa inter-rater agreement coefficient of PAS was 0.968 (p<0.001).

Figure 2 shows frequency of participants that exhibited pharyngeal residue distributed by volume and consistency. The Kappa inter-rater agreement coefficient of pharyngeal residue severity rating scale was 0.934 (p<0.001).

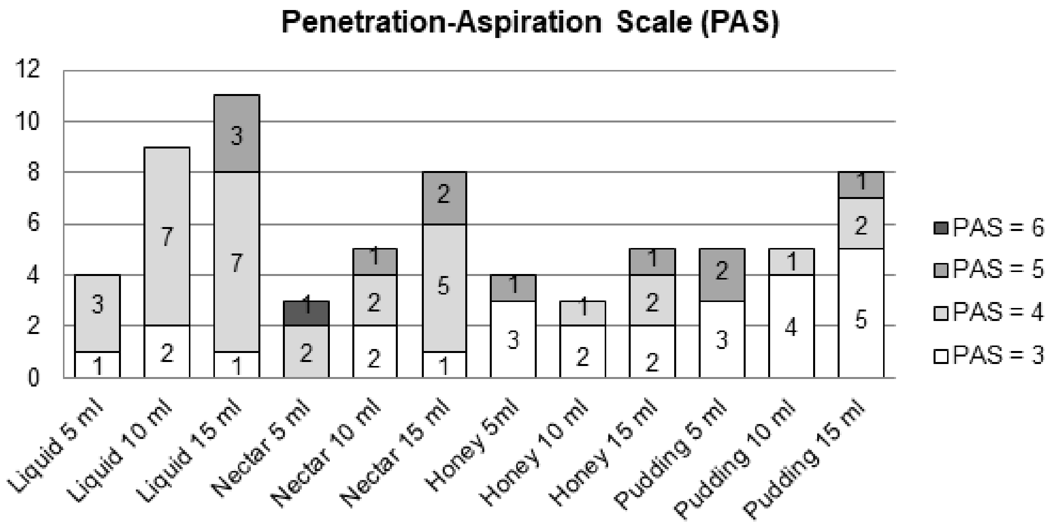

Figure 1. Absolute frequency of patients with abnormal penetration/aspiration scores

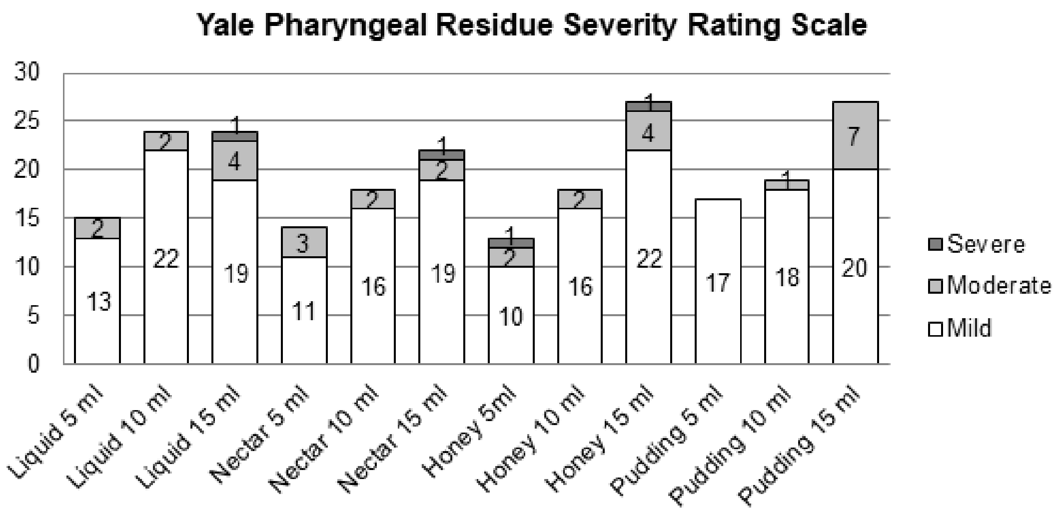

Figure 2. Absolute frequency of patients with pharyngeal residue

Table 1 presents demographic characteristics of groups with and without penetration/aspiration and with and without pharyngeal residue. There was no statistically significant difference in demographic characteristics between groups except for age and CPAP use between groups with and without penetration/aspiration. The group that exhibited penetration/aspiration was older than the group that did not exhibit penetration/aspiration. Besides that, most individuals using CPAP exhibited penetration/aspiration (Table 1).

