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Swallow Respiratory Patterns and Aging: Presbyphagia or Dysphagia?

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Background. Assessment referrals are increasing for unexpected dysphagia, particularly for older people. It is unclear if this is due to more impaired swallows or healthy age-related changes. Swallow respiration coordination prevents aspiration, and may deteriorate with age. Nonpathological features of the swallow in healthy aging and the factors that influence an individual's ability to eat and drink safely need greater understanding. Some changes might predispose an older person to dysphagic complications in the event of an insult such as a stroke. We investigated the effects of healthy aging on resting and swallow respiratory patterns.

Methods. Fifty healthy volunteers (aged 20–78 years) were recruited to have swallow respiration patterns recorded on a computer. Bolus volume and consistency variations were studied: 5 and 20 ml of water and 5 ml of yogurt.

Results. Measurable swallows significantly decreased with age for water boluses. Swallow apnea increased with age (5 ml of water $r = 0.433$, $p = .002$; 5 ml of yogurt $r = 0.367$, $p = .023$). Independent of age were: breathing out (occurred after 98% of boluses); multiple swallowing (occurred with all bolus types); postswallow respiration reset pattern (more irregular after yogurt, Wilcoxon signed rank $Z = -2.236$, $p = .025$); and resting respiration.

Conclusions. Subtle changes occur in swallow respiration coordination with age. These changes may be compensatory protective mechanisms rather than the result of decreased muscle mobility or reaction times, and not indicative of impairment. Misattributing healthy age-related changes to impairment affects patient care and the use of healthcare resources.

An increasing number of older people referred for swallowing assessment would not be expected to have dysphagia as part of their primary disorder—for example, patients admitted with hip fractures. It is unclear whether these patients have pathologically disordered swallows or healthy age-associated changes to function.

Dysphagia is a serious consequence of neurological disorders such as stroke (1). In 2000/2001 there were over 76,000 admissions for stroke in the United Kingdom (2). Persons aged 75 years or older accounted for 60% of finished consultant episodes (2), showing the serious result of secondary aging and the increase in prevalence of diseases that influence swallowing. Presbyphagia, changes in the swallow mechanism with age, may compound the risk for aspiration; this risk will increase as the mean age of the population shifts upwards.

Age-related changes occur in swallowing physiology. Primary aging causes change in the structure, motility, coordination, and sensitivity of the swallow process (3–7). Some of these changes may contribute to dysphagia, or perhaps more accurately *presbyphagia.* Respiration and swallowing are inextricably linked, using the same structures requiring fine coordination of the two processes. Efficient transport of food and drink to the esophagus has to co-occur with maintenance of a safe airway and prevention of material entering the lower respiratory tract. There is less evidence on the influence of age on swallow respiration patterns, but it does appear to contribute to an increased risk of aspiration (8,9). Complications due to aspiration are just one facet of nutrition and/or hydration issues in elderly persons. Increased knowledge is needed on what represents a pathological impairment and what is a harmless feature of aging to ensure appropriate management. The aim of this study was to investigate the effects of healthy aging on respiratory patterns at rest and surrounding the swallow.

Methods

Study Group

Fifty healthy volunteers were recruited (31 women) with as wide an age range as possible (20–78 years). Although we are interested in swallow features in older people, we must have young normative data for comparison. The group comprised hospital staff, relatives, and friends. Exclusion criteria were history of dysphagia/eating/drinking difficulties, neurological impairment, current medical conditions requiring medication, or structural abnormalities that affect the swallowing or respiratory systems.

Ethical Approval and Consent

Written informed consent was obtained for all participants in the study. The Newcastle and North Tyneside Joint Ethics Committee granted ethical approval for the study.

Equipment

Our system is based on a Pentium notebook computer (Toshiba, Tokyo, Japan), using an analogue-digital converter

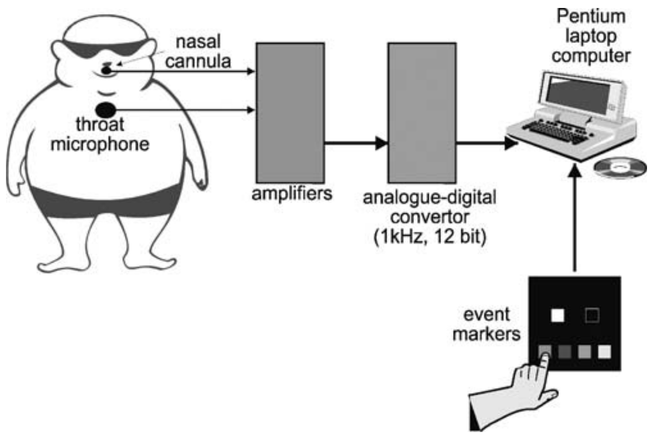

Figure 1. Schematic illustration of equipment.

