Dysphagia 17:202–207 (2002)
DOI: 10.1007/s00455-002-0053-8

Dysphagia

Swallow Respiration Patterns in Dysphagic Patients Following Acute Stroke

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Abstract. The aim of this study was to examine swallow respiratory characteristics using a notebook computer system. A relatively simple system assessing easily identifiable features is more likely to be incorporated into everyday clinical practice. Eighteen patients (age range = 51–82 years) with dysphagia poststroke and 50 healthy volunteers (age range = 20–78 years) were recruited. The patient group was less likely to always breathe out postswallow on water (9/15 cf 46/49), and some did not breathe out immediately postswallow at all (3/15 cf 0/49, $p < 0.01$). The pattern was similar with yogurt. Multiple swallowing was identified in the patient group and surprisingly with a large number of the volunteers for all bolus types but was more common in the patient group ($p < 0.01$). This trait is usually attributed to impaired swallows; that it is prevalent in the normal population has implications for using it as a dysphagia marker in clinical assessments. Yogurt has intrinsic features that increase multiple swallowing and caution should be used when identifying an impairment based on multiple swallowing with such a test substance. In the control group there was a high correlation of swallow apnea on 5 mL of water compared with 20 mL of water ($r = 0.759$, $p < 0.01$) and 5 mL of yogurt ($r = 0.871$, $p < 0.01$), indicating a possible individual swallow respiration pattern. This was also evident in the patient group. No significant difference in length of swallow apnea was found between the two groups. No evidence was found to link swallow respiration characteristics with aspiration as identified on simultaneous videofluoroscopy. The patient group had a wide range of impairments which suggests that stroke severity is not the sole determinant of swallow respiratory changes.

Key words: Respiration — Swallowing — Videofluoroscopy — Dysphagia — Stroke — Deglutition — Deglutition disorders.

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Swallowing and respiration use the same structures and hence require a fine degree of coordination. This is an area of increasing research. There are few studies with control groups who are of a clinically relevant age for stroke [1]. Variation exists in methodology and specific foci of studies, so comparison is difficult. The type of bolus affects swallow respiration in the normal population [2]. Neurological disease and concomitant dysphagia are linked to changes in swallow respiration [3]. Respiration disturbance may be one factor that increases the risk of aspiration. Simultaneous videofluoroscopic swallow study (VFSS) and respiration monitoring is rare but has shown changes in swallow respiration poststroke [4].

The aim of this study was to characterize the swallow respiratory patterns in patients with poststroke dysphagia and those of a control group of healthy volunteers. Simultaneous VFSS would be performed on the patient group to increase the data obtained. This study was performed in conjunction with the preceding article [5].

Study Groups

Controls

Fifty healthy volunteers were recruited to act as the control sample, with an age range (20–78 years) selected to include the clinical population (see preceding article [5]). Exclusion criteria were previous history of dysphagia or eating/drinking difficulties, neurological impairment, current medical conditions requiring medication, or structural abnormalities that could affect the swallowing or respiratory systems.

Dysphagic Stroke Patients

Over a 12-month period, 18 dysphagic stroke patients (age ranges = 51–82 years) who failed a clinical swallow assessment were recruited [5]. Exclusion criteria were general medical unfitness, neurological condition other than stroke, methicillin-resistant *Staphylococcus aureus* infection, previous history of dysphagia, or involvement in other studies. Some suitable patients were transferred or discharged within a few days and before the respiratory study could be performed. The patients were studied a minimum of 48 hours poststroke. This allowed the physical system to stabilize and aimed to reduce the anxiety that the patient might experience poststroke.

Clinical Stroke Assessment

As part of the clinical routine, specialist stroke staff completed a standard stroke pro forma assessment form when the patient was admitted to the hospital. Details of the assessment were made available to the researcher. These included Bamford classification, Scandinavian Stroke Score (SSS), previous history of dysphagia, and other medical information. The patient's nurse calculated the Barthel Index (BI) on the day of the assessment.

Clinical Swallow Assessment

The patient was assessed for swallow function and recruited to the study if considered at risk of aspiration [5].

Ethical Approval and Consent

Written informed consent was obtained for all participants involved in the study. For those patients with language disorders (dysphasia), consent was obtained from the next of kin and the researcher explained the study as far as possible to the patient with gesture and modified language. The Newcastle and North Tyneside Joint Ethics Committee granted ethical approval for the study.