Table 1. Demographic characteristics of patients grouped according to presence or absence penetration/aspiration and pharyngeal residue

Characteristics	All patients	Penetration/aspiration		p value	Pharyngeal residue		p value
	(n=85)	No (n=56)	Yes (n=29)		No (n=33)	Yes (n=52)	
Sex, % females	63 (74.1%)	45 (80.4%)	18 (62.1%)	0.068[a]	25 (75.8%)	38 (73.1%)	0.783[a]
Age (years)	60 (55-63)	58 (53-61.75)	63 (60-64)	**0.001**[b]	59 (55-61.5)	61 (55-64)	0.061[b]
Smoking	9 (10.6%)	6 (10.7%)	3 (10.3%)	0.635[c]	5 (15.2%)	4 (7.7%)	0.231[c]
BMI (kg/m^2)	33.7 (28.7-37)	34.1 (29.5-37.1)	32.8 (27.2-36.3)	0.247[b]	32.2 (26.9-35.8)	34.7 (29.1-37.4)	0.070[b]
NC (cm)	41 (38-44.5)	41 (39-44)	40 (37.5-45)	0.599[b]	40 (38-43.5)	41.5 (38.25-45)	0.423[b]
AHI	22 (10-38)	20.5 (8.25-36.75)	27 (15-57.5)	0.152[b]	22 (10-40)	23 (9.75-35.75)	0.914[b]
Severity of OSA							
- Mild	30 (35.3%)	23 (41.1%)	7 (24.1%)	0.237[a]	13 (39.4%)	17 (32.7%)	0.803[a]
- Moderate	23 (27.1%)	15 (26.8%)	8 (27.6%)		8 (24.2%)	15 (28.8%)	
- Severe	32 (37.6%)	18 (32.1%)	14 (48.3%)		12 (36.4%)	20 (38.5%)	
CPAP	19 (22.4%)	7 (12.5%)	12 (41.4%)	**0.002**[a]	8 (24.2%)	11 (21.2%)	0.739[a]

Values are presented as relative and absolute frequencies or medians (interquartile range).
Abbreviations: BMI, body mass index; NC, neck circumference; AHI, apnea-hypopnea index; OSA, obstructive sleep apnea.
[a] Pearson´s chi-square test.
[b] Mann-Whitney test.
[c] Fisher´s exact test.
p value for bivariable comparisons between groups with and without penetration/aspiration and between groups with and without pharyngeal residue.

We observed that the group with pharyngeal residue presented lower initial frequency and intensity with statistically significant differences in all volumes and consistencies, except 5 ml of liquid and 15 ml of pudding. The group with pharyngeal residue also presented lower second peak frequency with statistically significant differences in 5 ml and 10 ml of nectar and pudding consistencies. In addition, the group with pharyngeal residue showed lower final intensity with statistically significant differences in all volumes of nectar, 10 ml of liquid, 5 ml and 15 ml of honey and 5 ml of pudding (Tables 2 to 7). But we did not find differences in the acoustic signal related with penetration/aspiration.