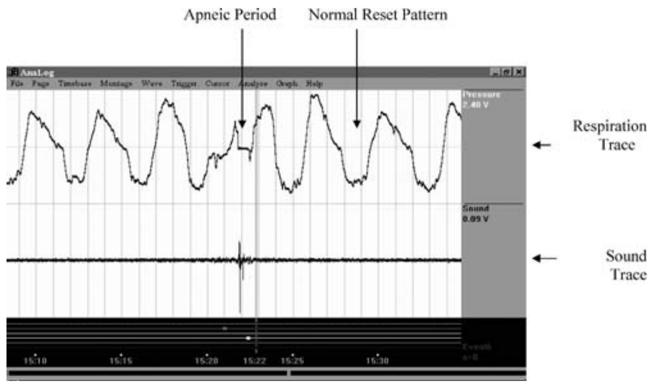

Figure 2. Respiration trace as seen on notebook screen.

(DAQcard 700; National Instruments, Austin, TX) and C++ programming language. Respiratory airflow was measured via a nasal cannula and an external pressure transducer (Gaeltec, Dunvegan, Scotland) (10). Sound was recorded from a throat microphone (Medical Physics, Freeman Hospital) (Figure 1). Both signals were sampled at 1000 Hz, and then down-sampled to maximum and minimum values at 100 Hz. The easily portable system fits into a computer case.

Procedure

Volunteers were seen in the hospital's Speech-Language Department or in their homes. The same researcher conducted all studies whether hospital or home based. The apparatus is noninvasive, and no overt signs of tension were observed during any recording. Resting respiration was recorded for 10 minutes following 5 minutes of familiarization with the equipment and quiet breathing. Ten boluses each of 5 ml of water, 20 ml of water, and 5 ml of yogurt were presented to the participants.

Water was measured by graduated syringe into a small plastic cup; the participant was asked to drink the entire contents in one swallow to mimic real drinking as closely as possible. Injecting water into the mouth may affect the timing of the swallow within the respiratory cycle, whether or not you are then allowed to swallow at will. We were trying to make the situation as normal as possible, so it was important not to make the person too conscious of their swallow and affect the natural respiratory pattern.

Yogurt was measured using a 5 ml medicine spoon calibrated with a graduated syringe. Training was provided in how to obtain a standard 5 ml, and then participants fed themselves in the same way as for the water, with the researcher checking that bolus size was standard. For all bolus types, some values could not be measured. If, for example, a person stopped breathing for a period around the actual swallow apnea or they consciously modified swallow-respiration as one or two reported, data could not be recorded or used. Initially we intended to use 20 ml of yogurt, but participants found it difficult to swallow in one mouthful, so 5 ml of yogurt was used.

Respiratory Analyses

At rest.—Each respiratory cycle was measured from the definitive inspiration–expiration boundary, which is reliably identified. The cycles were analyzed in sets of five to enable a measure of regularity to be calculated: the coefficient of variation.

$$\text{Coefficient of Variation} = \frac{\text{RMSSD}}{\text{mean respiratory cycle length}} \times 100\%$$

where RMSSD is the root mean square of successive differences calculated by:

$$\text{RMSSD} = \sqrt{\left\{\left[\sum(\text{difference in successive breaths})^2\right]\Big/(n-1)\right\}}$$

This allows a measure of regularity independent of the mean cycle length. If a confounding event occurred, for example, a cough or talk, then that data set was ignored. Measurements recommenced after five cycles to allow reestablishment of the resting respiration pattern.

Measurable swallows.—In most studies, data are ''lost'' because they cannot be analyzed. Some swallows were not measurable because of confounding factors, piecemeal swallows (where the bolus is ingested as several small bits), or because the participant was not breathing out through the nose (so breath direction could not be assigned). Initial examination of the data suggested a relationship between age and the number of boluses that could have their features ''measured.'' We investigated the number of swallows that could be characterized as a proportion of the total number of boluses given; data are presented as percentages.