Method

Equipment

Our system is based on a Toshiba notebook computer with a Pentium processor (Intel, Santa Clara, CA) and is easily portable [5]. Respiratory airflow was measured via a nasal cannula and an external pressure transducer and sound was recorded from a throat microphone to mark the moment of swallow. Markers were recorded to signal entry of the bolus to the mouth and lifting of the larynx to identify the moment of swallow.

Procedure

The respiratory apparatus is noninvasive and no overt signs of tension were observed during any recording. Healthy volunteers attended the Speech and Language Department at the hospital or were seen in their own homes. Five boluses each of 5 mL of water, 20 mL of water, and 5 mL of yogurt were presented to the control group. Patients were seen in the X-ray department where respiratory recording was performed during the VFSS. The patients received up to 5 each of the trial boluses, but this was reduced if they were seen to be aspirating on VFSS. Use of the term "water" with the patients refers to a standardized runny barium sulfate contrast liquid of 52% weight/volume. This was the most dilute material that could still be imaged clearly on VFSS but is still not rheologically identical to water.

The water was measured by graduated syringe into a small plastic cup and the participant was asked to drink the entire contents in one swallow. This was done in order to try to mimic real drinking as closely as possible. Injecting the water into the mouth may affect the timing of the swallow within the respiratory cycle, whether or not a person is then allowed to swallow at will. Participants were requested to swallow the water in a single mouthful.

Yogurt was measured using an accurate 5-mL medicine spoon. Members of the control group were trained to obtain a standard 5-mL spoonful and were able to feed themselves in the same manner as that outlined for the water boluses, with the experimenter checking that bolus size was standard. The patients were aided by the speech and language therapist. This involved supporting the cup/spoon or feeding the patient but letting the patient guide the process.

The boluses were presented in the same order to all participants. To avoid "learner" effects or fatiguing, the boluses would ideally have been presented in a random order. This was not possible as the patients had the materials presented in the standard order for a VFSS. The control group had to have their boluses in the same order, i.e., 5 mL, of water, 20 mL of water, and 5 mL of yogurt. Analysis of data on the development of the system indicates, however, that there were no learner or fatiguing effects in any case.

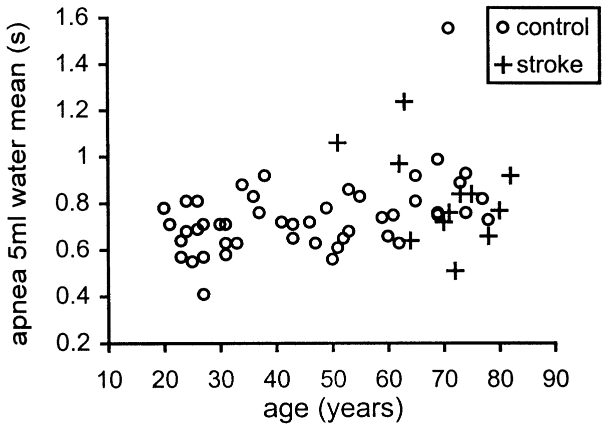
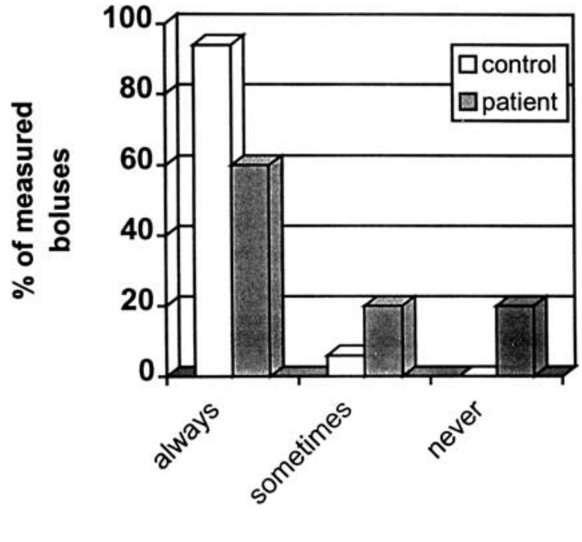


Fig. 1. Apnea duration on 5 mL of water: the effect of age.



Fisher's exact test p<.01

Fig. 2. Expiration after 5-mL water bolus.