Table 2. Initial frequency (Hz) of the swallowing sound in groups

	Penetration/aspiration		p value	Pharyngeal residue		p value
	No	Yes		No	Yes	
Liquid						
5 ml	634.43 (518.92-749.93)	681.34 (443.24-789.32)	0.879	637.08 (511.40-761.88)	637.08 (520.25-729.13)	0.494
10 ml	644.16 (548.57-775.16)	587.52 (510.52-676.03)	0.275	704.35 (553.00-782.24)	561.85 (492.81-637.08)	0.007
15 ml	638.85 (500.78-760.99)	591.06 (456.52-704.35)	0.681	669.83 (542.38-774.27)	539.72 (483.96-664.07)	0.021
Nectar						
5 ml	614.07 (488.83-750.37)	555.65 (534.41-555.65)	0.881	637.08 (508.74-755.68)	541.49 (392.36-653.02)	0.013
10 ml	614.07 (486.62-758.34)	605.22 (495.47-838.89)	0.665	670.71 (534.85-773.39)	560.96 (448.56-626.02)	0.034
15 ml	647.70 (470.68-757.45)	576.89 (491.93-807.02)	0.829	706.12 (536.62-764.53)	530.87 (422.89-653.01)	0.005
Honey						
5 ml	627.35 (466.26-746.83)	637.08 (601.68-770.73)	0.447	647.70 (498.12-762.76)	431.74 (406.96-601.68)	0.001
10 ml	637.08 (475.99-743.29)	615.84 (605.22-615.84)	0.640	676.91 (485.73-755.24)	520.25 (411.38-699.48)	0.040
15 ml	637.08 (452.98-745.95)	686.65 (628.23-757.46)	0.296	686.65 (484.85-760.99)	559.19 (421.12-658.33)	0.020
Pudding						
5ml	619.38 (484.85-748.60)	679.57 (517.60-756.97)	0.651	651.24 (520.69-760.99)	477.76 (438.82-668.19)	0.008
10ml	647.70 (483.07-750.37)	589.29 (398.11-706.12)	0.461	653.01 (522.02-768.08)	520.25 (426.43-690.19)	0.019
15ml	679.56 (491.93-767.19)	571.58 (468.03-668.51)	0.220	660.09 (491.93-780.47)	603.45 (456.52-732.67)	0.541

Values are presented as medians (interquartile range); Mann-Whitney test.
p value for bivariable comparisons between groups with and without penetration/aspiration and between groups with and without pharyngeal residue.

Table 3. Initial intensity (DB) of the swallowing sound in groups

	Penetration/aspiration		p value	Pharyngeal residue		p value
	No	Yes		No	Yes	
Liquid						
5 ml	55.35 (46.23-64.47)	59.06 (40.26-67.58)	0.863	55.56 (45.64-65.41)	55.56 (46.34-62.83)	0.487
10 ml	56.12 (48.58-66.46)	51.65 (45.57-58.63)	0.269	60.87 (48.92-67.02)	49.62 (44.17-55.56)	0.006
15 ml	55.70 (44.80-65.34)	51.93 (41.30-60.87)	0.633	58.14 (48.08-66.39)	47.87 (43.47-57.69)	0.020
Nectar						
5 ml	53.74 (43.85-64.50)	49.13 (47.45-49.13)	0.881	55.56 (45.43-64.92)	48.01 (36.24-56.82)	0.013
10 ml	53.74 (43.68-65.14)	53.04 (44.38-71.49)	0.665	58.21 (47.49-66.32)	49.55 (40.67-54.69)	0.034
15 ml	56.40 (42.42-65.06)	50.81 (44.10-68.98)	0.829	61.01 (47.63-65.62)	47.18 (38.65-56.82)	0.005
Honey						
5 ml	54.79 (42.07-64.22)	55.56 (52.76-66.11)	0.447	56.40 (44.59-65.48)	39.35 (37.39-52.76)	0.001
10 ml	55.56 (42.84-63.94)	53.88 (53.04-53.88)	0.640	58.21 (43.61-64.89)	46.34 (37.74-60.49)	0.039
15 ml	55.56 (41.03-64.16)	59.47 (54.86-65.07)	0.305	59.47 (43.54-65.34)	49.41 (38.51-57.10)	0.020
Pudding						
5ml	54.16 (43.54-64.36)	58.91 (46.13-65.20)	0.621	56.68 (46.37-65.34)	42.98 (39.91-58.08)	0.008
10ml	56.40 (43.40-64.50)	51.79 (36.69-61.01)	0.461	56.82 (46.48-65.90)	46.34 (38.93-59.75)	0.018
15ml	58.91 (44.10-65.45)	50.39 (42.21-58.04)	0.223	57.38 (44.10-66.04)	52.91 (41.30-63.11)	0.564

Values are presented as medians (interquartile range); Mann-Whitney test.
p value for bivariable comparisons between groups with and without penetration/aspiration and between groups with and without pharyngeal residue.