Swallow apnea.—The respiratory trace was recorded before, during, and after swallowing. Apnea duration was measured by the length of zero airflow on the respiratory trace (Figure 2). The small apparently inspiratory ''breath,'' which often accompanies the apnea, was included in the timing. This is rarely reported in studies of swallow

Table 1. Healthy Resting Respiration Parameters Correlated With Age

Parameter	N	Mean (SD)	Range	Pearson's r (95% CI)	p Value
Age, y	50	47 (19)	20–78	—	—
Cycle length, s	48	3.91 (0.69)	3.18–6.78	0.12 (−0.17, 0.39)	0.41
Resting rate, breaths/min	48	16 (2)	9–19	−0.12 (−0.39, 0.17)	0.42
Coefficient of variation, %	48	11 (5)	5–28	0.04 (−0.25, 0.32)	0.79

Note: SD = standard deviation; CI = confidence interval.

respiration, probably due to the respiration recording technique rather than to the infrequency of the occurrence. Changes in the position of the structures postswallow cause a partial vacuum, and pressure drops (11). Measuring breath direction with a pressure-sensitive device can give an apparent ''airflow'' reading when the patient is in fact apneic. If a confounding event occurred within five cycles of the start of a swallow, then it was not analyzed.

Postswallow breath direction.—Airflow direction postswallow was noted for all boluses. Breathing in after a swallow is rare in the healthy population (8), but there is evidence that this changes with age (12). Results are presented as percentage of boluses after which the person breathed out (for each bolus type). A person who breathed out after 7 of 10 yogurt boluses was classified as having 70% postswallow expiration.

Multiple swallowing.—A bolus was classified as having multiple swallows if one or more swallows occurred within four respiratory cycles after the main apnea (excluding piecemeal swallows or swallows during which some of the bolus remained in the cup/spoon). Results are presented as percentages of boluses after which the person swallowed multiple times (for each bolus type). A person who swallowed multiple times after 7 of 10 yogurt boluses was classified as being 70% multiple swallowing.

Breathing reset pattern.—The reset pattern for respiration was classified as normal or abnormal for each person. Respiration generally switched back to a typical sine-type wave very soon after the end of apnea (Figure 2). This was assessed for 5 ml of water and 5 ml of yogurt. If the reset pattern did not return to a typical sine wave, it was classified as abnormal.

Data Collection/Statistical Analysis

Data were entered into an Excel 2000 (Microsoft, Redmond, WA) spreadsheet and analyzed with SPSS for Windows (Release 11.0; Chicago, IL). Parametric tests including Pearson's correlation (r) were used, because the results were normally distributed. For the categorical breathing reset pattern, nonparametric Spearman's correlation (r_s) and Wilcoxon signed rank test were used. Results were accepted as statistically significant at the 5% level of probability.

Table 2. Proportion of Swallows During Which Feature Could Be Measured Correlated With Age

Parameter	N	Mean % (SD)	Pearson's r (95% CI)	p Value
Breath out PS, 5 ml of water	49	84 (21)	−0.402 (−0.61, −0.14)	.004
Breath out PS, 20 ml of water	47	73 (33)	−0.277 (−0.52, 0.01)	.059
Breath out PS, 5 ml of yogurt	42	75 (31)	−0.019 (−0.32, 0.29)	.907
Multiswallow PS, 5 ml of water	49	84 (21)	−0.398 (−0.61, −0.13)	.005
Multiswallow PS, 20 ml of water	47	73 (31)	−0.318 (−0.55, −0.03)	.029
Multiswallow PS, 5 ml of yogurt	42	75 (31)	−0.018 (−0.32, 0.29)	.911

Note: SD = standard deviation; CI = confidence interval; PS = postswallow.

Results

At Rest

Two people were excluded because they were mouth breathing, and the direction of nasal airflow could not be measured. In the remainder of the participants, age was not significantly correlated with any of the resting respiration characteristics (Table 1).