Respiratory Analysis

The respiratory trace was recorded before, during, and after the swallow. The duration of the swallow apnea was measured by noting the length of the zero airflow on the respiratory trace. A small inspiratory or expiratory "breath," the *Schlucktamung*, often accompanied the swallow apnea and was included in the timing. The cause of this apparent airflow is not clear but it appears likely to be due to movement of oropharyngeal structures and a corresponding pressure change rather than a true flow of air in to or out from the lungs [6]. If a confounding event, e.g., cough, talk, or dry swallow, occurred within five cycles of the start of a swallow, then it was not analyzed.

The direction of airflow postswallow was noted for all boluses. Breathing in after a swallow is very rare in the normal population and represents a risk factor for aspiration. A bolus was classified as having multiple swallows if one or more swallows occurred within four respiratory cycles after the main apnea. This excluded piecemeal swallows or where some of the bolus remained in the cup/spoon.

Data Collection/Statistical Analysis

Data were entered into an Excel 97 spreadsheet (Microsoft Corp., Redmond, WA) and analyzed with SPSS for Windows (7.5) (SPSS, Inc., Chicago, IL) and Stata (Stata Corporation, College Station, TX) packages. Parametric tests were used as the results were normally distributed. The group mean values were compared using analysis of covariance to allow for the effect of age on the swallow apnea. Correlation of the swallow apnea on 5-mL water bolus with 20-mL water bolus and 5-mL of yogurt bolus was performed using Pearson's coefficient. Fisher's exact test was used to test for significant differences in the postbolus respiration direction and multiple swallowing. Student's *t*-test was used to investigate the differences between aspirators and nonaspirators in the patient group. Results were accepted as statistically significant at the 5% level of probability.

Results

The patients poststroke had wide ranges of neurological impairment (SSS range = 6–51) and disability (BI range = 2–20), indicating that dysphagia—and hence the risk of aspiration—was not solely dependent on the stroke severity. Full details of the patient characteristics are given in the preceding article [5].

The 20-mL water bolus test was stopped for all but two of the patients as clinical and/or VFSS evidence indicated that it would not be in the patients' best interests to continue. Thus, the analyses for this bolus size were limited. With all bolus types some values could not be measured; for example, if a person stopped breathing for a period of time around the actual swallow apnea or if a person consciously modified swallow respiration, as one or two people reported doing. Initially we intended to use 20 mL of yogurt rather than 5 mL. Members of the control group tried the former but they found it difficult to manage, so 5 mL of yogurt was used with all the other participants.

Swallow Apnea

The effect of age on swallow apnea was investigated and found to be a significant covariate for apnea duration with 5 mL of water ($p = 0.02$) and marginally significant with 5 mL of yogurt ($p = 0.06$). Mean apnea duration tended to increase with age regardless of whether the person had a stroke or not (Fig. 1). The two groups were compared while adjusting for the effect of age. There were no significant differences between the control group and the patient group. With 5 mL of water, the mean apnea duration

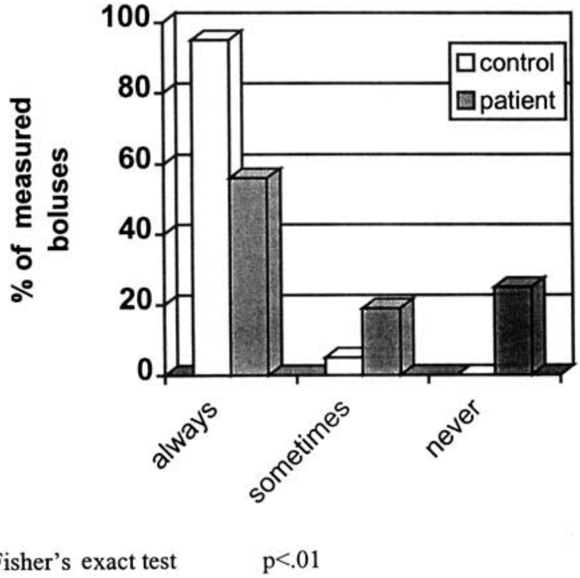


Fig. 3. Expiration after 5-mL yogurt bolus.