Table 4. First peak frequency (Hz) of the swallowing sound in groups

	Penetration/aspiration		p value	Pharyngeal residue		p value
	No	Yes		No	Yes	
Liquid						
5 ml	942.44 (866.76-1011.92)	955.71 (915.00-989.79)	0.619[b]	959.25 (863.67-1011.49)	938.01 (863.66-1022.98)	0.879[a]
10 ml	930.93 (860.12-998.20)	987.58 (869.86-1037.14)	0.764[b]	948.63 (861.89-1014.13)	911.46 (872.96-1022.98)	0.736[a]
15 ml	934.47 (872.52-1008.82)	966.34 (853.04-1040.69)	0.597[b]	938.02 (876.06-1028.74)	920.31 (839.77-1004.40)	0.419[b]
Nectar						
5 ml	942.44 (838.88-1005.28)	1001.74 (732.67-1001.74)	0.900[a]	959.26 (853.04-1008.82)	862.78 (743.29-999.53)	0.108[a]
10 ml	939.78 (847.74-1017.67)	1005.28 (957.49-1053.96)	0.089[a]	941.55 (875.62-1026.52)	928.28 (784.45-1017.67)	0.267[a]
15 ml	969.88 (877.83-1024.76)	1015.90 (860.12-1051.30)	0.613[a]	975.19 (903.49-1038.02)	940.67 (772.50-1007.05)	0.078[a]
Honey						
5 ml	934.47 (838.44-1005.88)	982.27 (776.04-1042.46)	0.765[b]	936.25 (841.54-1013.25)	913.23 (839.77-985.81)	0.466[b]
10 ml	959.26 (874.29-1026.52)	923.86 (700.81-923.86)	0.249[a]	982.27 (876.94-1027.85)	904.38 (794.63-986.70)	0.062[a]
15 ml	929.16 (862.78-1015.02)	987.58 (799.94-1038.92)	0.624[a]	968.11 (902.61-1015.90)	895.53 (824.72-984.04)	**0.035**[b]
Pudding						
5ml	930.93 (843.31-1001.74)	1009.71 (949.96-1041.57)	0.117[a]	948.63 (842.86-1015.90)	909.69 (856.58-964.57)	0.184[a]
10ml	946.86 (860.12-1012.36)	877.83 (776.04-1053.08)	0.881[a]	966.34 (863.67-1019.44)	934.47 (799.94-994.66)	0.163[a]
15ml	931.82 (879.60-1016.79)	906.15 (810.56-1016.79)	0.497[b]	941.55 (883.14-1022.98)	927.40 (822.95-1015.28)	0.079[b]

Values are presented as medians (interquartile range).
[a] Mann-Whitney test.
[b] Independent samples t-test.
p value for bivariable comparisons between groups with and without penetration/aspiration and between groups with and without pharyngeal residue.