Measurable Swallows

As age increased, fewer swallows could be analyzed. The number of swallows during which airflow direction postbolus could be measured had a significant negative correlation with age for the 5 ml water bolus, but was only approaching a trend with 20 ml of water (Table 2). With multiple swallowing postbolus, there was a significant negative correlation between the number of analyzable swallows and age for the 5 ml and 20 ml water boluses (Table 2).

Swallow Apnea

Mean apnea increased significantly from 0.74 to 0.86 seconds (p = .001) with increased volume but not with change in consistency (p = .520). A significant, positive correlation was found between age and duration of swallow apnea for both the 5 ml water boluses and 5 ml yogurt boluses (Table 3). The statistical significance of this relationship was not maintained with 20 ml of water, which had a wider range and standard deviation of apnea duration. Each individual showed a significant correlation between

Table 3. Health Swallow Apnea Correlated With Age

Parameter	N	Mean (SD)	Range	Pearson's r (95% CI)	p Value
Age, y	50	47 (19)	20–78	—	—
Apnea (5 ml of water), s	48	0.74 (0.17)	0.41–1.56	0.433 (0.17, 0.64)	.002
Apnea (20 ml of water), s	40	0.86 (0.28)	0.53–2.05	0.223 (−0.08, 0.51)	.167
Apnea (5 ml of yogurt), s	38	0.73 (0.19)	0.37–1.58	0.367 (0.05, 0.61)	.023

Note: SD = standard deviation; CI = confidence interval.

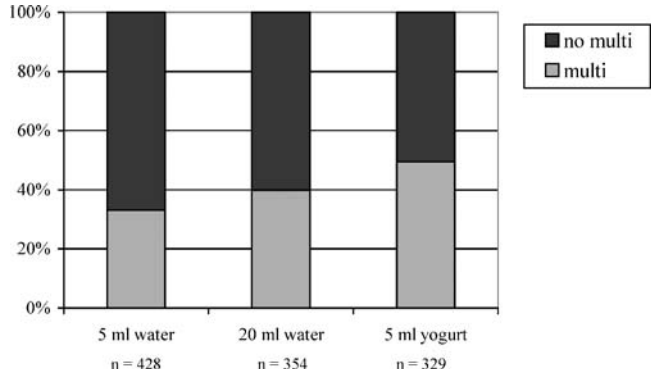

Figure 3. Boluses followed by multiple swallowing by bolus type.

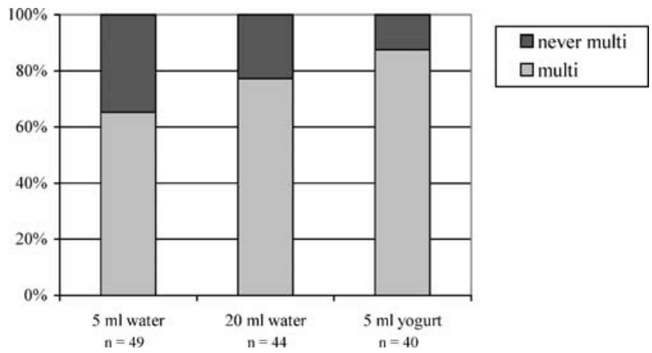

Figure 4. People exhibiting multiple swallowing by bolus type.

apnea duration on 5 ml of water and each of the other bolus types; these data have been reported previously (13).

Postswallow Breath Direction

Most people always breathed out after swallowing: 1095 of the 1113 boluses (98%) across the three types were followed by an out breath, with no significant difference between bolus types. For each bolus type, only 2 or 3 of the 40+ people ever breathed in after swallowing, and it was not the same people. There was a significant correlation between a person's breath direction on 5 ml of water and each of the other bolus types but, given the considerable positive skew toward breathing out postswallow, this is unsurprising. Age was not correlated with airflow direction postswallow.

Multiple Swallowing

The proportion of boluses followed by multiple swallowing increased as the bolus type changed from 5 ml of water to 20 ml of water to 5 ml of yogurt ($\chi^2 = 20.8$, $p = .00003$, Figure 3). The proportion of people multiple swallowing also increased ($\chi^2 = 6.0$, $p = .05$, Figure 4). Each individual had a strong correlation between multiple swallowing on 5 ml of water and 20 ml of water ($n = 44$, $r = 0.684$, $p < .001$) and between 5 ml of water and 5 ml of yogurt ($n = 40$, $r = 0.753$, $p < .001$). Age was not significantly correlated with multiple swallowing.