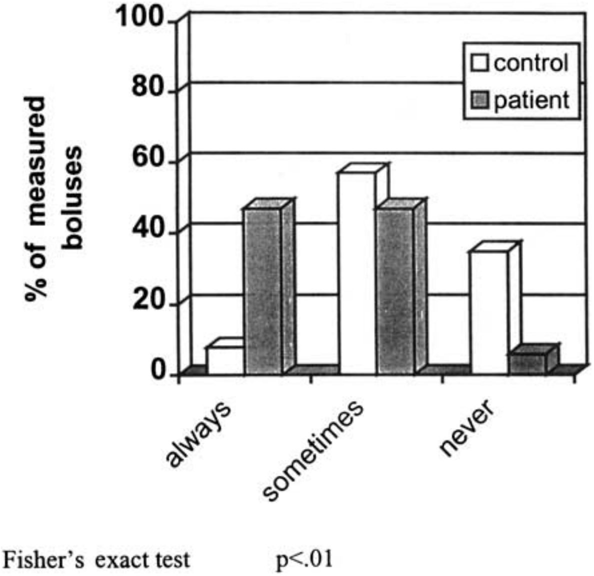


Fig. 4. Multiple swallows after 5-mL water bolus.

was 0.76 s (SE = 0.03) for the control group (n = 48) and 0.77 s (SE = 0.05) for the patient group (n = 12), 95% confidence interval = -0.12–0.13. With 5 mL of yogurt, the mean apnea duration was 0.75 s (SE = 0.03) for the control group (n = 38) and 0.69 s (SE = 0.06) for the patient group (n = 13), 95% confidence interval = -0.08–0.21.

Positive Pearson's correlations were found in the control group between apnea duration with 5 mL of water with that of 20 mL of water (n = 40, r = 0.759, $p < 0.01$) and also 5 mL of yogurt (n = 38, r = 0.871, $p < 0.01$). This was also evident in the patient group data for the 5-mL of water and 5-mL yogurt swallows (n = 10, r = 0.956, $p < 0.01$).

Postswallow Respiration Direction

Significantly fewer patients always breathed out postswallow, whether it was after water or after yogurt, and some did not breathe out immediately postswallow at all (5 mL water bolus: control n = 49/50, patient n = 15/18; 5-mL yogurt bolus: control n = 40/50, patient n = 16/18). Figures 2 and 3 show the proportional patterns for 5 mL of water and 5 mL of yogurt, respectively, for the boluses that could be measured. Fisher's exact test was used and $p < 0.01$ for both cases.

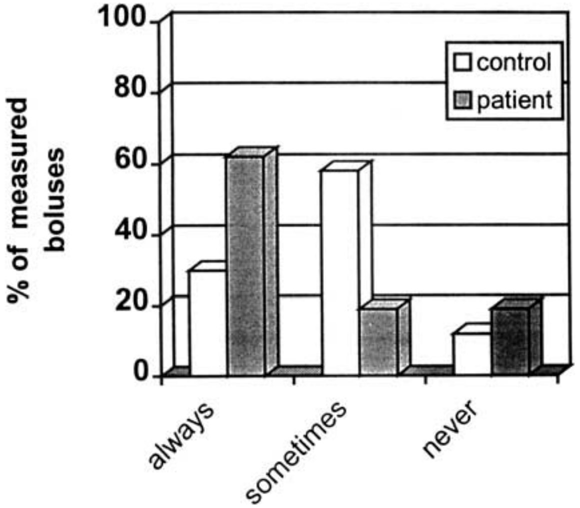
Postbolus Multiple Swallowing

Multiple swallowing postbolus was common in both groups. A significantly higher number of the patient group always swallowed more than once on water and yogurt (5-mL water bolus: control n = 49/50, patient n = 15/18; 5-mL yogurt bolus: control n = 40/50, patient n = 16/18). Figures 4 and 5 show the proportional patterns for 5 mL of water and 5 mL of yogurt, respectively for the boluses that could be measured. Fisher's exact test was used and $p < 0.01$ for both cases.

Respiration Monitoring and Improved Prediction of Radiologically Defined Aspiration

All members of the patient group had their swallows recorded as part of a VFSS. VFSS was performed between 4 and 28 days postonset of stroke. Of the 18 patients, 11 aspirated on 5 mL of water and 7 aspirated on 5 mL of yogurt, and 6 out of the 7 aspirated on both. The numbers in each group are small so only highly significant differences are likely to show up. Most patients had several boluses of each consistency and they were classified as an aspirator if they aspirated on any of the boluses. Water aspiration was classified separately to that for yogurt.