Table 5. Second peak frequency (Hz) of the swallowing sound in groups

	Penetration/aspiration		p value	Pharyngeal residue		p value
	No	Yes		No	Yes	
Liquid						
5 ml	949.52 (859.68-1015.46)	894.64 (811.45-987.14)	0.398[a]	961.03 (854.81-1015.02)	936.24 (838.88-1017.68)	0.709[a]
10 ml	959.26 (884.91-1015.90)	934.48 (784.01-966.34)	0.089[a]	963.68 (906.59-1015.02)	899.07 (828.26-1004.84)	0.185[a]
15 ml	941.55 (862.78-1007.94)	868.98 (743.29-1049.54)	0.422[a]	971.65 (867.20-1022.10)	912.35 (784.45-998.64)	0.101[a]
Nectar						
5 ml	937.13 (829.59-996.43)	1037.14 (647.70-1037.14)	0.418[a]	955.71 (862.78-1007.94)	861.89 (753.91-943.32)	**0.036**[a]
10 ml	957.49 (861.89-1021.21)	1008.82 (769.85-1066.36)	0.314[a]	991.12 (882.25-1026.08)	896.42 (806.58-949.52)	**0.021**[a]
15 ml	925.63 (840.65-1008.82)	966.34 (668.94-1040.68)	0.636[a]	972.54 (877.83-1024.31)	853.93 (768.52-917.21)	**0.000**[a]
Honey						
5 ml	909.69 (817.64-1000.41)	867.21 (735.33-935.36)	0.352[a]	930.93 (845.08-1001.74)	778.70 (711.43-820.30)	**0.000**[a]
10 ml	969.88 (877.83-1028.29)	891.99 (739.75-891.99)	0.220[a]	977.85 (878.27-1033.60)	929.16 (784.01-977.85)	**0.040**[b]
15 ml	934.47 (845.08-1014.13)	987.58 (881.37-1040.68)	0.384[a]	934.48 (853.04-1022.98)	936.24 (821.18-994.66)	0.512[a]
Pudding						
5ml	941.55 (840.65-1002.63)	943.33 (828.71-1019.44)	0.875[a]	945.09 (861.01-1003.07)	913.23 (748.61-1001.74)	0.268[a]
10ml	934.48 (846.85-1020.33)	753.91 (702.58-934.47)	**0.039**[a]	930.93 (840.65-1015.90)	909.69 (776.93-1044.22)	0.982[a]
15ml	941.55 (841.54-1021.21)	962.80 (760.11-1025.64)	0.821[a]	938.01 (842.42-1021.22)	945.09 (881.37-980.50)	0.639[a]

Values are presented as medians (interquartile range).
[a] Mann-Whitney test.
[b] Independent samples t-test.
p value for bivariable comparisons between groups with and without penetration/aspiration and between groups with and without pharyngeal residue.

Table 6. Final intensity (DB) of the swallowing sound in groups

	Penetration/aspiration		p value	Pharyngeal residue		p value
	No	Yes		No	Yes	
Liquid						
5 ml	56.40 (45.81-64.96)	57.87 (40.30-64.01)	0.833[b]	56.68 (46.06 – 66.32)	56.68 (43.26 – 60.87)	0.243[a]
10 ml	56.12 (46.62-64.50)	56.54 (49.27-63.04)	0.954[a]	60.59 (49.69 – 65.45)	50.53 (41.79 – 58.14)	**0.017**[a]
15 ml	56.12 (48.08-64.71)	55.98 (48.85-61.99)	0.946[a]	58.91 (48.85 – 66.25)	52.07 (47.84 – 58.84)	0.061[b]
Nectar						
5 ml	54.79 (45.25-64.61)	52.20 (51.93-52.20)	0.704[a]	55.70 (47.24 – 65.06)	48.30 (43.26 – 57.94)	**0.031**[a]
10 ml	55.56 (44.31-64.58)	57.24 (46.62-66.88)	0.836[a]	58.91 (47.42 – 65.83)	47.10 (42.63 – 56.19)	**0.025**[a]
15 ml	53.04 (45.22-64.09)	64.22 (44.94-70.93)	0.232[a]	59.82 (48.12 – 65.41)	46.20 (41.10 – 57.20)	**0.003**[a]
Honey						
5 ml	54.09 (44.73-63.56)	58.78 (53.25-68.07)	0.289[a]	56.54 (47.03 – 64.99)	45.22 (41.93 – 54.02)	**0.010**[a]
10 ml	53.61 (47.46-64.50)	54.44 (52.76-54.44)	0.514[b]	56.68 (47.67 – 65.20)	50.39 (44.03 – 58.77)	0.069[a]
15 ml	53.32 (47.59-64.43)	62.27 (53.32-65.77)	0.208[a]	58.35 (48.57 – 64.50)	51.09 (48.01 – 57.52)	**0.047**[a]
Pudding						
5ml	55.28 (45.64-64.50)	57.31 (45.88-62.97)	1.000[a]	57.10 (47.73 – 65.59)	44.94 (40.61 – 55.35)	**0.003**[a]
10ml	55.14 (47.59-64.43)	54.86 (43.54-60.73)	0.679[a]	56.68 (49.41 – 65.62)	51.65 (42.70 – 59.33)	0.089[a]
15ml	56.26 (45.12-64.57)	52.91 (44.31-57.45)	0.235[a]	56.82 (44.80 – 65.34)	53.04 (48.29 – 63.81)	0.430[a]

