Respiratory Patterns Associated with Swallowing: Part 1. The Normal Adult Pattern and Changes with Age

W. G. SELLEY, F. C. FLACK, R. E. ELLIS, W. A. BROOKS

Summary
Simple, non-invasive equipment was designed to record respiratory patterns associated with swallowing food or drink in young and elderly healthy adults, to compare with neurologically impaired patients who complained of dysphagia. The timing of the entry of the test drink from a spoon into the mouth, the swallow event and respiration were recorded electronically and were presented in chart form. The equipment proved to be easy to use and the results were consistent. All 33 subjects showed a well-defined respiratory pattern, with individual minor variations, but different from the pattern of their resting respiration. The direction of respiration during spoon contact was consistent for each individual and the pharyngeal stage of swallowing was almost always followed by a large expiration. Thus the resting respiration is not simply arrested during swallowing, but is substituted by a different, well-controlled pattern.

Introduction
During previous research with the use of palatal training appliances in treating stroke patients who complained of dysphagia [1], it was observed that the intra-oral appliances, which extended to the base of the uvula, were well tolerated without causing gagging, indicating a loss of sensory function. It was suspected that the patients' respiratory control during swallowing was affected by the stroke and it was decided to determine if that sensory loss and possible respiratory malfunction were related. However, before this hypothesis could be tested, it was necessary to establish the normal respiratory patterns associated with swallowing in young and elderly adults.

Respiratory airflow and the passing bolus are regulated during the pharyngeal stage of swallowing, in such a way that the lungs are protected from aspiration. This stage of swallowing is controlled by a reflex arc, with the afferent sensory receptors situated in the region of the mouth between the pillars of the fauces where the gag reflex is normally elicited, conveying stimuli to the swallow centres and then to the respiratory centres. It is possible, therefore, that sensory loss in that region, presenting as a reduced gag reflex, may show as disorganization of the normal respiratory patterns during swallowing.

It is generally accepted that breathing is arrested, at whatever the actual phase of respiration, during the act of swallowing in adults [2]. In 1920 Clark [3] recorded deglutition apnoea and laryngeal elevation during swallow-
ing and found that the respiratory pause lasted between 0.5 and 2.5 s and the act of swallowing was followed by expiration. More recently Nishino et al. [4], made similar recordings, but under abnormal swallowing conditions, in subjects lying supine and wearing a nose clip. Both spontaneous and water-induced swallows occurred during all phases of the respiratory cycle, but approximately 80% of swallows occurred during the expiratory phase. A swallow coinciding with an expiratory phase prolonged the duration of that expiration, whereas a swallow coinciding with an inspiratory phase interrupted the inspiration and was followed by an expiration. They concluded that the changes induced in the respiratory pattern by swallowing may depend on some mechanism that regulates the co-ordination of respiration and swallowing.

Further studies are thus required of respiratory control during swallowing normal food and drink with simultaneous recording showing the timings of various major stages of deglution. It is also desirable to determine whether the patterns change with increasing age.

The standard investigation of swallowing with video-radiography is able to show whether the larynx is open or closed and whether the pharynx is filled with air, but does not show the directions of air-flow. It is an unnatural feeding environment and unpleasant for patients suffering from some neurological conditions, particularly if they aspirate or are unable to balance. It was decided, therefore, to record the relevant events electronically with equipment which could easily be taken to the patient and used with normal drink or food.

Subjects, Materials and Method

Approval was obtained from the Medical Ethics Committee of Exeter District Health Authority.

Two groups of adults with normal swallowing were tested: 15 volunteer University students and staff (five women and ten men) aged between 18 and 30 with a mean age of 21 years and 18 willing inpatients without neurological disease or swallowing problem (nine women and nine men) aged between 60 and 90 with a mean age of 76 years.

The direction of nasal airflow was determined by means of a soft polythene tube 3 mm in diameter inserted into a nostril and connected to a micromanometer (Furness FCO 14), sensitivity 10 mm H\textsubscript{2}O full scale. The volume of air flowing was not recorded, only the event and the direction of airflow. The timing of the entry of the bolus into the mouth was made by connecting a metal spoon with an insulated handle to a visual speech aid control box [5] with an indifferent electrode attached to the cheek of the subject. This electronic switch detected contact between spoon and lip. The swallow sounds, which mainly consisted of two ‘clicks’ [6], were recorded by placing a throat microphone laterally below the angle of the mandible. The signals from these three pieces of equipment were recorded on an audio cassette tape via a four-channel tape recorder (Teac R-61). Charts were subsequently made from the tapes using a Gould 2200S chart recorder.

The subjects were seated comfortably, the electrode and nasal tubing attached with Micropore tape and the self-supporting throat microphone suitably placed (Figure 1). No mention was made that breathing was being recorded—only that the equipment was necessary to record swallowing. It was explained that they would be asked to swallow a small amount of fruit juice from a teaspoon. Recordings were made first of resting respiration to establish the pattern of the individual’s respiratory cycle. Recordings continued as about 5 ml of fruit juice was repeatedly offered on the special teaspoon and swallowed.