The following factors were assessed to see if they were risk factors associated with aspiration as detected on VFSS: age, existing apneic breathing pattern, resting respiration characteristics (cycle length, coefficient of variation), postswallow characteristics (direction of breathing, reset pattern), and clinical (Scandinavian Stroke Score, Bamford Classification, number of items failed in the clinical swallow screen). Duration of the swallow apnea was



Fisher's exact test p<.01

Fig. 5. Multiple swallows after 5-mL yogurt bolus.

not included as it did not differ between the control and patient groups. There was no significant difference between the water and yogurt consistencies. There was no significant difference between patients with or without radiologically defined aspiration for any of the factors investigated.

Discussion

The system used in this study has no radiation risk and is noninvasive, unlike VFSS or endoscopy. VFSS is considered to be the "gold standard" in identifying aspiration, although there is some debate about how this links to chest infections and morbidity. We hoped to be able to link features of the swallow respiratory pattern with radiologically defined aspiration. This might have future potential as a screening tool to identify those at greater risk of aspiration but this was not demonstrated in our study. Members of the patient group did not manage all of the bolus types. Of the swallows recorded, some could not be analyzed which further reduced the data set. VFSS assessment for thin liquids often uses dilute barium sulfate solution. There is a limit to how watered down the contrast material can be and still give a clear image. Barium sulfate tends to remain a sticky liquid and so feels different than water. This has consequences in terms of the advice being offered on the competence of a patient's swallow with regard to "thin" or "normal" liquids.

The effect of stroke on the duration of the swallow apnea is still an area under investigation [4,7,8]. No significant difference in the duration of swallow apnea was found in this study. The patient group number was small and therefore may have influenced the significance of the results.

The high degree of correlation between the swallow apnea with 5-mL of water and 20 mL of water or 5 mL of yogurt in the control group suggests that there is an individual swallow respiration pattern. This may be subject to a degree of peripheral modification by bolus characteristics and affected more by volume than consistency variation. The existence of such an individual pattern may present a further risk for aspiration if it is disturbed poststroke. Interestingly, in this study the respiration patterns appeared to be maintained.

The inclusion of a nondysphagic poststroke group would have been of interest as it could be argued the swallow respiration changes are simply due to a person having had a stroke. The dysphagic group had a broad and representative range of stroke severity.

As previous studies [2,9,10] have found, the healthy population tends to breathe out postswallow rather than in. The data are more variable on healthy people who never breathe out postswallow. There are few long-term studies and Hadjikoutis et al. [7] did not find evidence for pneumonia or survival being linked to postswallow respiration direction over 12–18 months poststroke.

Multiple swallowing after a single bolus was found to be common in the patient group and surprisingly in the control group. Multiple swallowing poststroke is rarely reported on [7,11] and yet it is often said to signal an impaired swallow. Over half of the healthy volunteers showed multiple swallowing with 5-mL water boluses and even more so with 5-mL yogurt boluses. That multiple swallowing occurs in the healthy population should make us more cautious when citing multiple swallowing as a problem in a clinical bedside assessment. It may be a protective mechanism.

During bedside and other swallow assessments, yogurt or apple sauce is often used. Several healthy volunteers reported that the yogurt actually made them want to swallow more. This was due to (a) the "stickiness" of yogurt which seemed to require several swallows to clear it from the oropharyngeal tract; (b) the acidity of the substance made people salivate more, which again caused more swallowing. In a clinical assessment, we are giving the patient a substance that is possibly more likely to make them multiple swallow, then we identify this as a factor indicating possible impairment.

From this study there is evidence of significant differences between the swallow respiration patterns of a group of patients with poststroke dysphagia and those of healthy volunteers. There is a considerable body of evidence on the precise timing of events in this field but little consensus [2]. This is an important area for swallow research but what of the clinical practice? The equipment used in this study is compact and easily transported in the hospital and outside the hospital. The authors still suspect that swallow respiration parameters are linked to dysphagia and aspiration risk. Perhaps we should concentrate on patterns of events rather than on specific timings? A relatively simple system that looks for easily identifiable features might encourage more clinicians to incorporate this type of assessment into their everyday practice.

Acknowledgments. We are grateful to the Stroke Association for financial support (grant 10/98) for this project. We would also like to thank the speech and language therapists involved in recruiting and monitoring the patients and the nursing and medical staff of the Freeman Hospital Stroke Service.

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