Values are presented as medians (interquartile range).
[a] Mann-Whitney test.
[b] Independents samples t-test.
p value for bivariable comparisons between groups with and without penetration/aspiration and between groups with and without pharyngeal residue.

Table 7. Time (S) of the swallowing sound in groups

	Penetration/aspiration		p value	Pharyngeal residue		p value
	No	Yes		No	Yes	
Liquid						
5 ml	0.66 (0.48 – 0.84)	0.73 (0.37 – 0.98)	0.829[b]	0.70 (0.50 – 0.84)	0.58 (0.42 – 0.85)	0.365[b]
10 ml	0.72 (0.52 – 0.85)	0.50 (0.40 – 0.70)	0.059[a]	0.72 (0.53 – 0.85)	0.58 (0.43 – 0.75)	0.160[b]
15 ml	0.68 (0.48 – 0.84)	0.65 (0.56 – 0.79)	0.699[b]	0.69 (0.52 – 0.86)	0.64 (0.47 – 0.70)	0.305[a]
Nectar						
5 ml	0.64 (0.47 – 0.83)	0.47 (0.42 – 0.47)	0.310[b]	0.68 (0.47 – 0.84)	0.52 (0.42 – 0.65)	**0.002**[b]
10 ml	0.68 (0.52 – 0.82)	0.45 (0.37 – 0.81)	0.222[b]	0.70 (0.50 – 0.82)	0.61 (0.51 – 0.69)	0.178[b]
15 ml	0.72 (0.56 – 0.81)	0.59 (0.39 – 0.84)	0.396[b]	0.71 (0.53 – 0.82)	0.73 (0.55 – 0.83)	0.803[b]
Honey						
5 ml	0.70 (0.46 – 0.83)	0.57 (0.37 – 0.72)	0.330[a]	0.72 (0.50 – 0.83)	0.48 (0.29 – 0.73)	**0.038**[a]
10 ml	0.71 (0.59 – 0.85)	0.63 (0.36 – 0.63)	0.339[a]	0.72 (0.60 – 0.85)	0.66 (0.47 – 0.82)	0.549[a]
15 ml	0.70 (0.58 – 0.80)	0.59 (0.32 – 0.77)	0.147[a]	0.73 (0.60 – 0.81)	0.60 (0.49 – 0.71)	0.051[b]
Pudding						
5ml	0.65 (0.53 – 0.79)	0.48 (0.39 – 0.77)	0.291[b]	0.63 (0.51 – 0.79)	0.73 (0.50 – 0.87)	0.431[b]
10ml	0.69 (0.50 – 0.83)	0.50 (0.38 – 0.82)	0.338[b]	0.71 (0.50 – 0.84)	0.64 (0.41 – 0.73)	0.258[b]
15ml	0.67 (0.52 – 0.79)	0.58 (0.39 – 0.73)	0.313[a]	0.66 (0.48 – 0.79)	0.70 (0.50 – 0.77)	0.832[a]

Values are presented as medians (interquartile range).
[a] Mann-Whitney test.
[b] Independent samples t-test.
p value for bivariable comparisons between groups with and without penetration/aspiration and between groups with and without pharyngeal residue.