Breathing Reset Pattern

Some people had an unusual respiration reset pattern: irregular or prolonged. The multiple swallowing judgment sometimes precluded that of the reset pattern. A normal reset pattern (Figure 2) was shown by 41 of 49 (84%) people after 5 ml of water compared with 30 of 42 (71%) people after 5 ml of yogurt. Individuals had a high correlation of reset pattern between 5 ml of water and 5 ml of yogurt with $r_S = 0.641$, $p < .001$ ($n = 42$). The Wilcoxon signed rank test gave a significant difference for the reset pattern, depending on bolus type with $Z = -2.236$, $p = .025$ ($n = 42$). There was no evidence of age affecting respiration reset patterns.

Discussion

This is one of the largest studies to investigate the effects of healthy aging on swallow respiratory patterns across a wide age range of men and women. Subtle but distinctive changes in swallow function occur with age. To our knowledge, this is the first study to investigate the effect of advancing age on the "measurability" of swallow respiration features. The increase in unclassifiable swallows suggests delicate changes in swallow respiration coordination. Subtle variation in the swallow process due to aging (presbyphagia rather than dysphagia) exists, but the overall coordination of the swallow is preserved (14).

This group is one of the largest to provide supporting evidence of increasing apnea duration with age (8,15). Such a change may be a protective mechanism rather than solely a result of decreased muscle mobility or reaction times. This increased duration of apnea may enable the system to compensate for other age-related changes such as longer oropharyngeal and hypopharyngeal transit times (3) and delayed initiation of maximum hyolaryngeal excursion (16). Vocal cord closure is one of the primary airway-protective mechanisms against aspiration of foreign material. Airway protection must be maintained while the bolus is passing through the pharynx, i.e., bolus transit time is less than that of vocal cord adduction (17). Reducing the margin of safety between the two increases aspiration risk. The lack of correlation between age and apnea duration on 20 ml of water may indicate that the bolus is approaching a size at which respiration patterns become unstable or that a larger bolus is required to maintain an age-independent swallow mechanism. This would fit with sensation decreasing as we age, and so older people need larger, more flavorsome boluses (not the opposite, as has been traditionally thought).

Some gross features of the swallow respiration pattern, such as breath direction and multiple swallowing postbolus, are unaffected by age. Multiple swallowing is more common in general with yogurt (13), which may mask age effects. Resting respiration patterns do not appear to change with age. This may be constant for an individual, independent of age. The observed changes seem confined to swallow respiration patterns. Yogurt bolus characteristics may also hide age effects on measurability: subtle changes with age concealed by the powerful reactions of multiple swallowing and increased salivation to a sticky, acidic substance.

Changes in the swallow process with age may predispose individuals to be at risk of dehydration, malnutrition, dysphagia, and aspiration. Malnutrition is increasingly being identified in the community and in patients on admission to hospital (18), and is interlinked with dysphagia in a vicious cycle (19). Dysphagia obviously affects nutrition, but malnutrition can exacerbate dysphagia or cause a borderline swallow to decompensate.

Changes with age may not be pathological. What we categorize as a poststroke impairment may simply be a feature of increased age. Clinically, it is important to distinguish these. Older people are at risk of malnutrition for a variety of reasons, including low socioeconomic status and difficulties with activities of daily living (20). They may simply be too weak to eat the meal or so slow it becomes unpalatably cold (21). Restricting oral intake is a serious step in terms of nutrition and cost (for example, that of food supplements). Clinicians should be very cautious about taking such action with a population already at risk of malnutrition, especially considering that the evidence for poor outcomes with aspiration is far more limited than that for the effects of malnutrition.

This study contributes to the small body of knowledge on how the healthy swallow changes with age. We have established some features that remain constant and some that are age dependent. These may be confused with pathological sequelae. Clinicians need to increase their awareness of what is normal as the patient gets older to identify problems earlier and to prevent decline. The field of healthy swallowing is an under-researched area, particularly with respect to the effects of aging. We need to modify our current thinking on the swallow: are all of the changes we observe in the 85-year-old poststroke patient due to dysphagia or simply oropharyngeal presbyphagia? We must increase our knowledge of the effects of presbyphagia on the increasing healthy older population and the effects of dysphagia in these people as they succumb to age related illnesses.

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