Results

Some events in the swallowing sequence need to be defined to aid the presentation of the results (Figure 2):

rc: respiratory cycle. One cycle of resting respiration.
da: deglutition apnoea. This is the period when no nasal airflow was recorded during swallowing.
ss: swallow sounds. Represented by two vertical arrows which correspond to the two clicks of the swallow sounds.
pp: pharyngeal part. Measured from the first swallow sound to the post-swallow respiration.

The terms oral part and pharyngeal part were chosen because the timing and clinical value of these events are similar to the terms oral phase and pharyngeal phase commonly used when analysing a barium swallow radiographic investigation, but they are not necessarily identical.
Reproducible results were obtained from all subjects. Patterns recorded were consistent when comparing the major events in all the subjects tested and any minor individual variations were regularly and consistently repeated throughout the subject's test and again if tested on subsequent occasions.

A tracing of a chart constructed from a 78-year-old subject: rc = respiratory cycle; op = oral part; pp = pharyngeal part; sc = spoon contact; ss = swallow sounds; da = deglutition apnoea. Spoon contact (1), inspiration at spoon contact (2), small expiration just before swallow (3), deglutition apnoea (4), post-swallow expiration (5), absence of small expiration before swallowing (6).
subject's recording (a woman aged 78 years) is shown in Fig. 2. At spoon contact (1) the subject inhaled (2), a small expiration occurred just before the swallow (3), swallowing occurred during deglutition apnoea (4), then she exhaled (5). The most common variation of this respiratory pattern was the absence of the small expiration just before swallowing (6). The subjects usually exhaled following the swallow (95% of all the swallows recorded from all the subjects), but exhibited either or both of the patterns (3 and 6) in their tests.

Analysis of the timings for all the subjects is shown in the Table. Only one difference was seen between the two age groups, viz. the duration of the deglutition apnoea. In the younger group it was 0.6 ± 0.2 s, while in the older group it was 1.0 ± 0.2 s; a significant difference (p = 0.05%). It is important to note that all the 33 subjects usually exhaled immediately after swallowing. At spoon contact, 11 inhaled and then produced a small exhalation while 22 inhaled only. A preferred individual pattern was generally followed with occasional changes to a second pattern.

The characteristic findings of clinical relevance of a subject being fed may be summarized as follows:

(a) For an individual, a preferred pattern of respiration at spoon contact appeared throughout the test, either an inspiration or an inspiration/expiration combination
(b) Duration of oral part was 1–3 s
(c) Only one swallow took place per teaspoonful
(d) 95% of swallows were followed by a large expiration
(e) Usually each swallow-sound had no other associated noise relating to coughing or spluttering
(f) There was consistent individual deglutition apnoea within the range of 0.3–1.4 s.

**Discussion**

The technique described was non-invasive, reliable and simple to use in a natural feeding environment with any suitable food or drink.

A co-ordination pattern common to all subjects was found, with minor variations peculiar to each individual, which were repeated regularly. A healthy adult can consciously arrest his respiration at any phase to swallow, but the unsuspecting subject follows a well-defined pattern. Organization of respiration occurred as the drink approached the subject's lips and the direction of respiration during spoon contact was consistent for each individual. The pharyngeal stage of swallowing was almost always followed by a large expiration, reducing the risk of mist aspiration. It is possible to determine oral and pharyngeal transit times and, together with the number of attempts to swallow one spoonful, intra-oral efficiency (repeated partial swallowing is found in abnormal groups and reported in part 2).

During swallowing it appears that the respiratory changes are not just a simple arrest of the normal resting respiration anywhere in the cycle, but a rearrangement of respiration into another well-controlled pattern initiated by a variety of sensory inputs. The most important of these is an adequate stimulus to the swallow centre via the sensory (afferent) side of the reflex arc which triggers the pharyngeal stage of the swallow. If this is deficient, proprioception,
visual and tactile perception and taste may become important to help produce a comfortable, safe swallow in neurologically impaired patients complaining of dysphagia.

In order to demonstrate the clinical significance of these findings, a further investigation was carried out on neurologically impaired patients who were complaining of dysphagia thought to have been due to neurological illness. The results of this investigation are reported in part 2 of this paper [7].

Acknowledgements

The authors are grateful to the Northcott Devon Medical Foundation for the grant which made the research possible. We are also grateful to the medical and nursing staff of the Royal Devon and Exeter Hospitals for their help and encouragement.

References


Authors' addresses

W. G. Selley
Department of Dentistry, Royal Devon and Exeter Hospitals, also University of Exeter.

F. C. Flack*, R. E. Ellis, W. A. Brooks
Medical Physics Group, Department of Physics, University of Exeter, Stocker Road, Exeter EX44 QL

* Author for correspondence

Accepted in revised form 10 June 1988