DISCUSSION

Several researches evaluated the acoustic signal of swallowing through swallowing sounds pickup with Doppler sonar and the registry and analysis of acoustic signal with Voxmetria software[11-14,23,24]. However, this is the first study that proposed to investigate the relationship between the resource and the main deglutition disorders (penetration/aspiration and pharyngeal residue) detected by FEES, considered one of the gold standard methods[10] and that presents a greater sensitivity to identify such alterations[29]. Besides that, this is also the first study that investigated the acoustic signal of swallowing in individuals with OSA.

In line with the literature, our results show that frequency of pharyngeal residue is higher than frequency of penetration/aspiration in individuals with OSA[4,5]. In relation to demographic characteristics, the groups are similar. There was no difference in frequency of penetration/aspiration between the different degrees of OSA, however individuals with OSA, mainly moderate and severe, exhibited a higher frequency of pharyngeal residue, although without a statistically significant difference. Other researchers did not find differences in the degree of penetration/aspiration and pharyngeal residue between individuals with moderate and severe OSA[4]. Similarly, another research did not find differences in AHI, body mass index, neck circumference, gender and smoking between groups with and without dysphagia[8]. However, while a previous study revealed an age difference between individuals with OSA with and without dysphagia,[4] this research also exhibited an age difference between individuals that present penetration/aspiration. Although individuals over 65 years of age were excluded of this study due to the possibility of presbyphagia, the average age of participants remained high what might have contributed for this result. The aging process may cause changes in the physiology of swallowing, including decrease of the strength of suprahyoid muscles, which impairs the closure of the laryngeal vestibule and the UES opening[30], thus increasing the risk of laryngeal penetration. Regarding the use of CPAP, we did not find any study comparing this condition between groups with and without dysphagia. According to the literature, the increase of OSA severity may be associated with the worsening of the sensory neural function of the upper airways[31]. Considering that CPAP is indicated to patients with moderate to severe OSA and with symptoms, it can be assumed the hypothesis of these individuals presenting more important sensory changes, thus, justifying why this study found a higher frequency of penetration/aspiration in individuals using CPAP. One study, however, found that OSA treatment with CPAP was able to reverse the endoscopic findings of swallowing dysfunction such as premature escape and pharyngeal residue[8].

This study revealed that FI and II measurements are lower in individuals that exhibit pharyngeal residue compared with those that do not exhibit pharyngeal residue. On the other hand, FI and II did not statistically differ between individuals with and without penetration/aspiration. These two measurements of the beginning of the acoustic signal of swallowing are associated with the beginning of the pharyngeal phase of swallowing[32]. Thus, these findings may be justified by reduction in oral ejection force[32] of these individuals, which results in pharyngeal residue[33].

According to the literature, F1P is associated with laryngeal elevation while F2P is associated with UES opening[11,32,34]. Our results show, in nectar and honey consistencies, a lower F2P in individuals that exhibit pharyngeal residue compared with those that do not exhibit pharyngeal residue, however there was no difference in relation to F1P, nor in relation to penetration/aspiration. Such result may indicate that swallowing dysfunction in this population is possibly not associated with the amplitude of laryngeal elevation, but with oral ejection and, in some consistencies, with UES opening too. Other researchers agree with the perspective that the amplitude of hyoid laryngeal excursion is not altered in the swallowing of individuals with OSA. Ellis et al. did not find differences in laryngeal elevation nor in hyoid bone excursion between individuals with OSA and those in control group[35]. Besides the vertical and horizontal excursion of hyoid laryngeal complex, the other components that contribute to UES opening are: UES relaxation, UES distensibility and the pressure imparted from within to the UES wall[30]. Alterations in any of these components may result in pharyngeal residue[30]. Thus, another aspect that may be involved in the exhibition of pharyngeal residue in this population is related with the pharynx function. Some authors highlight the importance of intrabolus pressure transmitted from the base of the tongue and pharynx in UES opening[36]. Considering the muscle alterations in the pharynx of individuals with OSA,[37] this action may be damaged in these individuals. Besides that, a possible interference mechanism in UES opening in this population may be also related with consequences of gastroesophageal reflux disease (GERD). This is due to OSA association with a higher risk of GERD[38] and some researchers presume that the chronic exposure to acid in the esophageal body probably causes hypertonicity of the UES[39].

Researchers related IF with laryngeal descent in the end of swallowing[34]. Our results show that IF is lower in individuals that exhibit pharyngeal residue compared with those that do not exhibit residue, what suggests a weaker force in larynx return movement in individuals that present pharyngeal residue. In line, another study found a lower IF average in the group with oropharyngeal dysphagia compared with control group[23].

Abdulmassih et al.[23] reveal that individuals with oropharyngeal dysphagia present a lower T compared with control group. Our study found similar results: in some bolus there was statistically significant differences in T value, being lower in individuals that exhibit pharyngeal residue compared with those that do not exhibit such alteration. Thus, individuals that present pharyngeal residue exhibit a shorter time range between the beginning of the pharyngeal phase and larynx return to the end of the pharyngeal phase of swallowing. A possible explanation is that the time reduction of the pharyngeal phase reduces the time of one or more events of this phase (UES opening time, for example) what may result in pharyngeal residue. Strengthening this hypothesis, a study revealed that the support time of hyoid bone excursion, considered an important mechanism to maintain UES opening, was significantly shorter in individuals with OSA compared with control group[7]. In addition, considering the GERD risk in this population[38], researchers point out that the duration of cricopharyngeal muscle relaxation during swallowing, an important mechanism for UES opening[30], is shorter in individuals with mild GERD compared with individuals without GERD[40].

Independently of bolus volume and consistency, our results show that frequency of penetration/aspiration was lower in this population, what represents a study limitation to evaluate a relation between acoustic analysis of swallowing and penetration/aspiration. FEES presents some limitations, such as impossibility of assessing the oral phase and loss of events during white-out. According to some researchers, FEES allows a partial assessment of the oral phase[29] due to observation of the tongue posterior third[29], tongue base movement[33] and ability to keep the bolus contained in the oral cavity during the oral phase[26,29]. Regarding the difficulty of assessing penetration/aspiration during deglutition, we followed the recommendations in literature to minimize it using food coloring to ease bolus visualization[33]; the evaluation of the exam frame by frame, since the events in the pharyngeal phase are very fast[29]; in addition to the protocol suggested by Hiss and Postma in which, after deglutition, the endoscope must be placed in the larynx to observe traces not seen before white-out but when white-out is released characterizing penetration/aspiration during deglutition[26]. We understand that episodes of penetration/aspiration which may have occurred during white-out without resulting in traces in the larynx or trachea were not detected, therefore being another limitation of the study. Another study shortcoming is related to the sample size that makes it impossible to generalize the results.

Finally, the importance of identifying physiological abnormalities that result in unsafe swallowing, such as aspiration and pharyngeal residue, is highlighted in the evaluation of dysphagia[41]. Therefore, we suggest the development of studies that investigate the correlation of synchronous swallowing acoustic tracing with physiological and pathophysiological events of the pharyngeal phase of swallowing in the population of individuals with OSA. This would make it possible to elucidate, through a low-cost instrument, swallowing disorders, the moment when they occur and physiological causes of these disorders.

CONCLUSION

The results of this study indicate a relationship between acoustic analysis of swallowing, using a Doppler sonar, and the pharyngeal residue detected by FEES in resistant hypertensive patients with OSA. The acoustic parameters that differ between individuals that present pharyngeal residue and those who do not, are FI, II, F2P and IF. However, there is not a relationship between parameters of acoustic analysis of swallowing considered in this study and the penetration/aspiration detected by FEES in this population.

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